II World Congress on Integrated Crop-Livestock-Forestry Systems

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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PREFACE

Promoted by the Ministry of Agriculture, Livestock and Food Supply - MAPA; Brazilian Agricultural Research Corporation - Embrapa; ICLF Network Association; State Secretariat for the Environment, Economic Development, Production and Family Agriculture - SEMAGRO; Federation of Agriculture and Livestock of Mato Grosso do Sul - Famasul; and FB Eventos, the II World Congress on Integrated Crop-Livestock-Forestry Systems (WCCLF 2021) took place on the 4th and 5th May 2021 in a 100% digital format.

The objective of the Congress was to provide a forum for discussion, theoretical insights and practical applications related to technology as well as economic and environmental aspects of mixed agricultural systems that combine integrated production of crops, animals and trees in the same area, having an efficient use of inputs, all being essential for food security in the future.

ICLF is a production strategy that integrates crop, livestock, and forestry farming in the same area, in a consortium, rotated or in succession, so that there is interaction among components, generating mutual benefits.

For two days, we discussed issues related to challenges and opportunities for ICLF systems around the World; solutions and demands from Agribusiness Companies; scenarios and trends of ICLF in the World; current hot topics in ICLF; solutions and demands for ICLF from the farmer’s view; Public Policies for Supporting ICLF; and innovation on ICLF systems.

The integrated agricultural production systems can be implemented combining two or three components, according to the particularities of each farm and region. They can also be adopted in small, medium, and large farms, in different biomes, using different crops, livestock and trees species. Among the many benefits of ICLF are increasing total yields of a given area, diversification of income sources, better use of inputs, improvement of soil chemical, physical and biological qualities, along with improvement of animal welfare as well as jobs and income generation. In addition, ICLF systems reduce pressure to clear new areas, it helps to recover degraded low yielding areas while mitigating greenhouse gas emissions, increasing carbon sequestration in soil and biomass. These benefits corroborate with three of the Sustainable Development Goals - SDGs:

- SDG 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture;
- SDG 13 - Take urgent action to combat climate change and its impacts; and
- SDG 15 Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

These Proceedings report 166 scientific contributions approved by the scientific committee of the WCCLF 2021 and 18 papers from speakers that also contributed to this publication.

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Lucimara Chiari (Executive Secretary of the WCCLF 2021)

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Summary

1. Climate change, resilience, and adaptation

CLIMATE CHANGE PROJECTIONS AND THEIR IMPACT ON WATER DEFICIENCY IN JAÚ-SP

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ABSTRACT

Climate changes projected for the coming years could significantly affect the agricultural sector, causing changes in variables such as water availability. In this context, the objective of this research is to determine the influence of different scenarios of climate change on the water balance of Jaú-SP. To this end, temperature and precipitation data obtained from the weather station of the Jahu College of Technology between 2009 and 2018 were employed. These data were used as the basis for the construction of 6 climate change scenarios. For temperature, it was considered a 1.5ºC or 3.5ºC increase in the average temperature, combined with the current precipitation scenario, as well as a 20% increase or decrease in precipitation. The original data, as well as the projected one, were used in the construction of a ten-day sequential water balance to analyze the change in water availability. The increase in temperature causes a strong increase in the volume and duration of the annual water deficiency, if there is no simultaneous increase in precipitation in the region of Jaú-SP. In the current scenario, the annual water deficiency average is 59.3 mm, with a duration of 180 days, and in the scenario of 3.5ºC temperature increase with a reduction of 20% in precipitation, these values increase to 620.7 mm and 320 days, respectively.

Key words: Agrometeorology; Water Balance; Agricultural Planning

INTRODUCTION

The agricultural production represents one of the main sectors of the national and global economy. However, the development of agricultural activities depends on several factors ranging from the definition of the culture and its implementation strategies, to the harvest and/or industrialization of the final product in certain cases (VIEIRA FILHO; FISHLOW, 2017). Rural activities are mostly performed at the field level, and are often exposed to weather conditions, which in certain years may present adverse characteristics. Climate adversities can represent a potential risk to the agricultural sector, and to minimize the effects of such a risk, several works are carried out to establish forecasting and mitigation measures for these risks (MALUF; FLEXOR, 2017; FELDENS, 2018).

For the establishment of agroclimatic management strategies, a very important aspect is the knowledge of the climatic characteristics of each region, as well as possible changes or variations that the climate of this region may present over time (MONTEIRO, 2009). In the context of climate change, studies are conducted to identify how agricultural areas and/or crops will be influenced by it. However, due to the existence of many uncertainties in production systems, forecasting is still complex, even with the existence of such a discussion on climate change (PINTO, 2015).

The Intergovernmental Panel on Climate Change (IPCC) is possibly the leading source for dissemination of future scenarios' projections involving the increase in global temperature, modification of precipitation and increase in the accumulation of atmospheric $_{CO2.}$ In view of the information described by the IPCC reports, many studies have been carried out considering different scenarios, for example, the works of Pimenta (2012), Faria and Haddad (2013) and Castro (2014).

Among the variables influenced by climate change, possibly the water availability for crops is one of the most worrying for the agricultural sector. One of the main ways to determine the water availability of a region for crop establishment is by determining its water balance (CARVALHO et al., 2013; MORAES, 2018). The water balance represents the trade-off between inputs and outputs of water in a given region, represented by precipitation, irrigation and evapotranspiration, respectively, as a function of the water storage capacity in the soil (DWC) and in the atmosphere (CECÍLIO et al., 2012; SILVA JUNIOR et al., 2018).

In this context, the objective of this research is to determine the influence of different climate change scenarios on the water balance of the city of Jaú-SP.

MATERIAL AND METHODS

To determine the influence of different climate change scenarios on the water balance of the city of Jaú-SP, daily data on precipitation and temperature from 01/01/2009 to 31/12/2018 (10 years), obtained from the meteorological station of the Faculdade de Tecnologia de Jahu (FATEC Jahu), located at coordinates: latitude 22°18'50", longitude 48º32'54" and altitude of 583.4 m, were used.

This information represents the basis for the climate change projections. These projections were derived from the ranges of temperature and precipitation change for the region, according to the IPCC (2014). Based on these ranges, six possible climate change scenarios were generated. For temperature, an increase of 1.5 or 3.5ºC in its average value was considered, whereas for precipitation, the current scenario with no change was considered, as well as the increase or decrease of 20% in the average precipitation. It is noteworthy that these projections consider regular changes during the year, ignoring the occurrence of extreme events of precipitation or temperature.

The original data (2009-2018) as well as the projected one for the six climate change scenarios were used to construct a ten-day sequential water balance. According to Gobo et al. (2018), these balances are useful for monitoring the water availability of a region and can be employed for several purposes The determination of the water balance was based on the Thornthwaite and Mather (1995) method, which uses information about average temperature and precipitation. To elaborate the water balance, the BHnorm software (version 4.0) developed by Rolim and Sentelhas (1998), was used, considering information about average temperature, precipitation, latitude of the region and water storage capacity in the soil (DWC) as input data. The DWC adopted for the research was 100 mm, considered an intermediate value by Horikoshi and Fisch (2007), between annual crops (75 to 100 mm) and perennials (100 to 125 mm).

Although the BHnorm software allows the generation of water balance graphs and water balance extract, only the latter was used to more prominently represent the water deficiency or surplus as a function of each condition assessed. The software's constitutive equations were verified before the projections were made, aiming to guarantee the reliability and veracity of the results obtained. Besides the graphical representations of the water balance, the characterization of the annual volume and the duration of the periods of water deficiency for each scenario was performed.

RESULTS AND DISCUSSIONS

Each climate change projection scenario caused significant changes in the water balance of the region. However, the temperature increases of 3.5°C (Figure 2) under any precipitation scenario was more impactful than the 1.5°C temperature condition (Figure 1) under water deficiency.

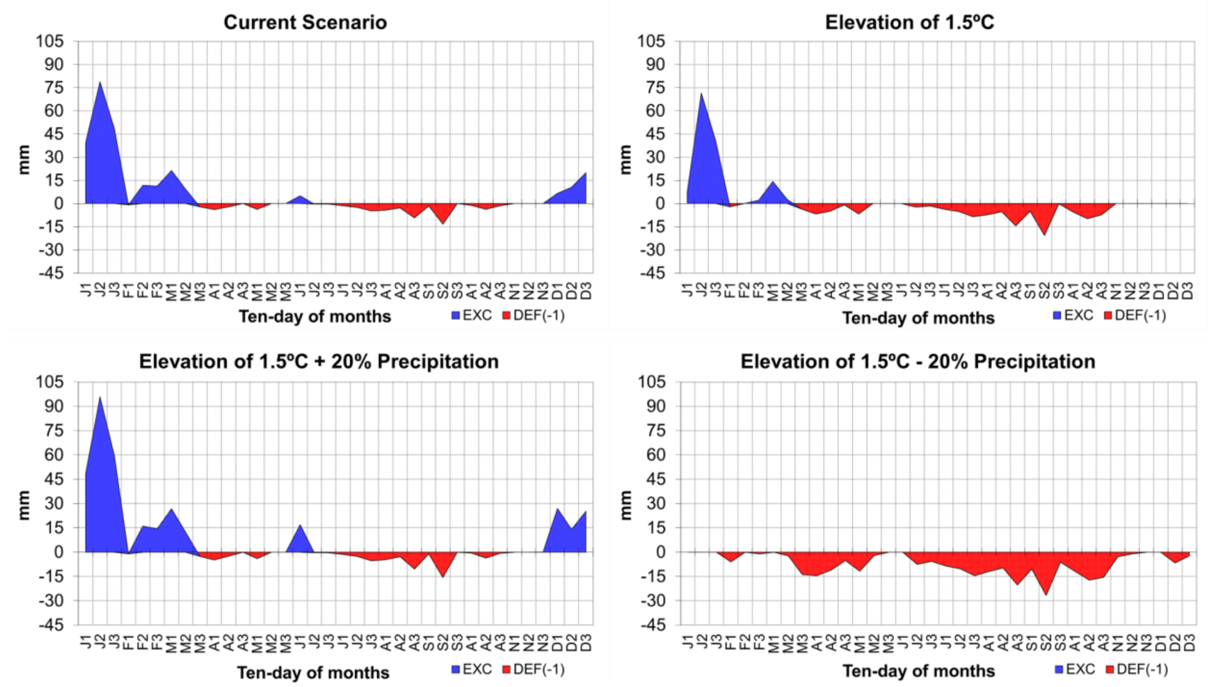

Figure 1. Extract from the water balance of Jaú-SP, considering different precipitation scenarios for a temperature increase of 1.5ºC compared to the average extracted between 2009-2018 (EXC = Water Excess and DEF = Water Deficiency).

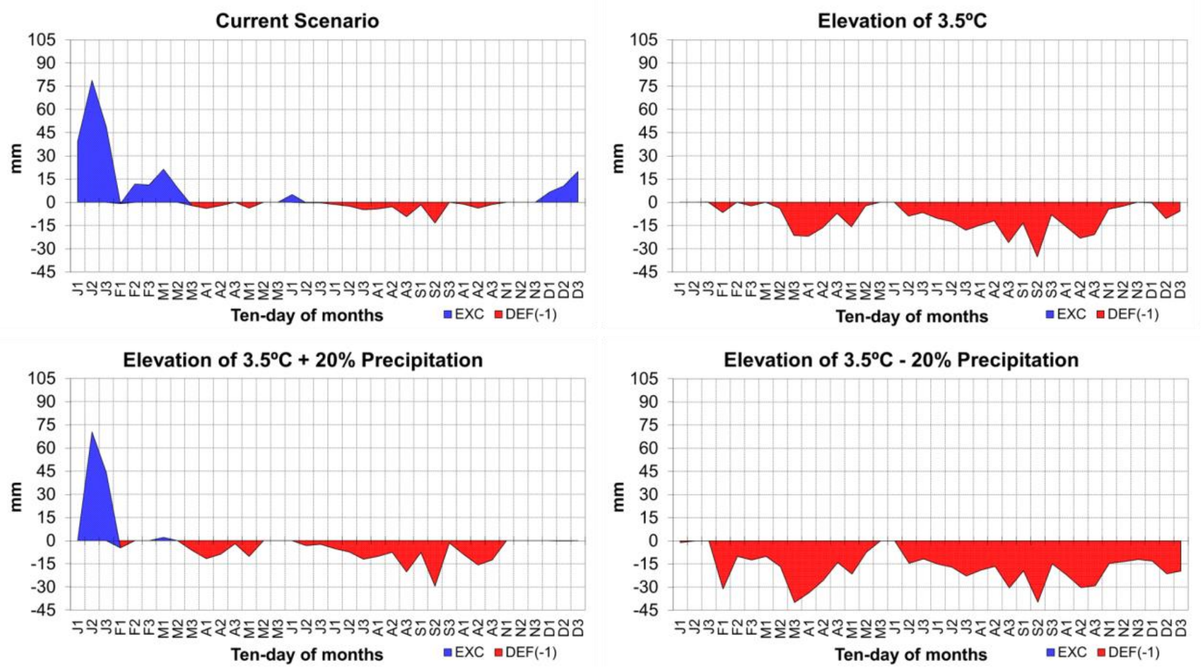

Figure 2. Extract from the water balance of Jaú-SP, considering different precipitation scenarios for a temperature increase of 3.5ºC compared to the average extract of 2009-2018 (EXC = Water Excess and DEF = Water Deficiency).

The current scenario has a total annual water deficiency of 59.3 mm, which extends over approximately 180 days (18 ten-day). These are the lowest values observed. In the projections with an average temperature increase of 1.5ºC the water deficiency was 121.5 mm, with a duration of 200 days. On the other hand, for the same increase, but combined with an increase in precipitation, resulted in a deficiency of 64.7 mm, with a duration of 180 days. Finally, the elevation of 1.5ºC together with a reduction in precipitation generated a water deficiency of 257.6 mm, with a duration of 270 days.

The projections involving temperature elevation of 3.5ºC were more impactful on water deficiency. The isolated increase in temperature generated a water deficiency of 346.0 mm, with a duration of 280 days, when combined with the increase in precipitation the deficiency reduced to 187.0 mm, with a duration of 220 days, however, when combined with the reduction in precipitation, the water deficiency value reached 620.7 mm, with a duration of 320 days.

Although these values are significant, it is necessary to demonstrate their use in practical terms. In the sugarcane crop, Manzatto et al. (2009) presents a classification of the production capacity for the crop, based on water deficiency. According to the authors, for regions with an annual water deficiency of less than 200 mm, the crop can be cultivated without limitations, whereas for regions with a deficiency of more than 200 mm, the crop needs strategies such as the adoption of irrigation. Note that not only the volume of the deficiency is important, but also its distribution, since this factor will allow the adoption of different management strategies.

Based on classification Manzatto et al. (2009), the temperature increases of 1.5ºC does not lead to water deficiency to a limitation point for sugarcane (except for the scenario combined with precipitation reduction). In contrast, the elevation of 3.5ºC generated scenarios above 200 mm, where practically no annual water surplus occurs (except for the scenario combined with precipitation elevation).

Still for sugarcane, Marin et al. (2007) carried out a study evaluating simulations of temperature increase considering values of 1.8, 2.9 and 4.0ºC. This study indicated that with elevations of 4.0ºC, almost the whole São Paulo state would become dependent on irrigation to produce the crop, due to natural water insufficiency, similar to what was observed in this study.

There exists considerable speculation regarding climate change scenarios, since some factors such as precipitation show variable behavior among the projections made, however, it is undeniable that if there is no increase in precipitation, the increase in average temperature causes an expansion in the water balance, both in volume and duration.

The water balance, among its functions in agricultural planning, supports in establishing agricultural zoning for certain crops, seeking to implement them in periods that avoid certain conditions in more sensitive stages of the crop (WAGNER et al., 2013). However, it can also be used in determining the potential development of the crop in that region and what will be the technological level invested (COLLICCHIO et al., 2015; RIBEIRO et al., 2015).

For example, while in the current scenario and in the most optimistic scenarios of a 1.5ºC increase in temperature, supplementary irrigation can be used for perennial crops; in the scenarios of a 3.5ºC increase, irrigation becomes practically mandatory. In both cases, for annual crops, due to the greater sensitivity of their root systems, the adoption of irrigation can represent the success or failure of the crop.

Therefore, being aware of the current climate characteristics, as well as its possible modifications, the crop of interest and the available technological level, are fundamental concepts for the development of the agricultural sector.

CONCLUSIONS

The climate change projection scenarios confirm that the increase in temperature can cause a strong increase in the volume and duration of the annual water deficiency, if there is no simultaneous increase in the precipitation level in the region of Jaú-SP. While in the current scenario the average annual water deficiency does not exceed 60 mm with a duration of 180 days, in the worst scenario (3.5ºC increase with 20% reduction in precipitation) these values increase to 620 mm and 320 days, respectively.

Thus, the evaluation and understanding of possible climatic modifications is fundamental in the establishment of agricultural management strategies, besides being a decisive factor in the adoption of technologies such as irrigation. The water balance presents itself as a simple tool, yet a great help in making decisions.

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EFFECT OF HYDROGEL AND COVERAGE FERTILIZATION UNDER THE WATER POTENTIAL OF CORN CULTIVATED IN ICLF

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ABSTRACT

The objective was to evaluate the effects of different doses of hydrogel application combined with and without top dressing in an ILPF system under the water potential of corn plants grown in consortium with forage *Panicum maximum* cv. Kenya and eucalyptus. The experiment was carried out at the Fazenda School of the Instituto Federal Goiano, Campus Iporá, Iporá, Goiás, Brazil. The experimental design used was randomized blocks, in double factorial schemes and three replications, for the intercropped cultivation of corn, forage and eucalyptus. The first factor consisted of five hydrogel doses: 0 kg ha^{-1} (0% of the recommended dose); 7.5 kg ha^{-1} (50% of the recommended dose); 15 kg ha^{-1} (100% of the recommended dose); 22.5 kg ha^{-1} (150% the recommended dose) and 30 kg ha^{-1} (200% of the recommended dose); and the second factor consisted of with and without nitrogen cover fertilization. Water potential was determined using a Scholander pressure pump at noon (Ψmd). There was an effect of hydrogel doses on the water potential of leaves of corn plants grown in an integrated system. The doses 0 and 4, presented the lowest values of water potential, being -1.3 and -1.2, respectively. The doses of 7.5 kg ha^{-1}.15 kg ha^{-1}, 22.5 kg ha^{-1} contributed to a greater leaf water potential in corn plants.

Key words: Competition; nutrient availability; nitrogen

INTRODUCTION

The world population is increasing, with an estimated 9.5 billion people for the year 2050, raising great concerns about the future of human lifestyle and food security. In order to produce more food without causing more deforestation, some measures can be directed towards the expansion of crops and pastures to areas already deforested (SALTON et al., 2014).

One of the sustainable measures that combines agricultural, animal and / or forestry activities is the integrated crop-livestock-forest system (ICLF), where it is possible to produce at least three types of products in the same area (BALBINO et al., 2011). The benefits of integrated systems include increased soil fertility due to the accumulation of organic matter, better nutrient cycling, increased efficiency of fertilizers and soil aggregation (COSTA et al., 2015; GIL; SIEBOLD; BERGER; 2015).

Corn (*Zea mays* L.) is an annual crop that has been widely used in ILPF systems, due to the numerous applications that this cereal has on the agricultural property (REGO et al., 2017). Even though corn is a crop well adapted to the ICLF system, water deficit is one of the factors that can most interfere in the agricultural productivity of this crop (ANDREA et al., 2018). And this problem has been increasingly present, due to climate change, which generates long periods without rainfall, associated with high temperatures (LANGNER et al., 2019).

In ICLF systems, crop management is extremely important, both in relation to crop treatments and fertilization, because, in addition to production, there is the issue of residual nutrients, responsible for the nutrition of the pasture that will follow (MAGALHÃES et al., 2019). In addition, due to competition between the components of the system, cover fertilization can help in the better use of nutrients by crops (SERRA et al., 2019). When it comes to fertilization, nitrogen (N) is one of the most important macronutrients for the cultivation of corn, so its production is directly related to the disposition of N in the soil (DEMARI et al., 2016).

Thus, it is necessary to search for tools that aim to minimize the effect of water deficit and that provide a better use of nutrients for maize culture. An alternative is the use of hydrogel, also known as hydrophilic or hydro-absorbent polymer (AHMED, 2015). Hydrogels have the ability to retain water helping to maintain the moisture content in the soil, reducing water consumption in the irrigation of agricultural crops (BEHERA & MAHANWAR, 2020).

With this, the objective was to evaluate the effects of different doses of hydrogel combined with cover fertilization in an ICLF system under the water potential of corn in consortium with forage *Panicum maximum* cv. Kenya and eucalyptus.

MATERIAL AND METHODS

The experiment was carried out at the Fazenda School of the Federal Goiano Institute, Campus Iporá, West Region of Goiás, Brazil, located at 16 ° 25'26.91 "S, 51 ° 9'5.23" W, 595m. In the experimental area, soybeans were grown in the 2016/2017 harvest and overseeded with pasture in the off-season. In the 2017/2018 harvest, triple planting was carried out with corn and two forages for the production of silage. Then the area was used in the off-season and between harvest for grazing for the purpose of meat production. The ILPF system was implemented in October 2018. For the spatial arrangement of the trees, the planting of two eucalyptus clones (*Urograndis* - i144 and *Urocam* - VM01) was used, with spacing of 1.5 m x 10 m.

For soil determinations, soil samples with undisturbed structure were collected, collected in Uhland rings of 6.34 cm in diameter and 5 cm in height, and also, deformed samples, in the depths of 0 to 20 and 20 to 40 cm, for physical determinations and chemical analyzes of the soil (TEIXEIRA et al., 2017). The soil in the experimental area is classified as Cambisol, with the following chemical characteristics: pH 4.8; MO 1.2%; P (Melich I) 2.0 (mg.dm^{-3}); 1.4; 0.4; 0.37; and 4.87 (cmolc.dm^{-3}) of Ca, Mg, K, and CTC, respectively. The texture showed 25, 6 and 69% of clay, silt and sand, respectively. Fertilizations were carried out according to the soil analysis using 400 kg ha-1 of NPK (4-30-10) in the base fertilization.

The experimental design used was randomized blocks, in split plot schemes, with two factors and three repetitions, for the intercropped cultivation of corn (*Zea mays*), forage (*Panicum maximum* cv. Kenya) and eucalyptus (*Eucalyptus urograndis*). The plots consisted of five hydrogel doses: 0 kg ha^{-1} (0% of the recommended dose); 7.5 kg ha^{-1} (50% of the recommended dose); 15 kg ha^{-1} (100% of the recommended dose); 22.5 kg ha^{-1} (150% the recommended dose) and 30 kg ha^{-1} (200% of the recommended dose); and the subplots were with and without fertilizer covering N, urea source, being applied 120 Kg ha^{-1} at 30 days after sowing.

Corn seeds of the P4285VYHR (Pioneer®) variety were used, which 3.8 seeds per linear meter were sown, totaling a density of 76,000 plants per hectare, in November 2020. The forage *P. maximum* cv. BRS Kenya, was sown at the time of sowing corn, between rows, using 5.0 kg ha^{-1} of pure viable seeds, with a cultural value of 80%, totaling 6.5 kg ha^{-1} of raw seeds. The hydrogel used was

Hydroplan®-EB, which was applied in the form of granules at the time of sowing. The leaf water potential of corn plants was determined using a Scholander pressure pump at noon (Ψmd).

The data obtained were subjected to analysis of variance by the F test at the level of 5% probability. In cases of significance, the Scott-Knott test was performed at 95% ($p < 0.05$) of significance between the means, using the SISVAR® statistical program (FERREIRA, 2011).

RESULTS AND DISCUSSIONS

There was an effect of hydrogel doses on the water potential of leaves of corn plants grown in an integrated system. Doses 0 and 4 showed water potential of -1.3 and -1.2, respectively, with the lowest leaf water potential at noon compared to the others that did not differ from each other. As with all other living organisms, water is essential for plants. It is used as a solvent for chemical reactions and participates in the transport of nutrients and biomolecules. Water is of paramount importance for turgor and cell growth. Furthermore, it is directly related to stomatal conductance, an important process to control CO_2 absorption and water loss through perspiration (SCHARWIES et al., 2019). Therefore, it is noted that hydrogel doses of up to 22.5 kg ha^{-1} contribute to a greater leaf water potential in corn, providing physiological improvements that may favor plant growth and productivity, given the importance of water for plant metabolism.

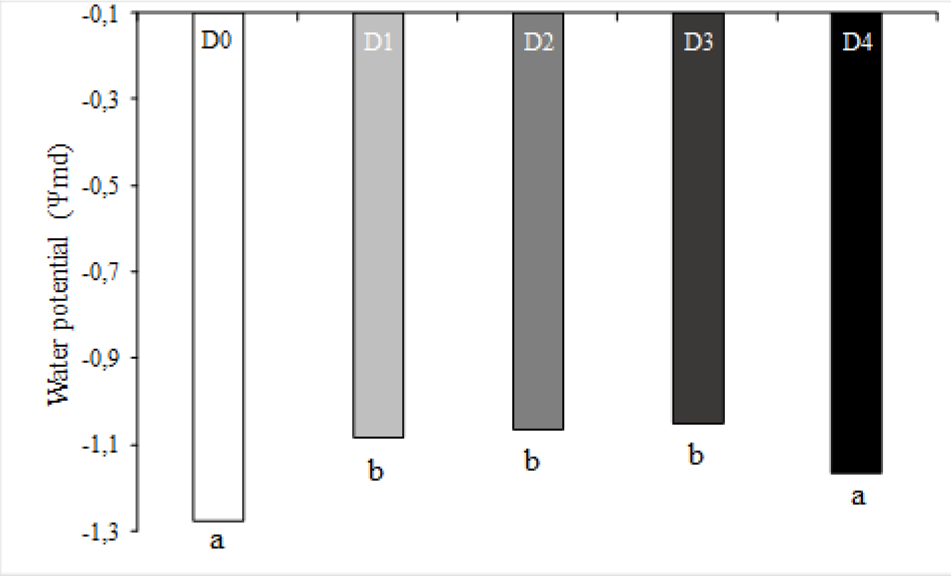

Figure 1. Water potential of leaves of corn plants grown in ILPF and subjected to 5 different doses of hydrogel (Dose 0: 0 kg ha^{-1}; Dose 1: 7,5 kg ha^{-1}; Dose 2: 15 kg ha^{-1}; Dose 3: 22,5 kg ha^{-1}; Dose 4: 30 kg ha^{-1}).

CONCLUSIONS

The doses of 7,5 kg ha^{-1},15 kg ha^{-1}, 22,5 kg ha^{-1} contributed to a greater leaf water potential in corn plants. The doses 0 kg ha^{-1} and 30 kg ha^{-1} were the doses that provided the lowest values of water potential.

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ECONOMIC ASSESSMENT OF SILVOPASTORAL SYSTEM IMPLEMENTATION IN SMALL-SCALE FARMS AT THE PERUVIAN AMAZON REGION

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ABSTRACT

Livestock production in the Peruvian Amazon is predominant based on smallholders who manage extensive grazing with degraded pastures by overgrazing. As it is associated to deforestation, alternatives for livestock production based on silvopastoral systems have being developed in the last decades. The present article aims to provide information about the economic feasibility to implement silvopastoral systems (SPS) in the Peruvian Amazon. The objective of this study was to conduct an economic assessment of small-scale farmers for estimating the investment and revenues due to SPS implementation in degraded pasture areas of the San Martin region. Four simulation scenarios were built, assuming a dairy farm of 10-ha. and different proportion of SPS implemented (0%, 15%, 30%, 50%). The results showed that, over a ten-year evaluation period, grazing areas with 50% of SPS present a positive Net Present Value (NPV) and higher Internal Rate of Return (IRR). However, it requires a high financial investment for its implementation. We conclude that government financial support is needed for promoting the implementation of SPS at small-scale farmer's level.

Key words: Livestock; Sustainable production; Peru

INTRODUCTION

Traditional animal production systems in Peruvian Amazon are based on using monocultures of grasses with low nutritional value and seasonal forage availability. As this raising cattle system is based on low capital costs, it is view for farmers as low-risk investment compared with crops that are subject to price swings or infestations. However, this leads to low productivity performance per animal and poor economic results, increasing the need of farmers to continue deforestating for obtaining more land to produce. The establishment of land-sparing strategies such as silvopastoral systems (SPS), which are a set of land-use techniques implying the combination or deliberate association of a woody component (tree or shrub) with husbandry in the same site, could promote a more sustainable livestock production. Despite the well-documented benefits of SPS across tropical countries in the region (i.e Colombia and Ecuador), their use in the Peruvian Amazon is still a novel approach. Peru's Nationally Determined Contribution (NDC) targets the promotion of more sustainable production systems and includes the restoration of 119 thousand hectares of degraded pasture in the Amazon through SPS implementation (GTM-NDC, 2018). However, investment cost to implement SPS if small-scale farmers would like to shift to these systems is limited. For this reason, the objective of this study was to conduct an economic assessment of small-scale farmers for estimating the investment and revenues due to SPS implementation in degraded pasture areas of the San Martin region in the Peruvian Amazon.

MATERIAL AND METHODS

Calculations were done using an excel spreadsheet. A baseline was built taking into account surveys to farmers, interviews with experts, and secondary information. Average production values were determined for dairy farms on degraded land: Milk production of 6.5 kg cow^{-1} day^{-1}, 0.75 animal units per hectare (AU ha^{-1}), and a lactation period of 210 days. For the evaluation of SPS scenarios, we considered a 10-ha grazing area with cultivated pastures (*Brachiaria brizantha*) and tree species such as bolaina blanca (*Guazuma crinita*) and capirona (*Calycophyllum spruceanum*) implemented in different proportions: (A=0%, A1=15%, A2=30%, A3=50%). Milk production in cultivated pastures (0% of SPS) was estimated in 9.3 kg vaca^{-1} día^{-1} (ROSEMBERG, 2019). In the case of SPS, 12% more production was determined compared to cultivated pastures, as reported by Pezo and Ibrahim (1996). A lactation period of 270 days and a stabilized number of cows were considered for all the scenarios. Bolaina and capirona were established in similar proportions per hectare (200 units per ha each one) but with different harvest time (seven and ten years for bolaina and ten years estimation for capirona).

A discounted cash flow (DCF) model was used (BULLARD; STRAKA, 2011). The economic investment of infrastructure, land cost and livestock component and farmer labor to implement SPS on the farm were included in all scenarios. Operative cost included fixed and variable costs. Economic incomes from milk sales, weaning calves (6 months of age), culling and timber (only from the SPS scenarios) were estimated. The economic assessment was carried out in a basis of 10 years' time horizon, taking into consideration economic indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR). A commercial discount rate of 13.7%, was used in all scenarios as it is the current reference national value for microenterprises requesting credits (SBS, 2020)

RESULTS AND DISCUSSIONS

The Net Present Value (NPV) was negative in scenarios with 0%, 15% and 30% of SPS implemented in grazing area of 10 ha. Internal Rate of Return (IRR) was increased when the proportion of SPS were higher (see table 1). These values are similar to those reported by Braun et al. (2016), who mention that the SPS generate more attractive earnings than traditional livestock production systems.

Table 1. Net Present Value and Internal Rate of Return of SPS, in San Martin Region, Peru.

	Scenario	NPV (USD)	IRR (%)
A	0% of SPS	- 18,575.8	7.96
A1	15% of SPS	-8,760.0	11.48
A2	30% of SPS	-2,072.1	13.27
A3	50% of SPS	10,216.2	15.33

Results also shows that investment for implementing SPS are expensive. For example, the implementation of SPS in scenario A1 (10 has of cultivated area with 15% of SPS) is equivalent to 65,441 USD.

As the level of investment for implementing SPS is high, probably it couldn't be possible to be leveraged by smallholder. Hence, external support is required. Regarding the Peruvian credit system, though bank loans are granted by some financial entitites, such as Corporación Financiera de Desarrollo (COFIDE) and Banco Agropecuario (AGROBANCO), unattractive proposals are often to the smallholder. In favor of this, an active role from the State is important to generate financial mechanisms for the implementation of pastoral systems, such as SPS, which give the smallholders access to loans with lower discount rates and a period from medium to long term.

CONCLUSIONS

Net Present Value and Internal Rate of Return of the SPS implementation were superior compared to only cultivated pasture. This research found that at commercial discount rates, solely SPS with 50% scenarios showed off positive NPV results. This results also highlight the need of having differentiated financial mechanisms in the country (from the Peruvian Government or private banks) for encouraging smallholders to implement SPS. Finally, we recommend a complete farm assessment for better understanding how the small landowner diversifies his incomes and also to estimate the contribution from livestock to this total profits.

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PERCEPTION OF LIGHT IN CORN PLANTS IN CROP-LIVESTOCK-FOREST INTEGRATION SYSTEM

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ABSTRACT

The consortium systems directly affect the oscillation of the brightness of the cultivation environment, resulting in greater shading in the crops. Despite the increase in production in the syndicated systems, there is considerable uncertainty about the adaptability of the crops to the shading provided. Thus, the objective was to evaluate the physiological response of corn (*Zea mays*) to this fluctuation of light when intercropped with forest and forage species. The experimental area was arranged in a Crop-Livestock-Forest Integration System, where the corn was intercropped with forest and forage species. The evaluations were carried out at the development stage R3 (pasty grains = ±80 DAP), following the spacing of 1.5 meters and 5.0 meters from the tree planting line. Corn plants in the planting lines at 1.5 meters, presented reduced chlorophyll and leaf area, compromising photosynthetic rates, indicating that the greater shading caused stress in these plants. Already plants grown at 5 meters, even showing a reduction in the efficiency of water use, promoted an increase in the photosynthetic rate. In conclusion, maize grown in consortium showed physiological adaptations in response to changes in light radiation, although greater susceptibility under low radiation, highlighting the limited photosynthetic capacity.

Key words: Adaptation; shading; photosynthesis

INTRODUCTION

The Crop-Livestock-Forest Integration Systems (ILPF or Agrosilvipastoral), which integrates the management of crops, animals and trees, were accepted as an integrated approach to promote sustainable management with the potential to improve land use and mitigate climate change while adding profitability to producers (ROSENSTOCK et al., 2019). Integrating trees into the system offers options to mitigate and adapt to climate change, since trees create a microclimate that reduces ambient temperature and thermal stress, conserving soil moisture, as well as enabling the production of firewood and fruits (GRISCOM et al., 2017). Finally, the integration of trees into the system helps in the storage of carbon in biomass and in soils, allowing the reduction of carbon dioxide loads in the atmosphere (AHIRWAL et al., 2021).

The planting of annual crops in consortium with trees has been widely practiced worldwide to increase crop production. However, the interception of canopy light by crops in consortium with forest species is a crucial factor for the modulation of various adaptive mechanisms with respect to morphology, tissue structure, photosynthetic characteristics, biomass production and other plastic properties of the plants (YANG et al., 2021). In the consortium, the adaptability of crops growing on the lines between trees varies widely between plant species and even within species, individuals at different stages of development may differ in their reaction to the altered light environment (XIE et al., 2020). Therefore, when light becomes the main limiting factor in the plant's development, its leaves have strong plasticity, allowing them to improve light capture, changing its shape and structure to adapt to this environment (ABBASI et al., 2021).

Therefore, the high level of shade in an integration system can negatively impact the production of annual crops, especially for species with the C4 photosynthetic pathway, such as corn and grasses (CASTILLO et al., 2020). Corn is a typical C4 that needs good solar radiation throughout the growing period to maintain high photosynthetic efficiency and yield. With the decrease in solar interception, the yield decreases (MOHKUM HAMMAD et al., 2016). In the reproductive growth phase of corn, a decrease in solar radiation will restrict the establishment of reproductive organs, and lead to declines in the leaf area index, photosynthetic rate, biomass and yield (GAO et al., 2018).

Corn is one of the most important crops in the world, with a high photosynthetic rate and large production of grains and biomass (MARTILLO ASEFFE et al., 2021). However, little is known about the process of acclimatization of plants grown in intercropping under shade. More knowledge of the regulatory mechanisms of photosynthesis, the effects of shading, chlorophyll fluorescence and leaf structure may provide new insights into the mechanisms of adaptation and shade tolerance in intercropping plants in the integration system. Therefore, the aim of this study was to investigate the performance, growth, leaf anatomy and photophysiological responses of corn to the shade provided by the trees in the consortium.

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the school farm, UEPE Tamanduá - ILPF of the Instituto Federal Goiano - Campus Iporá, located between the parallels 16º16'00 "and 16º39'20" of south latitude. The soil in the experimental area is classified as Cambisol, located at 602 m above sea level. The experimental area was arranged in a Crop-Livestock-Forest Integration System, with the respective treatments: Eucalyptus “Urograndis” - Clone I144 (*E. urophylla* x *E. grandis*); Eucalyptus “Urocam” - Clone VM01 (*E. urophylla* x *E. camaldulensis*); *Dipteryx alata* Voge and *Anadenanthera colubrina* Vel., The trees were arranged in rows of simple lines spaced 10 m between rows. The agricultural crop MILHO (*Zea mays*) was sown in a consortium with forage *Panicum maximum*cv. BRS Kenya and the forest species, of these 66 thousand corn plants per hectare were planted with 7 kg of forage seeds. The evaluations were carried out in the reproductive phase, stage of development R3 (pasty grains = + - 80 DAP). To verify the possible shading effects, evaluations were made following two spacings according to the tree planting line, being: 1.5 meters and 5.0 meters.

Were analyzedtwo spacings according to the tree planting line, being: 1.5 m and 5 m, with evaluations being carried out as: The total chlorophyll concentrations were determined using the portable meter, Clorofilog1030® (Falker®, Porto Alegre, RS, Brazil); The maximum quantum yield of FSII (Fv/Fm) and quantum yield of electron transport (PhiEO), by means of chlorophyll a fluorescence measurements, using the FluorPen FP 100 portable fluorometer (Photon Systems Instruments; Drasov, Czech Republic), where young leaves, completely expanded, not detached, were previously adapted to the dark for 30 minutes for complete oxidation of the photosynthetic electron transport system. Subsequently submitted to a pulse of 3000 µmol^{-2} s^{-1} of blue light (Strasser et al., 2004); The photosynthetic rate (*A*, µmol CO_2 m^{-2} s^{-1}) and the water use efficiency (*WUE*, µmol CO_2 mmol H_2O^{-1}) through gas exchange analyzes of plants, using a portable gas exchange meter LI-6800 XT (Li-Cor Inc., Nebraska, USA), between 8:00 am and 11:00 am with block temperature set at 25 ° C and photosynthetic photon flux density equal to 1000 µmol m^{-2} s^{-1} and the determination of the leaf area, where the leaf area (cm^2) of each sample was determined with the CI-203 portable laser leaf area meter (CID Bioscience). The experiment was distributed in a randomized block design (DBC) and the data were subjected to a normality analysis using the Shapiro-Wilk test followed by analysis of variance. The data were compared using the Tukey test at 5% probability using the Sisvar software (FERREIRA, 2019).

RESULTS AND DISCUSSIONS

The wide fluctuation of light in the Crop-Livestock-Forest Integration System modulated different responses of growth, physiology and water use in corn plants (Figure 1).

The results show that the shading circumstantially affects the development of corn, at first it appears that for pigments (Figure 1A), there is a higher rate of Clt (40.07) for plants 5 m away from the tree lines in relation to plants with a distance of 1.5 m (27.07). Pigments are related to the ability to absorb energy from light and transport it to the reaction center to produce ATP and NADPH, subsequently fixing carbon dioxide. So, the plant needs an ideal intensity for its growth, and when the low availability of light is contrasted, the production of ATP may be insufficient to fix CO2 and the biosynthesis of carbohydrates, this can limit its growth (SHAO et al., 2014).

The plants, even being in two spaced bands, show the ability to modulate their photosynthetic apparatus in view of the environmental condition at the moment, due to observing the no difference for the parameters of Fv/Fm (maximum quantum yield of photosystem II, Figure 1B) and PhiEO (quantum efficiency of electron transport, Figure 1C). Demonstrating the ability of plants to adapt even under different conditions, and keep their physiological machinery in balance, both in energy transport and in their performance (DELAGRANGE, 2011).

A potential adaptive effect for these shaded plants is the water use efficiency (*WUE*), as observed in Figure 1D, identifying the highest value of this parameter in plants at 1.5 m (6.55 µmol CO_2 mmol H_2O^{-1}) than plants at 5 m (5.58 µmol CO_2 mmol H_2O^{-1}). This answer indicates the maximum use of its resources to increase its photosynthetic yield, due to the low levels of available light, the plants open their stomata exclusively to prevent the limitation of the CO_2 influx, because, if they did not follow this coordinated behavior, it would boost the unnecessary loss of water (DEANS et al., 2019).

Even if the shaded plants increase their physiological efficiency, their performance can be compromised, as seen in Figure 1E the photosynthetic rate (*A*), whose plants at 5 m had greater photosynthesis (23.13 µmol CO_2 m^{-2} s^{-1}) than plants at 1.5 m (µmol CO_2 m^{-2} s^{-1}). This behavior throughout its cycle tends to directly influence the productive yield, and in this case, due to the shading, it verified the greater growth of the plants at 5 m than at 1.5 m, when verifying in Figure 1F (leaf area - LA) the values of 340.40 and 287.42 cm², respectively.

Thus, efficient light interception tends to positively influence the conversion of light energy into chemistry, and, consequently, CO_2 fixation. Additionally, there will be greater partitioning of carbohydrates for drain organs of greater commercial interest and, consequently, greater biomass production (LONG et al., 2015). Thus, it is essential to know the influence of radiation on the crops used in the ILPF system, after all, this process integrates other essential components, such as the photosynthetic capacity of the leaves, soil moisture, temperature, atmospheric CO_2 and, as already mentioned, light solar (DE ANDRADE et al., 2014).

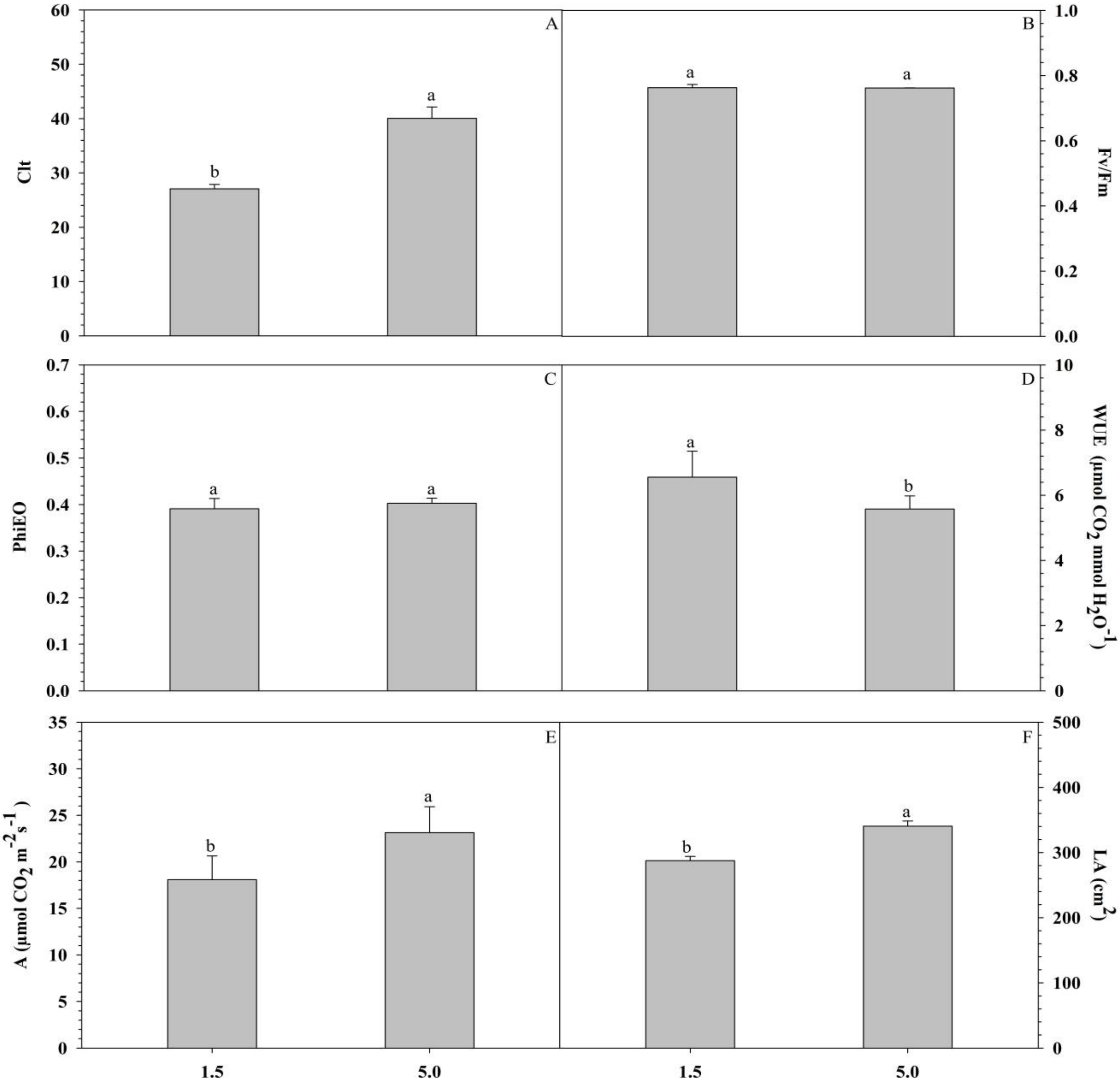

Figure 1. Total chlorophylls (Clt) (A), maximum quantum yield of photosystem II (Fv/Fm) (B); quantum efficiency of electron transport (PhiEO) (C); water use efficiency (*WUE*) (D); photosynthesis (*A*) (E) and leaf area (LA) (F) the wide fluctuation of light in the soybean culture in the Crop-Livestock-Forest integration system in the R5 development phase (grain filling = + - 80 DAP). Averages followed by the same letter do not differ according to the Tukey test at 5% probability. Values are presented as mean ± standard error (n = 5).

CONCLUSIONS

Corn plants showed physiological flexibility in response to changes in luminous radiation, mainly under reduced luminosity, showing the ability to modulate and maintain their photosynthetic apparatus in balance and greater efficiency in the use of water in view of the environmental condition. However, even though the plants under greater shading have increased their efficiency, they showed greater luminous susceptibility to low radiation, highlighting the limited photosynthetic capacity.

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CAATINGA AND INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS: ADAPTATION AND RESILIENCE FOR THE CLIMATE CHANGE

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ABSTRACT

Caatinga's agriculture used to be itinerant, with deforestation, slash and burn and overgrazing, exhausting natural resources. Also, population increasing, climate change worsening semi-arid characteristics, such as water shortages and high temperatures. So, the goal here was to propose the integrated crop-livestock-forestry systems to Caatinga’s family farmers as an adaptive strategy for a resilient farming production. Different integrated systems types were evaluated and analyzed which would be the most suitable for the recovery of Caatinga’s degraded areas, by a bibliographic review and online interviews with local entities. Integrated system can collaborate for agricultural production resilience thanks to environmental restoration capacity. Native and adapted plant species are the most indicated, especially legumes, for their nutritional value and enhanced soil fertility. Integrated crop-livestock-forestry systems associated with social technologies for water access are enhanced and even feasible, with irrigation and stock food production, an essential supplement. Integrated systems implementation is favored by certain characteristics as producers who already use agroecological practices and cattle raising in natural pasture. The acquisition of inputs, conventional cultivation and low technical assistance, may represent difficulties to this transition. Thus, it is importance encouraging the implementation of integrated systems, even if in an autonomous way.

Key words: Resilient agriculture systems; Brazilian semi-arid region; low carbon technologies

INTRODUCTION

Agriculture production in Caatinga began in the seventeenth century and was done in an intensive and predatory way with deforestation and burning, practices that became predominant in subsistence agriculture (ARAÚJO FILHO, 2013). This type of production led to the exhaustion of natural resources in a region already characterized by climatic extremes of prolonged droughts periods and water deficit, together with the low adaptability and population’s low HDI (UNDP, 2013). Thus, the producer became itinerant, searching for new areas to produce, while the abandoned area could regenerate spontaneously.

In this scenario of overexploitation of resources and overgrazing, as a result from intensive agriculture, the environmental quality and fertility of agricultural areas have been greatly reduced. Added to this the population growth, the increasing demand for food, and the abiotic characteristics of the biome, and the adoption of sustainable agricultural technologies, such as those of low carbon emission, become necessary for the recovery and maintenance of natural resources.

Moreover, considering the effects of climate change there may be a worsening of the adverse characteristics for production, typical of the semi-arid region, such as water shortages due to irregular rainfall and high temperatures, that increase evaporation. Given these conditions and the forecast of their worsening, based on future scenarios (MARENGO et al., 2010; MARENGO et al., 2011), it is essential to change the agricultural production type of familiar’s farmers in the Caatinga with the adoption of practices, techniques and specific technologies that improve resilient production and environmental sustainability (FARIAS et al., 2018).

Finally, since agriculture is one of the sectors with the highest greenhouse gas (GHG) emissions in Brazil, the implementation of integrated agricultural and livestock production systems is strongly indicated as an efficient transition strategy towards a more resilient and sustainable production that mitigates GHG emissions (BRASIL, 2019).

In the light of the climatic characteristics and the future scenarios foreseen for the Brazilian semiarid region in the face of climate change, a study was made of how integrated agricultural production systems, such as agro-forestry-pastoral systems, for example, could be proposed as an adequate and recommended adaptive strategy for Caatinga’s family farmers to establish resilient agricultural production with the recovery of degraded areas.

A transition was thought out from the evaluation of the main advantages and challenges of these integrated systems facing the opportunities and threats that exist in the Brazilian semiarid region according to the productive features, social, environmental, and economic aspects. Therefore, the goal of this work was to propose the implementation of integrated crop-livestock-forestry systems, adjusted to the reality of the Caatinga’s family farmers as an adaptive strategy to the worsening environmental characteristics of the semi-arid region and as an option for a resilient agricultural and livestock production.

MATERIAL AND METHODS

Different types of integrated systems were evaluated and then analyzed which would be the most suitable for the recovery of degraded areas of the Caatinga used for agricultural production by family farmers and what adaptations are necessary, according to the environmental and socioeconomic characteristics of the region.

The work started with a bibliographic review, corroborated with 12 semi-structured interviews via videoconference and 12 online questionnaires, summing up 24 local and wide-ranging entities in the Caatinga (research and development centers, universities, cooperatives, governmental and non-governmental institutions). The themes addressed in the interviews were related to the agricultural production methods of small and medium-sized family farmers in the Caatinga and their challenges in living under the semi-arid climate.

RESULTS AND DISCUSSIONS

The integrated and sustainable production system creates mutual benefits for all activities involved through a positive synergy between its components, forming an agro-ecosystem (BALBINO et al., 2011; BRASIL, 2012; LASCO et al., 2014; SOARES, 2020 apud TAVARES et al., 2020). It develops important functions, such as: soil conservation, with increased fertility due to the contribution of organic matter and protection against erosion; reestablishment of nutrient circulation and ecosystem services, resulting with increased water, pollination, and biological diversity. In this way, besides optimizing land use, increasing productivity, the diversity of generated products, and the producer income, without the need to open new areas, it also reduces the pressure on deforestation (RODRIGUES, 2020 and SOARES, 2020 apud TAVARES et al., 2020), Figure 1.

Figure 1. Integrated palm and algaroba system (Credits: MCP – SE, 2020).

This is essential, since these resources and dynamics are even more threatened, in view of the expectations predicted for the semi-arid region based on possible future scenarios that predict an increase in temperature between 3º to 4º C (2041-2070) and to more than 4º C in the period from 2070 to 2100, increasing the frequency and intensity of extreme events, such as droughts, decreasing rainfall (from 10 to 20%) and increasing evaporation rates, putting at risk biodiversity, agricultural production, water, energy and food security in the region (SCHAEFFER et al, 2008; MARENGO et al., 2010; MARENGO et al., 2011; MARENGO & BERNASCONI, 2015).

Integrated production is the most recommended form for the recuperation of an area degraded by intensive exploitation and accentuated by prolonged droughts and recuperation of a degraded pasture, due to the excess of animals in the herd, which cause overgrazing (ARAÚJO FILHO, 2013). Moreover, by being a strategy with different productive components in the same area, agroforestry systems serve as a management form in an area of the property and of the property itself, even more if we consider the characteristics smallholding (2 to 3 ha) of family farmers in the Caatinga.

Since cattle raising is one of the main economic activities in the Caatinga, and a source of subsistence for many families, especially with extensive goat, sheep and cattle raising (GIONGO et al., 2011) the most recommended integration models for this producer profile is the IPF (silvipastoral) that integrates ruminant livestock and forest, since the animals graze on Caatinga vegetation. It is also indicated the insertion of farming into the system (agrosilvipastoral), which is often aimed at feeding the herd, using the so-called protein banks. The tillage is collected together with pruning of the woody species to be transformed into hay and silo, important food supplements for the periods when the animals stay at the trough, so that the producer doesn't need to buy grains and industrialized feed.

For the implementation of these systems, native and adapted herbaceous and arboreal species are the most indicated, prioritizing the planting of legumes, for their nutritional value and capacity to fix nitrogen in the soil, favoring the replacement of nutrients without the need of chemical fertilization. The integrated system can collaborate in the resilience of the Caatinga agricultural production thanks to the function of environmental restoration and contribution of resources, making the region more productive. The main advantages in implementing an integrated system are listed in Table 1, among others as reuse of inputs generated from production, reducing the expenses of the producer and his labor and there is a guaranteed income throughout the year by diversifying products (KICHEL et al.,

2014) in addition to expanding their quality of life and food security (ARAÚJO FILHO, 2013). Therefore, the implementation of these integrated systems is favored in regions that already have certain characteristics and producers who already use agroecological practices or others that relate production with environmental preservation, such as beekeeping, for example.

Furthermore, there are characteristics that may be present in certain areas of the semi-arid region that become an obstacle and can become challenges for the implementation of these integrated systems, as it requires a change in the producer's habit, which needs planning and technical assistance. As well as the acquisition of seedlings, seeds, and specific machinery, which may represent an initial difficulty; other threats to this transition are shown in Table 1. However, it is worth mentioning that with encouragement and knowledge of good practices from other producers, these difficulties can be overcome.

Table 1. Strengths, weaknesses, opportunities and threats for implementation of integrated systems in the Caatinga.

Strengths: - Integrates productive components within the same agricultural area that interact with each other (crop, livestock and forest). - Optimizes efforts in management and production. - Allows the supply of diversified products. - Increases productivity per unit of agricultural area, without exhausting its natural resources and without the need to open and deforest new areas, contributing to the preservation and environmental quality. - Increases the conservation of organic matter, protection against erosion, increases biological activity and mitigates climate effects through the arboreal component.	**Weaknesses:** - Needs manpower and technical assistance for implementation. - Needs the integration between two or more components within the same agricultural area. - If carried out without the forestry component, it lacks the environmental benefits associated with it.
Opportunities: - Use of agro-ecological practices on the property. - Presence of permanent crops: banana and guava, cashew, acerola, mango and passion fruit. - Presence of temporary crops: beans, grain and forage corn, and forage palm. - Meliponiculture (and beekeeping). - Expressive sheep and goat raising. - Presence of dairy cattle raising. - Use of Caatinga as natural pasture.	**Threats:** - Low temporary crop production. - Low technical assistance. - Properties belong to others, lack of incentive to invest in implementation. - Low use of agro-ecological practices that include woody species. - High percentage of conventional cultivation. - Low percentage of natural vegetation on the properties.

Caatinga biome has 28% of its area under agricultural production, and so a proper management is necessary to recover and maintain soil fertility, access to water, seeds, and other resources. Aimed at building an agro-ecological system that recovers the variety and complexity of the natural systems. In order to increase the resilience of the area and the connectivity between islands of native vegetation, which helps maintain biodiversity and recovered ecological relationships (CASTELLETTI et al., 2003).

Integrated agricultural production systems associated with social technologies for capturing, storing and reusing water are enhanced and even made feasible by the possibility of supplying the water demand in periods of drought or at critical moments of crop development through irrigation, even though agriculture is essentially dryland. In the case of livestock, the social technologies of food production (hay and silage) work as an essential food supplement for moments when natural pasture is scarce or when the animals are in the trough.

Integrated crop-livestock-forestry systems work as an umbrella technology, because they can have a direct relationship by being associated with other technologies such as Biological Nitrogen Fixation and Sustainable Forest Management. The combination of these three technologies allows the improvement of coexistence with the semi-arid region and amplifies the resilience to climate change. Through them, it is possible to enhance the recovery of degraded areas and the feeding management of ruminants.

CONCLUSIONS

We reinforce the importance of encouraging the implementation of integrated systems, even if in an autonomous way, by exchanging experience and strengthening technical assistance, due to all the benefits they provide both to the producer and the biome. One of the biggest challenges is the insertion of the tree component in the arrangements, because they are not part of the local productive culture, and therefore may present limitations due to the acquisition and survival of seedlings, demand for water, as well as its isolation from the herd until it is established, about 3 years.

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2. Greenhouse gas emissions and carbon sequestration

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SPATIAL AND TEMPORAL DISTRIBUTION OF GREENHOUSE GAS FLUXES FROM THE SOIL UNDER AN INTEGRATED SYSTEM IN THE SOUTHERN AMAZON

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ABSTRACT

Integrated systems have practices and alternatives aligned with the purpose of greenhouse gas (GHG) mitigation, and knowing the spatial and temporal variability of soil gas fluxes is the first step toward understanding how integrated systems mitigate GHG emissions. This work aims to assess the spatial and temporal distribution of the GHG fluxes of soils cultivated with soybean and corn in integrated systems with trees in Brazil, southern Amazonia. Soil GHG fluxes were measured using static chambers during the whole cycle of soybean and corn cultivation in the integrated system. The trees formed alleys of triple rows of eucalyptus, with 30 m intervals between the alleys. Soybean and corn were successively cultivated in the space between the alleys. The spatial and temporal distribution of the GHG fluxes showed that the nitrous oxide (N_2O) and methane (CH_4) fluxes were highly related to soil management factors, such as fertilization and soil use. As the carbon dioxide (CO_2) fluxes showed a largely similar distribution among the points within the same sampling date, another condition similar across all points (such as precipitation) could be influencing the decomposition of the soil organic matter and root respiration, which are the main processes responsible for CO_2 production in soils

Key words: Nitrous oxide; Methane; Carbon dioxide

INTRODUCTION

Soil is an important source of greenhouse gases (GHGs), which mainly consist of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (OERTEL et al., 2016). If good agricultural practices are adopted, soil can act as a sink, decreasing or avoiding GHG emissions or removing carbon (C) from the atmosphere (OERTEL et al., 2016; SMITH et al., 2008). In the humid tropics, the search for agricultural systems adapted to that specific edaphoclimatic condition has been performed considering not only high productivity but also the provision of environmental services, such as GHG mitigation.

Integrated systems, which come in different configurations, have practices and alternatives aligned with the purpose of GHG mitigation (BEHLING et al., 2013). There are integrated systems that involve trees, which increase the C sequestration in the soil and the tree biomass. Moreover, trees in agricultural systems alter the exchanges of matter and energy compared to monocultures (BEHLING et al., 2013). These shifts are triggered by the type of spatial arrangement and the temporal succession of soil use, and they increase the number of cultures in a year (BEHLING et al., 2013). Thus, new tools must be used to understand the spatial and temporal distribution of attributes related to agricultural systems. This will lead to an understanding of these shifts, which are mainly linked to the shade of trees and the intensification of soil use. In the context of climate change, knowing the spatial and temporal variability of soil gas fluxes is the first step toward understanding how integrated systems mitigate GHG emissions.

The goal of this work was to assess the spatial and temporal distribution of the GHG fluxes of soils cultivated with soybean and corn in integrated systems with trees in Brazil, southern Amazon.

MATERIAL AND METHODS

This work was conducted in the experimental farm of the Embrapa Agrossilvipastoril, Sinop, Mato Grosso, Brazil. The Köppen climate classification of the region is Aw. The soils were classified as Hapludox (SOIL TAXONOMY, 1999) with clay textures in flat relief.

The studied integrated system was established in 2 ha in November 2011. The trees of the system are eucalyptus (*Eucalyptus urograndis* clone H13) that form triple-row alleys (3 m × 3.5 m), with intervals of 30 m between the alleys. In these spaces, soybean (*Glycine max* L.) was cultivated first, and corn (*Zea mays*) was intercropped with Marandu grass (*Urochloa brizantha* cv. Marandu) after soybean harvest. Soybean was sown on October 30, 2016 and harvested on March 3, 2017. Corn was sown on March 3, 2017 and harvested on July 21, 2017. Soybean was sown using a seeding rate to reach 10 plants m^{-1} and 0.45 m of row space, which received 90 kg ha^{-1} of K applied in the planted row and more than 90 kg ha^{-1} of K on the soil surface 30 days after sowing. Corn was sown using a seeding rate to have 3 plants m^{-1} and 0.45 m of row space in combination with the Marandu grass. Fertilization in the corn row consisted of 35 kg ha^{-1} of N, 60 kg ha^{-1} of P, and 60 kg ha^{-1} of K. The corn, in combination with the Marandu grass, also received fertilization of 67 kg ha^{-1} on the soil surface in the corn growth stages 4 and 6 (V4–V6). The whole fertilization was based on soil fertility status and crop requirements.

The GHG fluxes were measured during the whole cycle of both cultures. Fifteen samplings were performed in each cycle of the soybean and corn; each sampling started 3 days after sowing and ended during culture harvest. For this purpose, 12 chambers were distributed across 4 points of the assessed system: 7.5 m north, tree rows, 7.5 m south, and 15 m south. Each point had three replicates, and the average of each point was calculated. The GHG fluxes were evaluated using vented rectangular static chambers whose bases and tops were made of metal and polyethylene, respectively. The chamber size was 0.60 m × 0.40 m × 0.09 m (length, width, and height). The samples were collected in the top of the chamber using a 20 cm^3 syringe (PARKIN; VENTEREA, 2010). We sampled the gas weekly (between 8 and 11 am, with four samples collected within 60 min at 20 min intervals: 0, 20, 40, and 60 min) (PARKIN; VENTEREA, 2010). During gas collection, the internal temperature of the chamber was also measured using a digital thermometer. The samples in the syringes were transferred to vials subjected to a vacuum, then used to determine the N_2O, CO_2, and CH_4 concentrations in a gas chromatograph (SHIMATZU, 2014) equipped with an automatic injector, electron capture detector (ECD), and flame ionization detector (FID). The analytical curve was obtained by determining three known concentrations of standards to the three gases assessed.

Those analytical results were used to establish a linear equation between the increasing the GHG concentrations over the time of the chamber deployment (0, 20, 40, and 60 min). Equation parameters were used to calculate GHG fluxes from the soil to the atmosphere following the equation proposed by Hutchinson and Livingston (1993): Flux (µg N_2O/CH_4, mg CO_2 m^{-2} h^{-1}) = (dC/dt) x V/A x (m/Vm); where: dC/dt = change in gas concentrations within the chamber based on time; V = chamber volume (L); A = chamber area (m^2); m = molecular weight of the gas (g mol^{-1}); Vm = molar volume of the gas (m^3 mol^{-1}) corrected for the air temperature (K) of the headspace chamber.

The average of the GHG fluxes of each point (spatial) in the integrated system was distributed as a function of the time (temporal - days after sowing) of the soybean and corn stages, in which were applied the Spline method of interpolation using the ArcMap® software.

RESULTS AND DISCUSSIONS

Overall, N_2O fluxes were lower in the soil under the alley of trees in the integrated system (Figure 1a), with values between 5 and 25 µg N_2O-N m^{-2} h^{-1} throughout the cycle of the soybean. The highest fluxes were observed in the soil with soybean, with values between 5 and 120 µg N_2O-N m^{-2} h^{-1}. At the point 15 m south in the beginning of the culture cycle was observed high values of fluxes, what can be related to the soil changes in the sowing line, once it just received K fertilization in this period of the culture. The N_2O fluxes increased again 92 days after sowing, with the highest flux at the point 7.5 m north. In this period of the soybean occurs the dead of the nodule responsible for N_2 fixation and the senescent leaves fall in the soil surface, increasing soil temperature, what favor the N_2O formation (NASCIMENTO et al., 2021). Besides, when tree shade was more projected to the north, at the end of the soybean cycle, was observed the highest fluxes at the point 7.5 north, and, at the beginning of the culture, when the tree shade was projected to the south (MAGALHÃES et al., 2018), this point had the highest fluxes. All these may evidence the role of the temperature on the processes related to the N_2O formation (BUTTERBACH-BAHL et al., 2013).

The CO_2 fluxes were between 50 and 300 mg CO_2-C m^{-2} h^{-1} (Figure 1 b). Such as to the N_2O, the highest fluxes occurred in the soil with soybean, however, CO_2 fluxes seemed to have less influence of the soil management once the soil under the alley of tress and soybean had similar fluxes, forming more vertical zones of the same color. In this case, the rainfall, that is similar to the all points, could help to explain these similar fluxes, even on the influence of the shade.

In general, all the point assessed in the integrated system showed soil with CH_4 influxes during the soybean cycle (Figure 1c), with values mostly between 0 to less than -4 µg CH_4-C m^{-2} h^{-1}. When fluxes were observed they occurred in the soil cultivated with soybean. The homogeneous color zones more distributed in the horizontal can be an evidence of more influence of the soil management on the CH_4 formation in the integrated system.

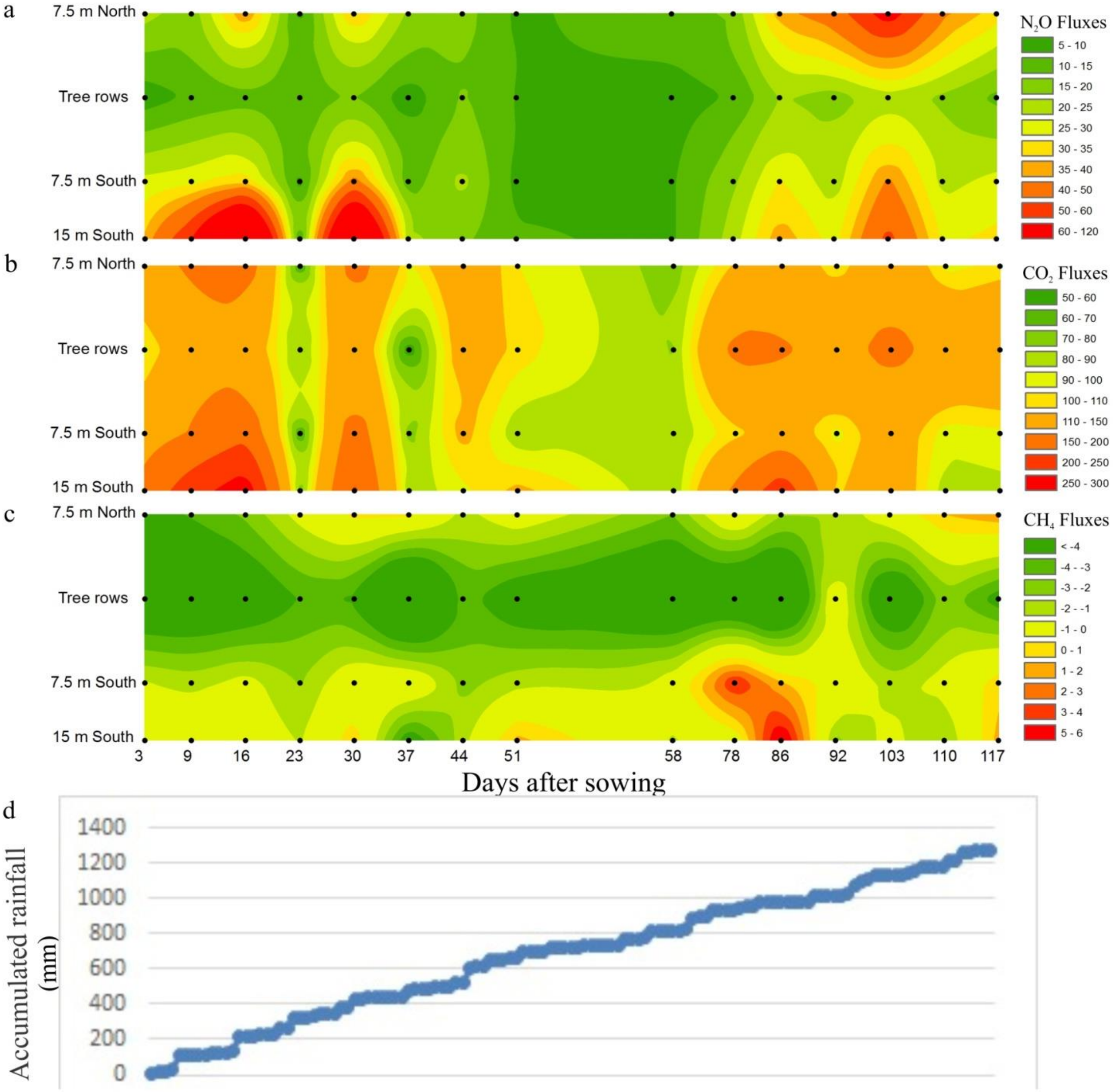

Figure 1. Spatial and temporal distribution of the fluxes of N_2O (µg N_2O-N m^{-2} h^{-1}) (a), CO_2 (mg CO_2-C m^{-2} h^{-1}) (b), and CH_4 (µg CH_4-C m^{-2} h^{-1}) (c) from the soil and accumulated rainfall (d) throughout the soybean cycle in intergraded system with trees in the Southern Amazon – Brazil.

Such as to the soybean, soil cultivated with corn showed higher N_2O fluxes than under the trees (Figure 2a). The highest N_2O fluxes occurred after N fertilization on the soil surface 24 to 30 days after sowing, with values between 50 and 120 µg N_2O-N m^{-2} h^{-1}. Increasing the N availability in soils with the fertilization, added the period of rainfall, triggered the formation of N_2O in the soil with corn (BUTTERBACH-BAHL et al., 2013). Even with high fluxes in the soil with corn, the soil under the trees showed fluxes below 25 µg N_2O-N m^{-2} h^{-1} at the same period.

Around 80 days after sowing, when there was no more rainfall, all the points and dates had N_2O fluxes below 20 µg N_2O-N m^{-2} h^{-1}.

Until 24 days after sowing, the highest CO_2 fluxes occurred in the soil under the trees (Figure 2b). From this period, homogeneous color zones in the vertical appeared with more frequency, showing likely more influence of the water availability than the soil management on the processes related to the oxidation of soil organic matter and the root respiration. Such as to the N_2O, the CO_2 fluxes decreased a lot 80 days after sowing, further highlighting the role of the rainfall on this gas.

The CH_4 fluxes were in general below zero throughout the corn cycle (Figure 2c). The higher values of influx occurred in the soil with trees, with values below -20 µg CH_4-C m^{-2} h^{-1} 24 day after sowing. In general, it was observed a trend of form homogeneous color zones in the horizontal, showing the role of the soil management on the formation of this gas.

Taken into account the both cultures, the soil under the alley trees showed more methanotrophy than the soil with soybean or corn, corroborating Oertel et al. (2016), who claim that forest soils have more methanotrophic potential and showed similar results that those shown here.

An important point to highlight during the soybean and corn cycles is the facts that on the dates when there was an increase in N_2O fluxes occurred an increase in CO_2 fluxes in the same points. What differentiates the two is the fact that the increases in N_2O occurred only in the points that underwent some management intervention, whereas the increases in CO_2 fluxes also occurred in the points without interference of these managements.

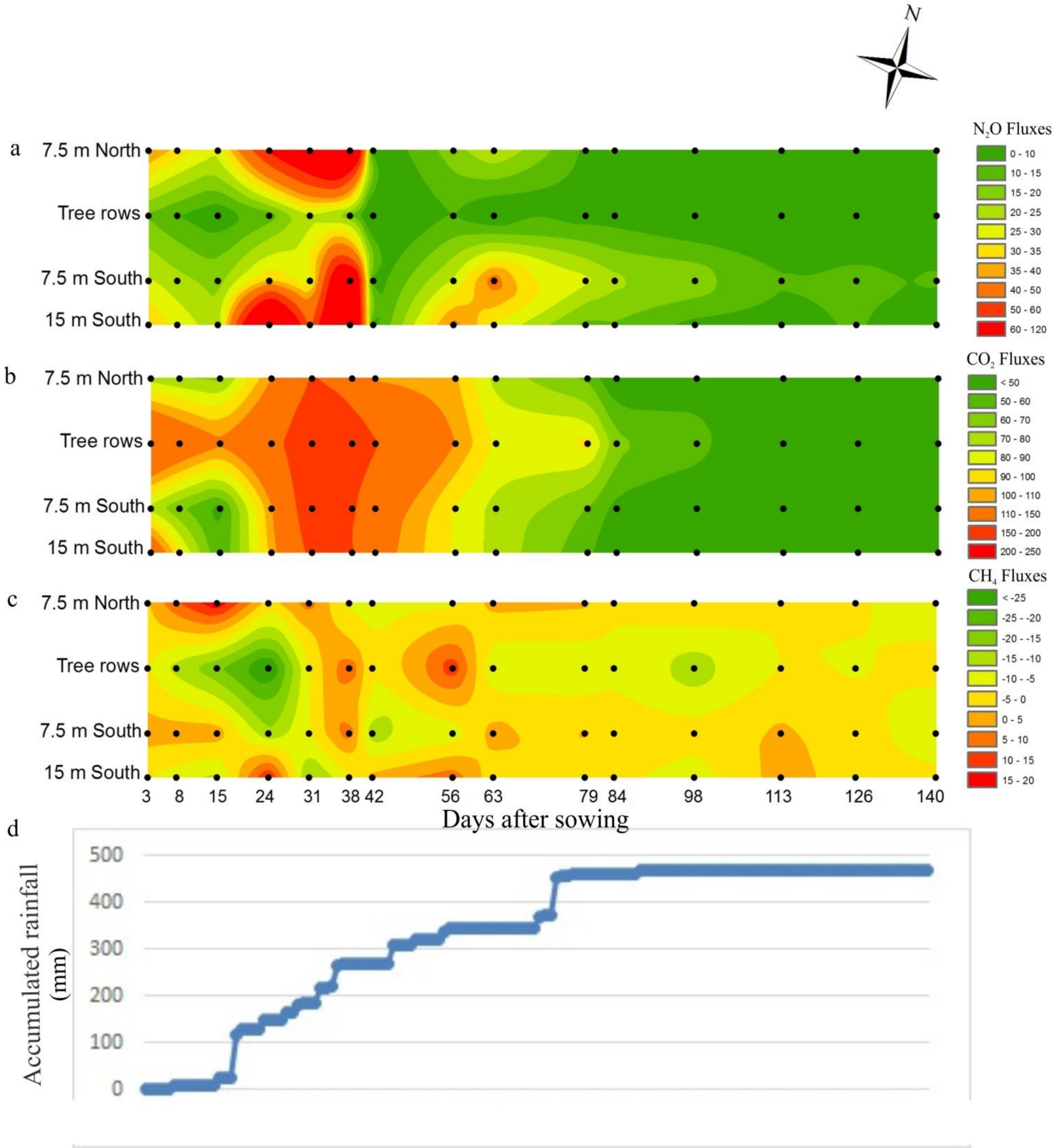

Figure 2. Spatial and temporal distribution of the fluxes of N_2O (µg N_2O-N m^{-2} h^{-1}) (a), CO_2 (mg CO_2-C m^{-2} h^{-1}) (b), and CH_4 (µg CH_4-C m^{-2} h^{-1}) (c) from the soil and accumulated rainfall (d) throughout the corn cycle in intergraded system with trees in the Southern Amazon – Brazil.

CONCLUSIONS

For the edaphoclimatic conditions of the Southern Amazon, the spatial and temporal distribution of the GHG fluxes of the soil cultivated with soybean and corn in intergraded system showed that N_2O and CH_4 fluxes are more related to the soil management, such as fertilization and soil use (tree, soybean, corn). As CO_2 fluxes showed more similar distribution among the points within the same sampling date, it seems that another condition, such as precipitation, similar to all points, could be a factor influencing the decomposition of the soil organic matter and root respiration, the main processes responsible by the CO_2 production in soils.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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BIOMASS PRODUCTION AND CARBON SEQUESTRATION IN AGROSSILVIPASTORIL SYSTEM OF DIFFERENT FOREST SPECIES

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ABSTRACT

During the 15th Conference of the Parties (COP-15), the Brazilian government announced its voluntary commitment to reduce greenhouse gas (GHG) emissions in the country, projected for 2020 between 36.1% and 38.9%. Among the components of the LFS (Livestock-Forestry Sistem) /CLFS, the tree component is the one with the highest carbon accumulation capacity. Through the growth of trees, part of the atmospheric CO_2 is sequestered by plants for the storage of luminous energy. The species implanted in the area are for wood extraction such as Eucalyptus, Australian Cedar, Teak and African Mahogany and others for fruit extraction such as Pequi and Baru. Eucalyptus stood out, being the species that most produces dry biomass and kidnaps carbon from the atmosphere, responsible for kidnapping approximately 80 Mg of C/ha. Among the noble wood, cedar was the species that most sequestered carbon from the atmosphere, 16.04 Mg of C ha^{-1}, while Teak was the species that least sequestered carbon from the atmosphere, 11.89 Mg of C ha^{-1}. The savannah native species, focused on fruit production, had values close to each other and much lower than those obtained by fast-growing species. In the area with eucalyptus, Carbon Neutral Meat (CNM) can be produced with a capacity of 8.5 AU ha^{-1}.

Key words: Crop-Livestock-Forest System; CO_2 sequestration; Carbon Neutral Meat

INTRODUCTION

Crop-Livestock-Forest System (CLFS) is a sustainable production strategy, which integrates agricultural, livestock and forestry activities, carried out in the same area, in a consociation cultivation, in succession or rotation, and seeks synergistic effects among the components of the agroecosystem, contemplating environmental adequacy, the valorization of man and economic viability (BALBINO et al., 2011).

CLFS systems enhance the best water dynamics, mainly with the insertion of the forest component, because there is an improvement in water vapor distribution, stabilization of temperature and relative humidity, protection of the soil surface, being considered efficient tools to combat global warming and climate change. Tree components act not only as thermal stabilizers and cloud-suppressing solar radiation interceptors, but, with their plant residues on the ground, they also act as interceptors and rainwater stores (PRIMAVESI, 2007).

During the 15th Conference of the Parties (COP-15), the Brazilian government announced its voluntary commitment to reduce greenhouse gas (GHG) emissions in the country, projected for 2020 between 36.1% and 38.9%. It was estimated at that time a decrease of around one billion tons of CO_2 equivalent (t CO_2 eq) by the year 2020. In this context, the goal for the agricultural sector is to reduce from 133.9 to 162.9 million t CO_2 eq by 2020 through the adoption of various agricultural techniques mitigating GHG. (ASSAD et al., 2019).

The trees of silvopastoral systems serve as an instrument for the renewal and recovery of pastures and favor the cycling of nutrients, especially using woody legumes, assisting in the availability of these resources for the associated crops. It is estimated that agroforestry systems (CFS) can store from 0.29 to 15.21 C t $ha^{-1}year^{-1}$ above ground and from 30 to 300 t $ha^{-1}year^{-1}$ up to 1 m soil depth. The accumulation of organic C in the soil grows with increasing diversity and density of trees (NAIR, 2011).

Among the components of the LFS (Livestock-Forestry Sistem) /CLFS, the tree component is the one with the highest carbon accumulation capacity. Through the growth of trees, part of the atmospheric CO_2 is sequestered by plants for the storage of luminous energy. Thus, by removing CO_2 from the atmosphere, the trees generate a positive balance for the productive system, enabling the neutralization of the GEEs released by the other components, most nodded, the enteric methane emitted by grazing cattle (ALVES et al., 2019).

Thus, the present work aims to observe the increase of biomass and carbon fixed by different forest species in ALFI over the 5 years of implantation.

MATERIAL AND METHODS

The experiment was installed at the Agrosilvipastoril System Study Center, at Fazenda Sobradinho, from IFTM Campus Uberlândia Sobradinho (726 m altitude, latitude 18° 46, 46.4" S, longitude 48° 17' 37.1" O), in an area of 5 ha, in clay soil and classification Red-dystrophic Latosol according to SiBCS Embrapa (2016), with declivity of 7%.

The agrossilvipastoril system was implemented in January 2016. The forest species are spaced in 15 m between rows and two meters between plants. In the spacing between the plants has been cultivated corn in summer and in winter remains with pasture.

Some of the species planted in the area are for wood extraction such as Eucalyptus (*Eucalyptus* spp.), Australian Cedar (*Toona ciliata*), Teak (*Tectona grandis*) and African Mahogany (*Khaya ivorensis*) and others for fruit extraction such as Pequi (*Caryocar brasiliense*) and Baru (*Dipteryx alata*). Eucalyptus, Teak, African Mahogany (propagated by seed), Pequi and Baru are arranged in 3 row single-line, each with 40 plants, totaling 120 plants of each species. The Australian Cedar is arranged in 2 row single-line with 40 plants each and 1 row single-line with 20 plants, totaling 100 plants. African Mahogany (propagated by stofa) is arranged in two row single-line with 30 plants in each, totaling 60 plants.

Annual measurements of total height and diameter, at 120 cm, were made in 20 plants of each row, in a total of 5 measurements (May 2016, February 2017, November 2018, September 2019 and July 2020). The plants evaluated were always the same and, for this, are properly identified.

While in the first evaluations, laser tape was used with leica model camera, in larger trees and topographic sight of 5 m in smaller ones. The last height measurement was performed with the aid of a Hagof forest clinometer. All measurements of DAP (diameter at chest height - 130 cm) were performed with a Diametric Trena.

For the estimation of biomass and carbon, the non-destructive method was performed, due to the impossibility of using the destructive method, due to the area being intended for study with their presence. Therefore, only the biomass of the sprit without bark and not of other forest compartments, such as branches, leaves, bark, etc. was evaluated.

According to Bolina & Barreira (2011), the following equation is used to estimate biomass:

$$Bt = dVt \qquad \text{Eq. (1)}$$

Where: Bt= Total biomass; d= Average density ($kg.m^{-3}$); Vt= Total volume (m^3)

The values of basic wood density for each species were obtained in the literature.

The calculation of cubation was performed through the equation, proposed by Souza & Alexandre (2010):

$$V = \pi(DAP/2)^2 H \qquad \text{Eq. (2)}$$

Where: V = volume; DAP = diameter at breast height; H = height.

Once this was done, the result obtained was multiplied by the form factor according to each forest species, in order to obtain the estimated volume (Miranda et al., 2015). The Form Factor of each species was removed from the literature.

To obtain the amount of dry biomass, the value suggested by HIGUCHI et al. (1998) was used, according to which, of the total weight of a tree 60% corresponds to the dry weight.

The carbon estimates fixed in the wood biomass of the trees were obtained by multiplying the biomass estimates obtained by the middle factor (0.5), an equation suggested by SOARES et al. (2006), considering that dry biomass contains approximately 50% carbon. To obtain the CO_2 value, it is considered that 1 (one) ton of carbon corresponds to 3.67 tons of CO_2 taken from the earth's surface (TITO et al., 2009).

RESULTS AND DISCUSSIONS

Table 1. Dry biomass (Bd) in Kg and CO_2 equivalent (CO_2 eq) in Mg/ha stock in the trunk of several forest species in CLFS with a population of 333 plants/ha.

Species	Months after planting							
	24		36		48		60	
	CO_2 eq	Bd	CO_2 eq	Bd	CO_2 eq	Bd	CO_2 eq	Bd
Eucalyptus	1.76	2.88	29.53	48.33	55.91	91.49	80.00	130.93
Australian cedar	0.01	0.01	3.28	5.38	8.08	13.22	16.04	26.25
Mahogany Af. (stake)	0.14	0.23	3.15	5.15	8.27	13.53	14.60	23.90
Mahogany Af. (seed)	0.22	0.36	3.01	4.93	6.52	10.67	12.44	20.35
Teak	0.52	0.86	3.45	5.64	6.83	11.17	11.89	19.45
Pequi	0.08	0.14	0.72	1.18	1.97	3.22	4.75	7.78
Baru	0.08	0.12	0.62	1.01	1.81	2.96	3.23	5.29

The first year of the results were disregarded due to the low value found. According to Table 1, after 60 months of planting, among the fast-growing species, eucalyptus stood out, being the species that most produces dry biomass and kidnaps carbon from the atmosphere, responsible for kidnapping approximately 80 Mg of C ha^{-1}, close value was estimated by Campanha et al. (2017) with same spacing and time of plantation, he estimated 54.63 Mg ha^{-1} of kidnaping carbon by the eucalyptus, these results are expected once eucalyptus is the species with most growth between the species evaluated. Among the noble wood, cedar was the species that most sequestered carbon from the atmosphere, while Teak was the species that least sequestered carbon from the atmosphere. The slow-growing species, focused on fruit production, had values close to each other and much lower than those obtained by fast-growing species.

Table 2. Potentially neutralized stocking rate for a Crop-Livestock-Forest Integration system with 333 trees per hectare.

Species	**Months after planting**		
	36	**48**	**60**
	AU ha^{-1} $year^{-1}$	**AU ha^{-1} $year^{-1}$**	**AU ha^{-1} $year^{-1}$**
Eucalyptus	5.2363	7.4346	8.511
Australian cedar	0.5824	1.0745	1.7064
Mahogany Af. (stake)	0.558	1.0992	1.5534
Mahogany Af. (seed)	0.5338	0.8667	1.323
Teak	0.6109	0.9077	1.2645
Pequi	0.1278	0.2618	0.5056
Baru	0.1099	0.2407	0.3438

According to Alves et al. (2019), Embrapa conceived the concept-mark "Carbon Neutral Meat" (CNM), whose objective is to attest to the neutralization of methane emitted by cattle produced in silvipastoril integration systems (livestock-forest system, LFS) or agrossilvipastoril (crop-livestock-forest, CLFS). To determine the potentially neutralized stocking rate, it was considered that one animal unit (1 AU = 450 kg of live weight of adult bovine) emits, on average, 1.88 Mg of CO_2 eq $year^{-1}$ (IPCC, 2006). According to Table 2, eucalyptus has the potential to neutralize the GHEs emitted by 8.5 AU ha $year^{-1}$, a value higher than that found by Campanha et. (2017).

According to Alves et al. (2015), the average stocking rate of Brazilian pastures reaches close to 1.0 AU ha $year^{-1}$, so it is noted that all fast-growing forest species studied have the capacity to produce an CLS mitigating the adverse effects of GHG emissions emitted by animals in meat production, in addition to considerably increasing, in the case of Eucalyptus, the animal capacity per area, in addition to adding value to the product with the production of CNM.

CONCLUSIONS

Eucalyptus was the species that produced the driest biomass and sequestered CO_2 eq from the atmosphere.

In the area with eucalyptus, CNM can be produced with a capacity of 8.5 AU ha^{-1}.

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BIOLOGICAL NITROGEN FIXATION OF COMMON BEANS REDUCES EMISSION INTENSITY IN AN INTEGRATED CROP-LIVESTOCK SYSTEM ON A FERRALSOL OF THE BRAZILIAN SAVANNAH

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ABSTRACT

The objective of the study was to evaluate the effect of biological nitrogen fixation (BNF) and mineral nitrogen (N) on the emission of nitrous oxide (N_2O), volatilization of ammonia (NH_3) and production of common beans in an integrated crop-livestock system (ICL). The ICL system has about 8 ha, was implemented in 2011/2012 on a clay soil in an experimental area of Embrapa Rice and Beans, in the municipal area of Santo Antônio de Goiás, Goiás State, Central West region of Brazil. The treatments were without application of N (CONTROL); beans inoculated with N-fixing bacteria (*Rhizobium* sp.) and growth promoters (*Azospirillum* sp.), without the addition of mineral N (BNF); Mineral N (urea) applied according to standard recommendation (65 N); and mineral N (urea) applied according to the N sufficiency index criterion (102 N). N_2O and NH_3 were measured using static chambers, according to the method described by Alves et al. (2012) and Araújo et al. (2009), respectively. Emission and volatilization were calculated as the sum of fluxes throughout the common bean crop season, between October 2019 and January 2020. The cultivar used was BRS FC104. Emission intensity was calculated as the sum of the amount of N lost ($N_2O + NH_3$) per kg of grain produced. The emission of N_2O was significantly lower in the treatment BNF (0.69 kg ha^{-1}) than in the treatments 65 N and 102 N (1.44 and 1.25 kg ha^{-1}). The volatilization of NH_3 was significantly lower in BNF (1.31 kg ha^{-1}) than in 102 N (11.38 kg ha^{-1}). The grain yield did not differ between treatments and was in average high (3,109 kg ha^{-1}), as a result the emission intensity was significantly lower in the treatment BNF (0.90 g N kg $grain^{-1}$) than in the treatment with the highest dose of mineral N, 102 N (3.86 g N kg $grain^{-1}$) in the ICL system.

Key words: Nitrous Oxide; Ammonia; Mineral N

INTRODUCTION

Integrated farming systems are one of the main strategies of the Brazilian government to reduce or compensate for carbon emissions from agriculture with simultaneous improvement in production eficiency (OLIVEIRA et al., 2018). To achieve maximum potential of crop-livestock integration, the system should be adapted to regional demands and should be diversified. It is important to include staple foods in integrated systems because, besides diversification of production, this strategy may contribute to sustainable production of food in more resilient agricultural systems.

Nitrogen (N) fertilization is essential for the sustainability of agricultural systems, since N is the macronutrient required in greater quantity by agricultural crops. An important portion of the N required by the plants can be supplied through the N contained in the organic matter of the soil, organic fertilizers, plant residues, and through the excreta of faces and urine of animals (LIMA, 2018). However, the N present in the soil is not sufficient to sustain high yields, requiring the addition of nitrogen fertilizers (RAIJ, 2011).

Biological nitrogen fixation (BNF) is a natural process and is quite common in plants, mainly, but not exclusively, legumes. It allows some plant species to use molecular nitrogen (N_2) after its transformation by symbiotic bacteria in soil. BNF is a process widely used in soybean production and eliminates totally the need for the use of mineral N fertilizers. Common beans (*Phaseolus vulgaris* L.) is capable of BNF, however in commercial varieties this characteristic is suppressed. Therefore, the use of BNF for common bean production is a challenge.

Research results indicate that is possible for common beans to benefit from FBN in field conditions, reaching productivity levels of up to 3,425 kg ha^{-1} without using irrigation (HUNGRIA et al., 2000), and of up to 4,355 kg ha^{-1} with irrigation (Mendes et al., 2004). Brito et al. (2015), found that the productivity potential of common beans inoculated with rhizobia associated with supplementation with N as top dressing can reach 2,500 kg ha^{-1} in the Brazilian savannah ecosystem (Cerrado).

Due to the dynamic of N in soil-plant-atmosphere systems, losses through volatilization of ammonia (NH_3), nitrous oxide emission (N_2O) or leaching of mineral N (mainly nitrate, NO_3^-) must be considered. The use of mineral N fertilizers, such as urea, can result in increased production costs and environmental contamination (SANTOS et al., 2016).

The emission of N_2O is a result of denitrification and nitrification of N by soil microorganisms (CARVALHO et al., 2010). N_2O is a greenhouse gas (GHG) that has a global warming potential (PAG) about 310 times greater than the PAG of CO_2, over a period of 100 years in the atmosphere (IPCC, 2007). The use of mineral N fertilizers, decomposition of plant residues and manure are among the main sources of N_2O emissions from agricultural systems in Brazil (CARVALHO et al., 2006; ALVES et al., 2006).

In addition to the emission of N_2O, N can be lost as ammonia (NH_3) via the volatilization process. Losses via volatilization are extremely important because mineral N, usually urea, is mainly applied via top dressing, a perfect condition for hydrolyzation of urea and further losses of N as NH_3. Volatilized NH_3 is deposited again on Earth's surface via precipitation, being considered an indirect source of N_2O emission (CARVALHO et al., 2018).

The increasing concentration of GHG’s in Earth’s atmosphere generates concern on emissions from anthropogenic activities as the main cause of climate change. The growing demand for food production due to the increased urban population, can result in increased pressure on environment. Therefore, there is an urgent need to implement practices and process that can increase production efficiency of agricultural systems.

Common bean is a staple food for Brazilian population. Brazil is one of the largest producers and consumers of common beans. The proposition of technologies that can maximize production and reduce financial and environmental costs is essential for the Brazilian agricultural sector. Given the above mentioned, this research aimed to evaluate the effect of biological fixation of N and mineral fertilization of N on N_2O emission and NH_3 volatilization and grain yield of common beans cultivated under a crop-livestock system on a Ferralsol of the Brazilian savannah.

MATERIAL AND METHODS

Description of field experiment

The study was conducted in an integrated crop-livestock (ICL) system implemented in 2011/2012 in 8 ha at the research farm of Embrapa Rice and Beans, in Santo Antônio de Goiás, GO. The geographical coordinates of the study site were: 16 ° 29' 59 " to 16 ° 29' 44" W and 49 ° 17' 35 " to 49 ° 17' 54" S. The altitude of the area is 804 m and the slope is approximately 0.3%. The soil is a Rhodic Ferralsol (53-58% clay) (SANTOS et al., 2010). According to the Koppen classification (1936), the climate is a tropical savanna (Aw) with well-defined rainy (from October to April) and dry (May to September). The average annual precipitation of the last 33 years is 1,490 mm, and the average annual temperature is 23 ° C (AGRITEMPO, 2017).

Since 2011/2012 the ICL is a rainfed system including a rotation between a crop, such as soybean, rice, corn and sorghum cultivated alone or in consortium with Brachiaria grass, throughout the summer season, and a pasture formed by Brachiaria grass that serves to cover soil or to feed beef cattle throughout the dry season. In the summer season 2019/2020, common bean (*Phaseolus vulgaris* L.) was cultivated throughout the summer season (from October 2019 to January 2020). The cultivar used was BRS FC104 developed by Embrapa for integrated systems with a very short cycle of 60 days. Within the ICL, four treatments were implemented in strips: without application of mineral or biological fixation of N (CONTROL); the biological N fixation via inoculation of common beans (seeds and plants) with *Rhizobium* and *Azospirillum* (BNF); 65 kg ha^{-1} of mineral N applied as urea according to the standard recommendation for the culture (65 N); 102 kg ha^{-1} of mineral N applied as urea according to the sufficient index of N for common beans (102 N).

Volatilization of Ammonia (N-NH_3) from soil

Static free semi-open collecting chambers (SALE) were used to determine volatilized ammonia NH_3, according to Araújo et al. (2009) and Jantalia et al. (2012). The SALE was made from a transparent plastic bottle made of polyethylene terephthalate (PET), with a capacity of 2 L and covering an area of 0.008 m^2 on soil. A plastic flask with a capacity of 80 mL was placed inside each chamber, containing 60 mL of capture solution (1 mol L^{-1} sulfuric acid and 2% glycerin). A sponge of polyurethane 2.5 mm thick, 2.5 cm wide and 25 cm long was soaked in the capture solution. The sponge remained hanging vertically inside the SALE, with the lower part inside the plastic flask with the capture solution (Figure 1a). These SALE's containing the sponge and capture solution remained in the field since common beans was sown, throughout the entire crop season. Changes of sponges and capture solution were done constantly, at each 3 or 7 days. The capture solution of each SALE was diluted, followed by further analysis to quantify N using the "FIAlab" system (Flow Injection Analysis). Volatilization of N-NH_3 was determined in kg ha^{-1} as the sum of fluxes measured for the entire common bean season.

Emission of Nitrous oxide (N-N_2O) from soil

Nitrous oxide fluxes were measured using rectangular closed static chambers, according to Alves et al. (2012). These chambers are composed of two parts (top and bottom), which were coupled to measure the accumulation of N_2O in 3 times after closure, at 0, 15 and 30 minutes. The lower part, or base of the chamber consisted of a rectangular box made of metal with a hollow (40 cm x 60 cm), with walls 10 cm high, having a gutter (2 cm wide x 2 cm high) across the upper perimeter (Figure 1b). The base of the chamber was inserted 10 cm into the soil, so only the gutter was visible. The upper part, or top of the chamber, consisted of a rectangular metal box (40 x 60 cm and 15 cm high), equipped with connections and vials to extract air samples from inside the chambers. Before coupling the parts of the chamber for air sampling, the gutters were filled with water to seal the system. First air sample was collected as soon as the upper and lower parts were coupled, then at 15 and 30 minutes after. A volume of 60 mL of air was sampled using syringes. At the laboratory, syringes were coupled to an automated vacuum pump, and part of the sample was transferred to a 20 mL vial (headspace). A volume of 30 mL was initially discarded by purging the vacuum system. The concentrations of N_2O inside the vials was subsequently analyzed using an automatic gas chromatography. Sampling was carried out always in morning time between 8:00 and 10:00 in order to take an adequate representation of daily fluxes (ALVES et al. 2012). Frequency of sampling was daily or weekly throughout the entire common bean season. Total emission of N-N_2O was determined as the integration of measured fluxes.

Statistical analysis

Analyses were performed using the linear mixed model procedure (Proc Mixed) in SAS/STAT (SAS, 2008). Treatments (CONTROL, BNF, 65 N, and 102 N) were considered as fixed effects and repetitions (chambers) as random effect. F tests was applied for the main effects (treatments). Dunnett's test was applied to check for linear contrasts between means of BNF and other treatments.

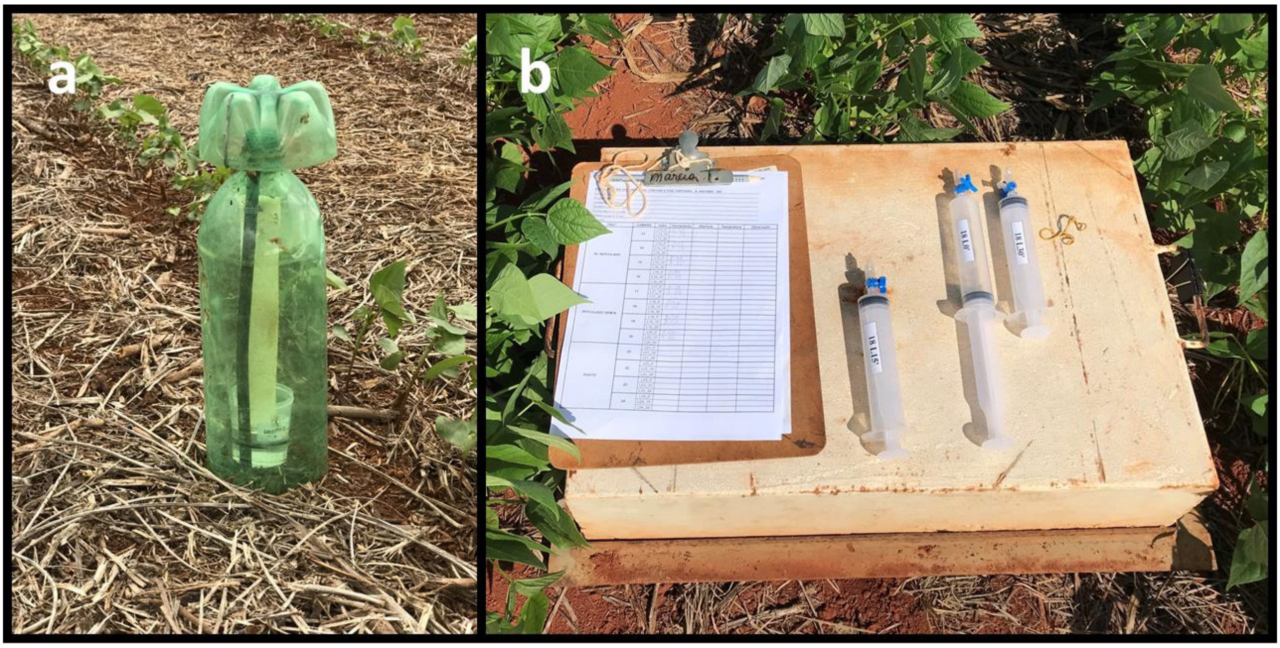

Figure 1. a. Static free semi-open collecting chamber (SALE) for ammonia, and b. static chamber for the collection of greenhouse gas fluxes from soil.

RESULTS AND DISCUSSIONS

The grain yield of common beans was similar for the respective treatments: 3,321.98 (CONTROL); 2,860.73 (BNF); 2,973.14 (65 N); and 3,279.53 (102 N) (Figure 2). The N-N_2O emission was, however, significantly lower for BNF treatment (0.69 kg N ha^{-1}) than for treatments with mineral N, 65 N (1.44 kg N ha^{-1}) and 102 N (1.25 kg N ha^{-1}). The N-NH_3 volatilization was also significantly lower for BNF treatment (1.31 kg N ha^{-1}) than for the treatment with highest dose of mineral N, 102 N (11.38 kg N ha^{-1}). As consequence, emission intensity was much lower for the treatment with biological N fixation, BNF (0.90 g N kg $grain^{-1}$) than for the treatment with highest dose of mineral N, 102 N (3.86 g N kg $grain^{-1}$). These results show that BNF can maintain high productivity of common beans and lower gaseous losses of N in the ICL system. High grain yield of rainfed common beans, regardless the treatment indicates that there is an improvement of soil quality along the years in the ICL system. The improvement of soil quality also contributed to a better response of common beans to inoculation with microorganisms. Further analysis can indicate correlations of soil properties with emission and volatilization of N in the ICL system.

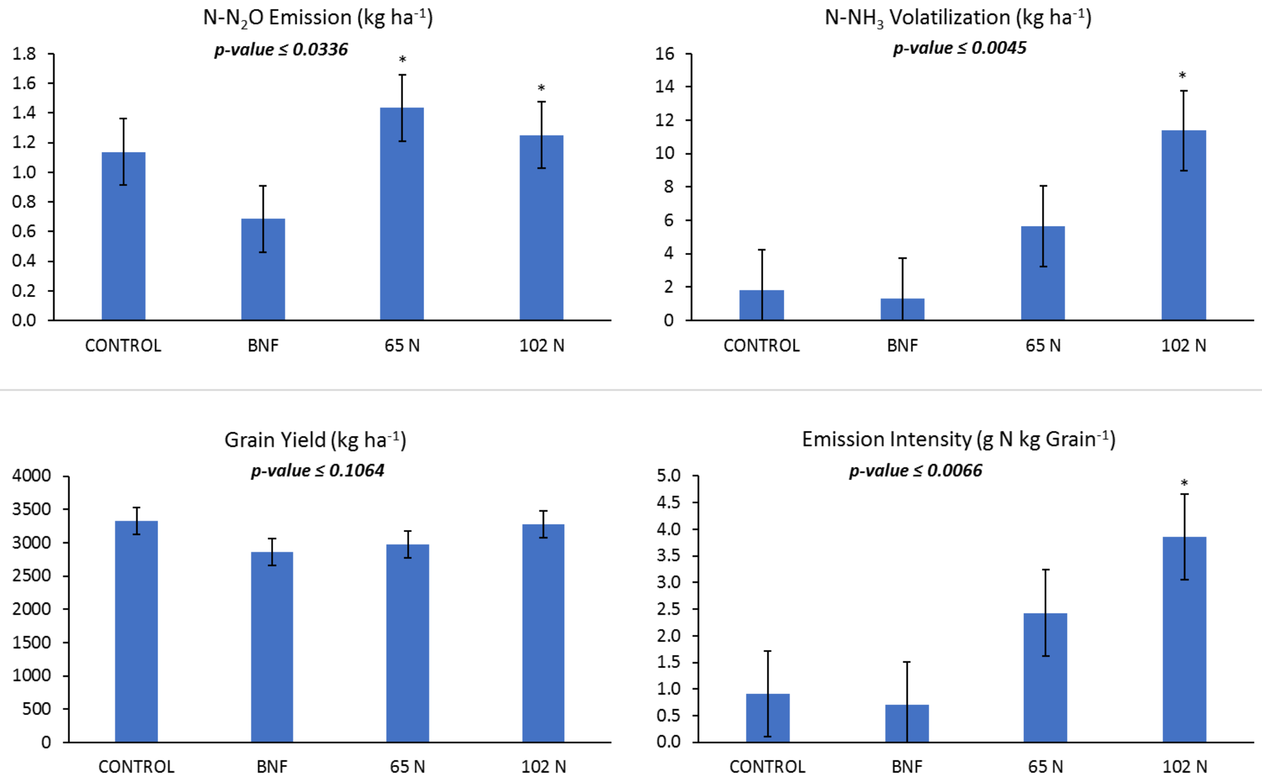

Figure 2. Effect of biological N fixation (BNF), mineral fertilization of N (65 N and 102 N), and soil without N fertilization (CONTROL) on N_2O emission, NH_3 volatilization, grain yield and emission intensity in one season of common beans cultivated under integrated crop-livestock system, from October 2019 to January 2020. P-values stands for nominal significance level of F-tests for the effect of treatments. Error bars are standard errors of means (n=4). *Means are significantly different from BNF treatment by Dunnett's test ($p\text{-value} \leq 0.05$).

CONCLUSIONS

Results showed the low efficiency of mineral nitrogen fertilization in the ICL system, as it is accompanied by large losses of N in the form of NH_3 and N_2O. On the contrary, the biological N fixation in common beans proved to be efficient, matching levels of productivity to that when using mineral fertilizers, however, with less N_2O emission and NH_3 volatilization. Biological N fixation can contribute to the environmental and financial sustainability of the ICL system, as well as to the circularity of the production, as it reduces, or even eliminates, the necessity to apply mineral N as an external input.

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EFFECT OF P AND K FERTILIZATION ON N_2O EMISSIONS IN LONG-TERM INTEGRATED CROP-LIVESTOCK SYSTEMS IN THE CERRADO REGION

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ABSTRACT

Integrated systems present the most efficient use of macronutrients due to crop rotation, succession, or intercropping, and consequently, they present a greater capacity to mitigate greenhouse gases, mainly nitrous oxide (N_2O). N_2O fluxes are related to nitrogen fertilization; however, there is little information about the interactions between N_2O soil fluxes and other macronutrients. The objective of this work was to evaluate the N_2O emissions in two agricultural systems (CC – continuous crop and ICLS – integrated crop-livestock system) based on two levels of phosphate and potassium fertilization (F1 and F2) adopted since the beginning of the experiment in 1991. N_2O fluxes were measured during two agricultural years, 2015/2016 and 2016/2017. Daily flows were submitted to an analysis of variance as repeated measures in a daily pairwise comparison (F-value; $p<0.05$). Cumulative emissions and soil chemical properties were analyzed as a 2 x 2 factorial design (land use x fertility levels). Over the 603-day evaluation period, the continuous crop (CC) system presented higher values of N_2O cumulative emissions than the integrated crop-livestock (ICL) system, i.e., 3.45 versus 2.28 kg $N\text{-}N_2O\ ha^{-1}$ ($p<0.05$), respectively. F1 and F2 showed values of N_2O cumulative emissions of 2.38 kg $N\text{-}N_2O\ ha^{-1}$ and 3.36kg $N\text{-}N_2O\ ha^{-1}$ ($p< 0.05$), respectively.

Key words: greenhouse gas emissions; low carbon agriculture; integrated systems

INTRODUCTION

Integrated crop-livestock systems (ICL) based on pasture–crop rotations associated with no-till systems present a greater diversification of plant species and nutrient cycling, greater capacity to accumulate soil C and to mitigate greenhouse gases (GHG), mainly N_2O (SATO et al., 2019). Furthermore, ICL is one of the strategies to increase soil quality obtained through crop rotation, succession, or intercropping with tropical grasses as cover crops (SALTON et al., 2014; SOARES et al., 2019). Moreover, the effects of soil fertility status and long-term N_2O emissions need to be better understood in modern Cerrado agricultural systems, considering various conditions of soil fertility after 30 years of agricultural expansion.

Phosphorus (P) plays a key role in agricultural productivity, and, generally, its availability is deficient in tropical soils, requiring the application of high doses of phosphate fertilizer (RODRIGUES et al., 2016). Also, in Brazilian clayey Oxisols, high phosphorus binding capacity occurs due to the effects of acidity and high levels of iron and aluminum oxides (OLIVEIRA et al., 2018; 2020). Studies have shown that nitrogen dynamics are strongly affected by the amount of phosphorus (P) in the soil, especially under high nitrogen availability (N) (BAHR al., 2015). The bioavailability of phosphorus, mainly of organic phosphorus (Po) fractions, is associated with the quantity and quality of crop residues added to the soil in crop rotations, consortium and soil management, as in integrated crop-livestock systems (CARVALHO et al., 2014; EBERHARDT et al., 2017; RODRIGUES et al., 2016). In integrated crop-livestock (ICL) systems, the available P residual fertilization of *Urochloa* *decumbens* contributes more to soybean productivity than P application at sowing (EBERHARDT et al., 2017). This result shows that corrective and early fertilization in the *Urochloa decumbens* pasture may be a strategy for improving nutrient cycling due to the bioavailability of P associated with pasture rotation.

Studies have shown that N_2O emissions are related to nitrogen fertilization (SATO et al. 2017; CARVALHO et al., 2017; FIGUEIREDO et al., 2018; CAMPANHA et al., 2019). However, there is little information about the interaction of N_2O fluxes with other macronutrients, such as P and K. Furthermore, P availability may be associated with soil N dynamics (CHEN et al., 2017). Martinson et al. (2013) observed that P addition in tropical forests without N limitation increases N transformation rate and NO_3^- levels in soil and increases N_2O fluxes with higher P fertilization.

Several studies have been conducted in Cerrado (CARVALHO et al., 2017; FIGUEIREDO et al., 2018; SATO et al., 2019) to evaluate N_2O fluxes under different agricultural systems, but it is unknown the relationship between N_2O and the status of soil fertility. The sustainable intensification observed in farming systems based on no-tillage and crop-livestock integration leads to better cycling and nutrient use efficiency, which may explain lower emissions in these systems (SANTOS et al., 2016; SATO et al. 2017; CARVALHO et al., 2017). Thus, it is necessary to elucidate the effect of the intensification of agricultural systems based on crop-livestock integration and no-tillage systems involving the management of phosphate and potassium fertilization on N_2O emissions.

We hypothesize that in integrated crop-livestock systems with lower soil P and K fertilization, we can reduce the N_2O fluxes due to more efficient nutrient use. In this context, the objective of this work was to evaluate N_2O emissions in two contrasting agricultural systems (CC - continuous crop and ICLS – integrated crop-livestock system) based on two levels of phosphate and potassium fertilization adopted since the beginning of the experiment, in 1991.

MATERIAL AND METHODS

The study was conducted in Planaltina, Federal District, Brazil, in an experimental area at Embrapa Cerrados (15°39' S and 47°44' W) with an altitude of 1,200 m and 2-3% slope. The rainy season in the region extends from October to April, with an average annual rainfall of ~1,400 mm. The soil is classified as a typical Oxisol, with 611 g kg^{-1} clay, 80 g kg^{-1} silt, and 309 g kg^{-1} sand. The mineral composition of the diagnostic horizon (Bw) is 500 g kg^{-1} gibbsite, 180 g kg^{-1} goethite, 140 g kg^{-1} kaolinite, 70 g kg^{-1} haematite, and 100 g kg^{-1} quartz and other minerals.

The long-term experiment based on crop-pasture rotations was started in 1991, with plots measuring 40 m × 50 m (2,000 m^2) arranged in a 2x2 factorial design with four replicates. Factors are characterized by the interaction between agricultural systems and soil fertility levels. The cropping systems evaluated were integrated crop-livestock and continuous crop under two soil fertilization levels: complete and half of the recommended P and K doses for the annual crops used between 1991 and 2013. In the crop-livestock system (4 years crop-pasture rotation), no fertilizations were made in the pasture phase.

The evaluation period started in the 2015/2016 crop season. Soybean BRS 8180 RR was sown on November 15th, 2015, and the crop cycle was 126 days. Soybean was harvested on March 27th, 2016. In the 2016/2017 crop season, soybean NS 7200 RR was planted on November 4th, 2016, and the plant cycle was 98 days. On the same day, on February 24th, 2017, *Sorghum bicolor* AG 1080 was planted intercropped with *Urochloa brizantha* BRS Piatã as a second crop in succession. The fertilization consisted of 90 kg ha^{-1} of the formulated NPK (4:30:12), 10 kg N ha-1, 50 kg ha^{-1} P_2O_5, and 30 kg ha^{-1} K_2O. Soybean fertilization for both crop seasons consisted of 400 kg $ha^{-1}$of NPK formulation (0:20:20), 115 kg $ha^{-1}$of P_2O_5, and 100 kg ha^{-1} of K_2O. Soybean seeds were inoculated with *Bradyrhizobium japonicum* ($1x10^9$ CFU g^{-1} of inoculant) at a dose of 200 g per 50 kg seeds in both crop seasons.

The N_2O fluxes were measured with closed static chambers, during two agricultural years (2015/2016 and 2016/2017), according to the methodology described in Sato et al. (2017). Two static chambers were placed in each plot, one on the rows and one between the rows. Once the plants had grown to a height of 20 cm, all the chambers were placed between soybean lines of each plot. Two chambers were installed on each plot totaling eight observations.

Air samples were collected at 0, 15, and 30 min between 8:30 am and 10:30 am, according to Alves et al. (2012), and the temperature of each chamber was determined at each sampling time. Samples were collected in 60 mL polypropylene syringes and immediately transferred to 20 ml glass pre-evacuated vials (-80 kPa). Soil and chamber temperatures were determined with digital thermometers during the gas collection at 5 cm depth. Air samples were collected for three consecutive days after rain events and crop nitrogen fertilization, and at other periods, the evaluations were weekly. During the dry season, the evaluations were made fortnightly.

The N_2O concentration was determined by gas chromatography (Thermo Scientific Model Trace 1310, Milan, Italy), with a column filled with Porapak Q and 32 columns and an electron detector, according to the methodology described in Sato et al. (2017).

The emission rates of N_2O (FN_2O) were calculated according to the following equation: $FN_2O = (\delta C/\delta t) \times (V/A) \times (M/Vm)$, where $\delta C/\delta t$ is the change in N_2O concentration in the chamber during the incubation interval; V and A are the chamber volume and the covered soil area, respectively; M is the molecular weight of N_2O, and Vm is the molecular volume at each sample temperature. The $N\text{-}N_2O$ fluxes were determined by calculating the linear regression slope of the N_2O concentration as a sampling time function (LIVINGSTON; HUTCHINSON, 1995). The molecular air volume was corrected to the temperature inside the chamber (T) during sampling, multiplying its value by a factor of $22.4*[273/(273 + T)]$. Cumulative emissions were estimated by plotting the mean values of the $N\text{-}N_2O$ flows and the time scale on a graph and calculating the resulting area under the integration curve using Sigmaplot® Version 10 software (Systat Software Inc., Chicago, USA, 2007).

Soil chemical properties (Al; Ca; H+Al; pH; K; P and SOM) in each area were obtained from soil samples collected in the flowering stage of soybean at 0.00-0.10, 0.10-0.20 and 0.20-0.30m depths in January 2016. Soil sampling was performed between rows with ten subsamples per plot.

The assumption of normality of the residues was verified by the Shapiro-Wilk test and the homogeneity of variances by the Levene's test. Daily N_2O flows were analyzed as repeated measures in a pairwise comparison (F-value; $p<0.05$). Cumulative N_2O emissions and soil chemical properties were analyzed as a 2 x 2 factorial design (land use x fertility levels). In this step, we use the SAS MIXED procedure (Statistical Analysis System v 9.4), considering blocks and samples (nested in fertility levels) as random effects.

RESULTS AND DISCUSSIONS

The cropping system CC and management fertility F2 resulted in higher N_2O emission averages during the evaluation period, showing a response to crop system and fertilization dose (Table 1), even though the application of different doses of phosphorus and potassium occurred between 1991 and 2013 and the N_2O evaluations were from 2015 to 2017. It is possible to observe the influence of the residual effect of P and K fertilization, which significantly altered the production of crop residues, contributing to increasing soil N_2O fluxes (CARVALHO et al., 2017; SATO et al., 2017).

In the layer 0-10 cm, phosphorus content was more than double in ICL (13.09 g kg^{-1}) compared to CC (5.82 g kg^{-1}). In F2, soil potassium (K) content was 154.4 g kg^{-1} while in F1 was 109.6 g kg^{-1} which may have contributed to the amount of crop residues that remained on the soil surface in the 2015/2016 crop season, which was higher in F2 (1.5 Mg ha^{-1}) than F1 (1.12 Mg ha^{-1}) ($P < 0.05$). This indirect fertility effect in increasing the biomass production in the system probably contributed to the higher accumulated N_2O emissions at the highest level of fertility F2. The crop system CC resulted in higher N_2O emission averages during the evaluation period, probably due to the decomposition of plant residues in the 0-10 cm layer, expressed in higher organic matter (OM) content ($P < 0.05$) in CC (4.32 g kg^{-1}) in relation to ICL (3.68 g kg^{-1}) in this layer. The lower emission of N_2O in ICL suggests greater nutrient cycling efficiency of the integrated systems (PIVA et al., 2014).

Concerning accumulated N_2O, the ICL system was an N_2O mitigating system, producing lower accumulated N_2O fluxes. Similar results were also observed by Buller et al. (2014), Carvalho et al. (2017) and Sato et al. (2017), in which this system of crop-livestock integration presented total N_2O accumulated emissions lower than the continuous crop.

The fertility with differentiated P and K levels (F1 and F2) for 18 years shows its effects on accumulated N_2O emissions, evaluated after three years of similar doses of these nutrients, indicate that possibly the action of soil microorganisms and plant biomass production (SOARES et al., 2019), alter soil nutrient dynamics and directly reflect N_2O fluxes. Furthermore, P applied to the soil (F1 and F2) for several years previously influenced the amount of crop residues produced (CARVALHO et al., 2014), with F2 generating 1.5 Mg ha^{-1} more than the F1 plots, which produced 1.12 Mg ha^{-1} ($p < 0.05$). For fertility levels (F1 and F2), K levels were higher in F2 ($P < 0.05$) (Table 1). Although the amount of K absorbed by the plants is high, their removal by the grains is relatively small (± 20%). Their straw content returns to the soil via biogeochemical cycling, intensifying with reasonable management practices (SOARES et al., 2019). Soil P content directly influenced the amount of straw produced and possibly higher organic P fractions associated with the quality of the crop residue added to the soil (CARVALHO et al., 2014). Oliveira et al. (2020) showed that with the reduction in total P and C contents of the soil, there was an increase in organic P, probably as a result of the successive corn/millet rotation in the unfertilized phase and conservation soil management in NT and fertilization with previously fertilized with reactive rock phosphate can be recommended as strategies to increase the bioavailability of residual P in tropical soils.

In the 2015/2016 crop season, soybean presented higher cumulative emission of N_2O ($P < 0.05$) in CC and F2. These results may be associated with the amount of nitrogen (supplied by the roots and nodules of the soybean, which are rich in N) and by the history of phosphate fertilization (LIU; ZANG, 2018). Therefore, ICL can be considered a mitigating system by decreasing 1.2 kg $N\text{-}N_2O$ ha^{-1} compared to CC over the 603-day evaluation period.

In the ICL system, there is a greater contribution of crop residues in relation to the continuous crop system (CC), both on the soil surface and in the soil profile by the roots (MORAES et al., 2014; PUGESGAARD et al., 2017; SOARES et al., 2019). Integrated crop-livestock (ICL) systems have lower N_2O emissions when compared to CC (CARVALHO et al., 2017; SATO et al., 2017) because has effect of grazing by animals.

Also, integrated crop–livestock system under no tillage with previously fertilized P and K also can be recommended as strategies N_2O mitigate. However, the definition as ICL (integrated crop-livestock) as a N_2O emission mitigation system is dependent on the type of intensification/practices and the crop rotation adopted.

Table 1. Chemical attributes of the soil in the treatments with different managements and fertilization.

Land use	**Al**	**Ca**	**H+ Al**	**pH**	**K**	**P**	**MO**
	cmol$_c$ dm^{-3}	**cmol$_c$ dm^{-3}**	**cmol$_c$ dm^{-3}**	**(H_2O)**	**g kg^{-1}**	**g kg^{-1}**	**g kg^{-1}**
0.00-0.10 m							
CC	0.032	4.78	5.78	5.58	125.1	5.82	4.32
ICL	0.030	4.46	5.20	5.45	138.9	13.09	3.68
F_{value}^{a}	0.03	1.65	2.82	8.91	2.29	4.82	13.13
F1	0.038	3.81	4.06	5.50	109.6	8.06	3.92
F2	0.024	5.43	3.07	5.53	154.4	10.85	4.09
F_{value}^{a}	1.20	43.62	3.67	0.46	24.25	0.71	0.89
LSD ($p \leq 0.05$)	0.0283	0.553	0.594	0.1004	20.557	7.496	0.400
SE	0.012	0.245	0.263	0.044	9.087	3.313	0.177
0.10-0.20 m							
CC	0.41	1.68	5.78	5.51	64.00	8.77	2.27
ICL	0.22	1.08	5.20	5.67	54.25	2.96	2.86
F_{value}^{a}	19.97	4.51	2.82	6.58	5.45	12.00	9.08
F1	0.46	0.84	5.82	5.55	51.12	5.63	2.40
F2	0.17	1.93	5.16	5.65	67.12	6.10	2.73
F_{value}^{a}	42.82	14.65	3.67	3.45	14.67	0.08	2.88
LSD ($p \leq 0.05$)	0.0976	0.645	0.779	0.1355	9.450	3.797	3.797
SE	0.043	0.285	0.344	0.0599	4.177	1.678	1.678
0.20-0.30 m							
CC	0.453	0.56	5.943	5.28	39.00	2.51	2.24
ICL	0.253	0.87	5.045	5.56	33.25	0.95	2.28
F_{value}^{a}	15.86	3.14	19.82	15.23	2.17	61.28	0.06
F1	0.402	0.49	5.55	5.37	29.87	1.54	2.22
F2	0.304	0.95	5.43	5.47	42.37	1.92	2.30
F_{value}^{a}	3.87	6.71	0.37	2.29	10.26	3.62	0.23
LSD ($p \leq 0.05$)	0.113	0.400	0.456	0.161	8.827	0.452	0.380
SE	0.050	0.177	0.202	0.071	3.902	0.200	0.168

Management System - **CC:** Continuous crop**;** **ICL** Integrated-**c**rop-livestock. Fertilization levels of P and K- **F1:** Maintenance fertilization**;** **F2:** Corrective fertilization. LSD: least significant difference; SE: standard error. *F value with 3 and 12^{a} of freedom for land use and the residual term effects, respectively. Italic indicates significance at the 5% probability level and bold significance at the 1% probability level; ns –, not significant.

CONCLUSIONS

Our results show that in addition to nitrogen fertilization, the amount of other nutrients (P and K) contributes to the emission of N_2O. The integrated crop-livestock integration (ICL) can be recommended as an N_2O emission mitigation system in the Cerrado region. Corrective and residual fertilization with P and K at the recommended dose in the systems under continuous tillage (CC) and ICL increased N_2O emission in relation to the application of half doses, indicating the need to re-evaluate recommendations of corrective P fertilization. Therefore, the adoption of integrated cropping systems, such as ICL, and the application of half of the recommended dose of P and K, should reduce N_2O emissions and promote greater efficiency in the use of these nutrients.

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SOIL CARBON STOCKS AT 3 AND 11 YEARS OF AN INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEM ON A CLAYEY FERRALSOL IN THE BRAZILIAN SAVANNA

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ABSTRACT

Integrated Crop-Livestock-Forestry systems (ICLF) are potential carbon sinks. Here we present soil organic carbon (SOC) stocks in an ICLF system at 3 and 11 years after implementation. The ICLF was implemented in 2008/2009 at Boa Vereda farm, in Cachoeira Dourada, Goiás state, Central-West region of Brazil, on a clay Ferralsol. SOC stocks were determined within rows of trees and between rows of trees, hereby called alley, in three soil layers (0.0-0.3, 0.3-1.0 and 0.0-1.0 m) in 2012 and 2020. A non-cultivated pasture was used as reference. Results show a trend for increased soil C stocks at 0.0-1.0 m under ICLF system from 3 to 11 years after implementation compared to the non-cultivated pasture. There was also a higher C accumulation rate under ILPF at this soil layer, compared to the same pasture. All treatments lost C at 0.3-1.0 m, but the non-cultivated pasture lost C the most rapidly. At 0.0-0.3 m all treatments gained C over time. These data only relate to the effect of the presence of trees in the ICLF, weighted COS stocks from tree-rows and alleys were not calculated in this paper.

Key words: soil C sequestration; eucalyptus trees; beef cattle

INTRODUCTION

Soil organic carbon (SOC) stocks depend on the interaction of soil with biosphere. Through photosynthesis performed by autotrophic organisms, C compounds are transformed into plant tissues which reach the soil through above and belowground biomass. Carbonaceous materials, root exudates and washing of soluble plant constituents by rainwater feeds soil microorganisms that in turn contribute to accumulation of soil C throughout time. Among terrestrial ecosystems, soil is the largest active C reservoir. About 1,500 Pg of C are stored as organic matter down to one meter of soil depth (IPCC 2013). SOC represents the C present in soil organic matter (SOM), which in turn comprises all living and dead organisms, in different stages of decomposition. For soil fertility management usually the non-living compartment of SOM is considered the main factor, represented by root and leaf litter, water soluble organic compounds, soil enzymes and very complex mixture of microbial and plant biopolymers and their degradation products (KELLEHER; SIMPSON, 2006; SIMPSON et al., 2007). The non-living SOM have a readily decomposable compartment, but also contains the largest pool of recalcitrant organic C in the terrestrial environment. The increment in SOM contributes to maintenance of soil C stocks and C removal from atmosphere. SOM management is, therefore, one key to manage the challenges of agriculture related to climate change (GELAW et al., 2014; ADHIKARI et al., 2017). This should also change the way we define soil fertility, including SOC as an attribute to define a fertile soil (LEHMANN; KLEBER, 2015). Production systems that are more biodiverse, such as the different variations of integrated crop-livestock-forestry systems, imply an ingenious dynamic in land use and management that can result in financial and environmental services (SANG et al., 2013, TORRES et al., 2014). In the Brazilian savannah, the integrated crop-livestock-forestry (ICLF) system is usually characterized by the association of trees, mainly eucalyptus, annual crops for grain production, soybean or corn, and livestock, for beef or dairy. The combination of these components of production generates positive synergy (VILELA et al., 2011). Franzluebbers et al. (2014) emphasize, for example, that increasing SOM and water infiltration are among soil attributes improved by the implementation of agricultural and livestock integration. The objective of this work was to investigate the potential of SOC accumulation under an ICLF system on a Ferralsol of the Brazilian savannah, central west region of Brazil. Here we show preliminary results.

MATERIAL AND METHODS

Location

This study was carried out at Boa Vereda farm, located in Cachoeira Dourada, Goiás (18° 27'43.19 "S, 49° 35'58.53" W), at 484 m a.s.l. The soil was classified as a typical clay Ferralsol (632 g kg^{-1} clay and 221 g kg^{-1} sand at 0-30 cm and 672 g kg^{-1} clay and 170 g kg^{-1} sand at 30-100 cm), with slope ranging from 0 to 15% (SANTOS et al., 2013). The Köppen-Geiger classification is Aw (tropical savanna climate with dry winters between May and October) (CARDOSO et al., 2014). The average annual precipitation is 1,315 mm with December being the rainiest and August the driest month. Maximum temperature is reached in September (± 32.00 °C) and minimum in July (± 15.53°C). The relative air humidity varies between 80% in January and 47% in August (INMET).

Area history and management of crop-livestock-forestry system

In the rainy summer season 2009/2010, the ICLF system was implemented on a 30-year-old pasture with rows of three lines of eucalyptus trees (*Eucalyptus urograndis*) in north-south direction. Each row of trees was spaced 3 m between lines, 2 m between trees along the lines and 20 m between rows, resulting in a total of 476 trees ha^{-1} in an area of 14.7 ha (Figure 1). At plantation establishment, eukalyptus was fertilized with 150 g plant^{-1} of the formula 08-30-10 + Zn and boric acid (10 g plant^{-1}). In August 2008, the soil of the alley between the tree rows was heavy-harrowed to 13 cm depth, and in October 2008 limestone was applied followed by light harrowing. Soybean (*Glycine max*) was sown in the alleys and received 12 kg ha^{-1} N, 90 kg ha^{-1} K_2O and 30 kg ha^{-1} P_2O_5 at sowing time. In the summer of 2010/2011, soil tillage was done with heavy-harrow and several passes of light-harrow before sowing corn with palisade grass (*Urochloa brizantha*) according to the Santa Fé System (KLUTHCOUSKI; AIDAR, 2003). The soil was fertilized with 24 kg ha^{-1} N, 90 kg ha^{-1} K_2O and 30 kg ha^{-1} P_2O_5 for corn (*Zea mays*) and 40 kg ha^{-1} P_2O_5, 24 kg ha^{-1} S and 15 g boric acid for eukalyptus maintenance. Since 2011, the soil under continuous pasture has annually received 56 kg ha^{-1} N and 52 kg ha^{-1} P_2O_5. Beef cattle was introduced for feeding on the brachiaria at a stocking rate of 2.1 animals ha^{-1} (Pacheco et al., 2013). Cattle was introduced in the dry winter (2011), around 70 days after corn harvest, when eucalyptus trees were about 6 m height and 10 cm diameter at breast height. As a reference, an area under 30 years of continuous pasture mainly consisted of signal grass (*Urochloa decumbens* formerly *Brachiaria decumbens*) was selected. Between 2012 and 2020 small amounts of limestone and NPK fertilizer have been applied to the soil for plant nutrient replenishment.

Sampling and analysis of Soil Organic Carbon

Within the ICLF system, soil samples were collected in five sampling modules (replicates), using soil profiles of 150 x 150 x 120 cm. In the tree-rows soil pits were placed in the middle of the tree-rows and in the middle of the alley (Figure 1). In the continuous pasture five soil profiles were placed in line at 20 m distance from each other in an east-south direction. In each soil profile samples were taken at seven depths (0.0-0.1 m, 0.1-0.2 m, 0.2-0.3 m, 0.3-0.4 m, 0.4-0.6 m, 0.6-0.8 m, and 0.8-1.0 m) in the rainy seasons of 2011/2012 and 2019/2020. Soil density was determined using Kopecky volumetric rings. The samples were taken in the middle of each soil layer. Soil C was analyzed by dry combustion (950 °C) using a Vario Isotope Cube coupled in series with a mass spectrometer (Isoprime, Elementar Inc., Hanau, Germany). Five replicates were taken for each measurement. According to Sisti et al. (2004), estimates of SOC stocks expressed as Mg ha^{-1} were based on quantification in equivalent soil mass using the continuous pasture as reference. As soil density suffers seasonal changes, for samples collected in the wet season 2019/2020 we used soil density from the wet season 2011/2012 in order to normalize data. Values of SOC stocks were calculated for three soil layers (0.0-0.3 m, 0.3-1.0 m and 0.0-1.0 m). Finally, estimates of SOC accumulation rate were calculated as the difference in SOC stocks from the wet season 2011/2012 to the wet season 2019/2020 in Mg C ha^{-1} year^{-1}.

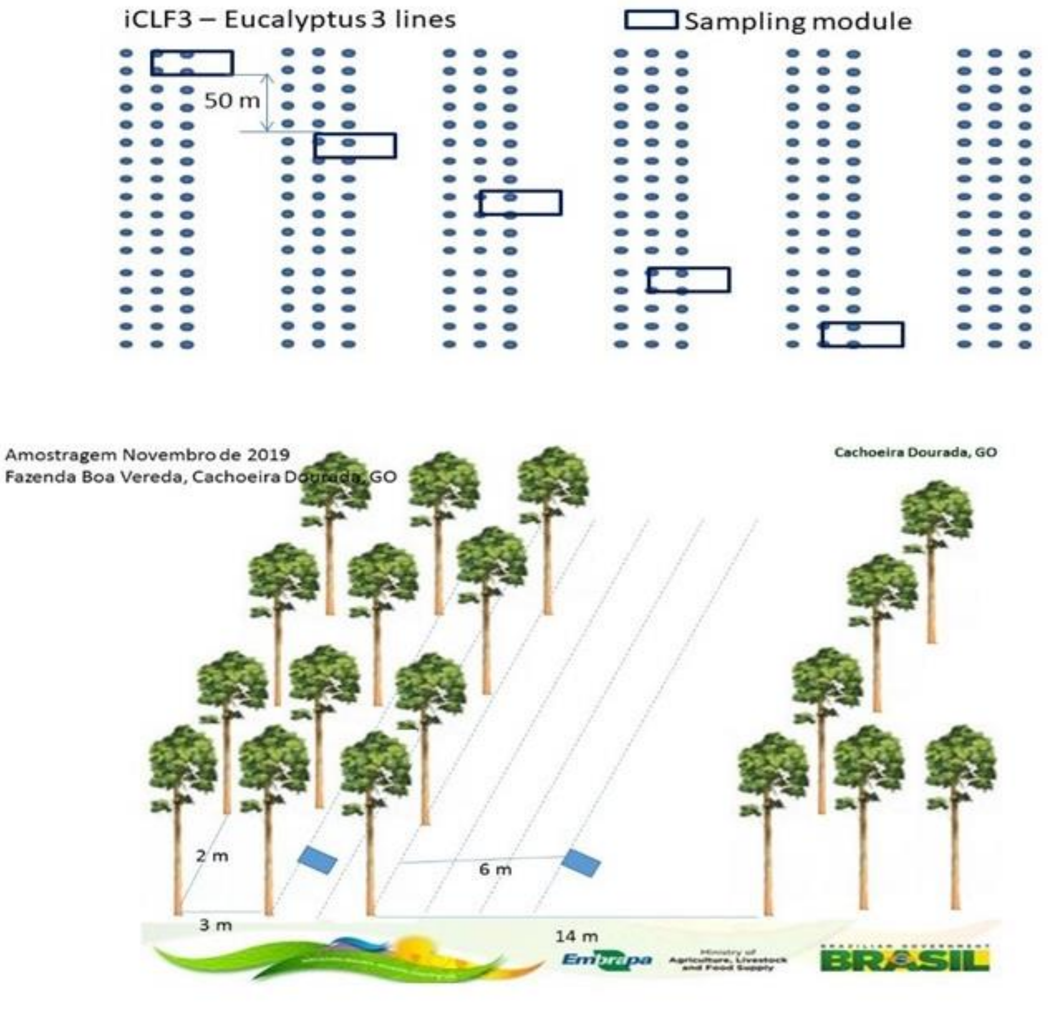

Figure 1. Location of soil profiles and sampling modules and display of trees on the area under integrated crop-livestock-forestry (ICLF) system at Boa Vereda Farm. Chachoeira Dourada, State of Goiás, Brazil.

Statistical analysis

Analyses were performed using the linear mixed model procedure (Proc Mixed) in SAS/STAT (SAS, 2008). Local of sampling (continuous pasture, ICLF-tree-rows and ICLF-alleys) were considered as fixed effects and repetition (modules) as random effect. F-test was applied to check for the interaction effect of year*place of sampling on SOC stocks and the effect of tree-row and alley on the rate of SOC accumulation within three soil layers (0.0-0.3, 0.3-1.0 and 0.0-1.0 m). Tukey's test was applied to check for differences between years for each treatment (tree-row, alley and continuous pasture) within each soil layer.

RESULTS AND DISCUSSIONS

Adoption time of ICLF systems had a significant effect on SOC stock changes at all depths (F = 5.75; $p \leq 0.005$). Despite the effect of the interaction year*place of soil sampling was not significant, SOC stocks increased from 3 to 11 years after implementation of the ICLF system (under tree-rows and in alleys) at all soil depths (0.0-0.3, 0.3-1.0, 0.0-1.0 m; Figure 2).

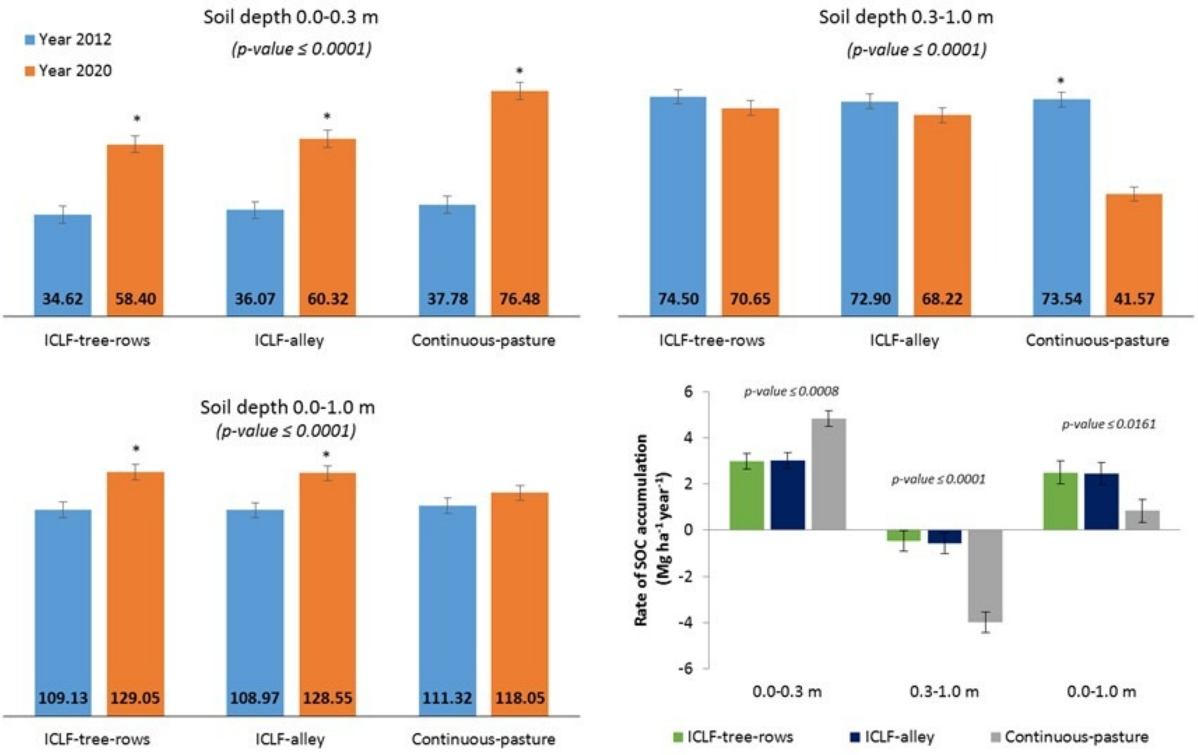

Figure 2. Effect of year (2012 and 2020) and place of sampling (ICLF-tree-rows, ILCF-alley and Pasture-non-cultivated) on soil organic carbon (SOC) stocks (Mg ha^{-1}) and local effect on SOC accumulation rate at 0.0-0.3, 0.3-1.0 and 0.0-1.0 m layers. In parenthesis are nominal significance levels (p-value) of F-tests for effects. Error bars represent standard error of means (n=5). *Means are significantly differet among years by Tukey's test (p-value).

The proportion of SOC stocks at 0.0-0.3 m to 0.0-0.1 m soil depth increased from 33% to 52%, average of 36.2 Mg ha^{-1} between 2012 and 2020. This increase could be attributed to the surface application of limestone (calcium or magnesium) and mineral fertilizers in all treatments. All treatments (sampling places at tree-rows, alley and continuous pasture) accumulated SOC during the last 8 years at 0.0-1.0 m, after the implementation of the ICLF. SOC accumulation occurred at 0.0-0.3 and SOC loss at 0.3-1.0 m at all treatments. The rate of SOC accumulation at 0.0-0.3 m was highest in continuous pasture (4.84 Mg SOC ha^{-1} year^{-1}), which also showed the highest rate of C loss at 0.3-1.0 m (-4.00 Mg SOC ha^{-1} year^{-1}) (Figure 2). At 0.0-1.0 m, the overall SOC accumulation rate was positive in all treatments, but ICLF-tree-rows (2.49 Mg SOC ha^{-1} year^{-1}) and ICLF-alley (2.45 Mg SOC ha^{-1} year^{-1}) outperformed the continuous pasture (0.84 Mg SOC ha^{-1} year^{-1}). The lower SOC accumulation in ICLF, either under tree-rows or in the alleys, at 0.0-0.3 m could be explained by the effect of the implementation of the ICLF that involved mechanical soil disturbance that likely resulted in initial SOC loss. Bieluczyk et al. (2020) found SOC accumulation rate (Mg ha^{-1} year^{-1}) of 1.68 for extensive grazing pasture; 1.96 for integrated crop livestock; and 1.74 between tree-rows of an ICLF system in 0.0-0.4 m soil layer of a sandy-clay-loam, between 2010 and 2016, in a 6-year period. SOC accumulation rates are expected to be higher in a shorter period of time than that we found in this study. However, SOC accumulation is influenced by various factors, from soil management to soil properties such as texture, mineralogy and original SOC content (ZINN et al., 2007; CARDINAEL et al., 2017). The Ferralsol in our study was clayey, which theoretically implies in high C sequestration potential, and the original SOC cc. in the Ferralsol in 2012 was moderate (1.06 to 1.09 % at 0.0-0.3 m). Considering this, the estimated SOC accumulation rate between 2.97 and 3.03 Mg SOC ha^{-1} year^{-1} at 0.0-0.3 m and 2.49 and 2.45 Mg SOC ha^{-1} year^{-1} at 0.0-1.0 m in the ICLF system found in this study is potentially at the higher end of SOC accumulation rate. Corbeels et al. (2016) calculated diachronic annual SOC accumulation rates at 0.0-0.4 m soil layer to be between 0.3 and 1.8 Mg ha^{-1} year^{-1} in pasture and between 0.09 and 0.63 Mg ha^{-1} year^{-1} in no-till fields, implemented on land under conventional tillage in a Ferralsol, located in southwest Goiás, within a biome in transition between savannah and Atlantic Forest. Additionally, Oliveira et al. (2019) calculated 1.47 Mg ha^{-1} year^{-1} SOC accumulation rate in 0.0-1.0 soil layer 12 years after implementation of an ICLF system in a lighter textured soil compared to the soil in this study.

CONCLUSIONS

Results show higher increment in SOC stocks in the Ferralsol from 3 to 11 years after adoption of the ICLF system, compared to continuous pasture at 0.0-1.0 m. Pastureland had higher increase in SOC stock at the upper soil layer of 0.0-0.3 m than the ICLF tree-rows and alleys, but it also lost much more SOC at 0.3-1.0 m than the soil under ICLF. In this study only the effect of tree-rows and alley in the ICLF were compared to the reference pasture separately to verify the effect of the components of ICLF on SOC accumulation. Further analysis will have to be done to explore the overall effect of ICLF, calculating the weighted SOC stock under ICLF based on the proportion of the land area under trees and alley. Also, determination of losses in dissolved organic carbon is recommended.

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GREENHOUSE GASES (GHG) QUANTIFICATION WITH STATIC CHAMBERS IN LATIN AMERICA: IS IT IMPROVING THROUGH TIME?

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ABSTRACT

Manual static chamber is one of the most widespread methods for the quantification of greenhouse gases (GHGs) emission from agricultural systems. But there are concerns about the reliability of measurements and a necessity to assess the static chambers used in the studies performed in the countries of Latin America. Thus, this study aims to investigate the quality of static chambers used for GHGs measurement in scientific articles following international recommendations and assess the confidence level of static chambers. A systematic review of databases was conducted to identify peer-reviewed articles that used the static chamber method in Latin América. A total of 90 articles were analyzed and separated according to the publication year (2000-2008, 2009-2015, 2016-2020). This time interval was selected to assess the influence of key publications with guidelines and criteria for the method published in 2008 and 2015. Six design and deployment chamber characteristics were evaluated. The chambers received a global score for a confidence level according to their characteristics scores and the weight of each one. The percentage of articles with high confidence level increased within the time, and the number of articles with low confidence level reduced. Researchers should continue to follow the Global Research Alliance protocols, especially the most updated ones.

Key words: methodology; nitrous oxide; GHG emissions

INTRODUCTION

Most of the understanding of soil greenhouse gases (GHGs) emission dynamics and emission factors (EF) are based on measurements using manual static chambers in which the gases are collected and transferred manually, or pumped directly, to glass vials with a vacuum, and then analyzed using the gas chromatography technique (CARDOSO et al., 2019; CHADWICK et al., 2018; HARVEY et al., 2020; PARKIN; VENTEREA, 2010; SHANG et al., 2020).

Different materials and designs of static chambers have been used together with different methodological procedures, which have implications and concerns on the reliability of measurements and the comparison between data in the literature (ALVES et al., 2017; BUCKINGHAM et al., 2014; LÓPEZ-AIZPÚN et al., 2020; ROCHETTE; ERIKSEN-HAMEL, 2008). Attentive to this, Rochette and Ericksen-Hamel (2008) proposed a set of sixteen criteria based on experimental data and considerations based on theories of gas dynamics to classify how reliable were the published measurements of N_2O emissions. They observed that 60% of the 356 studies from 1978 to 2007 all over the world generated results that could be characterized as very low and low confidence, which were the classification of 67% of the 27 studies from South America. Moreover, none of the chamber from studies of South America were considered of high confidence. The insertion depth of the chamber base, chamber height and the deployment period were characteristics related to chamber design highlighted as of concern according to Rochette and Ericksen-Hamel (2008). In more than 50% of the studies from South America, the index "chamber base insertion into the soil" was <5 cm h^{-1} and the chamber area/perimeter ratio was only satisfactory (good or very good rates) in less than 40% of the studies.

From the above, a reassessment of protocols adopted in Latin America for soil N_2O measurements based on the static chamber is desirable given the increasing importance and intensity of studies on GHGs in this century and to evaluate how effective were the efforts to establish standard practices for using static chambers.

Therefore, it is necessary to reassess the reliability of the static chambers used in the studies performed in the countries of Latin America following the standard criterion recommended by reference researchers in this area (Rochette & Eriksen-Hamel 2008) and by the Global Research Alliance on Agricultural Greenhouse Gases (GRA) (DE KLEIN et al., 2020; DE KLEIN; HARVEY, 2015). Latin America is an emerging continent for global food supply, and this role can be even greater in the future depending on improvements in technology and land use (FLACHSBARTH et al., 2015; SÁ et al., 2017), to which potential impacts on GHGs emissions and the development of mitigation practices must be reported accurately.

Thus, the objective of this study was to assess the confidence level of static chambers, according to their characteristics.

MATERIAL AND METHODS

We performed a systematic literature review (BUCKINGHAM et al., 2014) to compile scientific articles that quantify soil GHGs using the manual static chambers methods in agricultural systems in Latin America. The searches were made using the Web of Science, Science Direct, and Google Scholar web-platforms databases. A set of criteria was devised to screen scientific studies for relevance to our objectives in a standardized, systematic manner, that were: (i) studies quantifying N_2O or CH_4 emissions from soil/plant residues, from fertilizers and excreta (feces and urine) from livestock in the field conditions; (ii) only to consider studies that were carried out in Latin American (i.e., Central and South America) countries; and (iii) to include field studies performed in one of the three types of agricultural systems: pastures, crops or in Integrated Crop-Livestock-Forest (ICLF) systems.

The articles were selected according to the screening criteria cited above. Thus, articles were separated into three-date intervals, e.g., those published between 2000 and 2008, 2009 and 2015, and between 2016 and 2020. We decided to evaluate these time intervals due to two main reasons: i) in 2008 was published a milestone study taken as a reference with several recommendations and criteria related to the static chamber method (ROCHETTE & ERIKSEN-HAMEL, 2008); ii) in 2015, a guideline protocol was published by the Global Research Alliance on Agricultural Greenhouse Gases (GRA), a global alliance between countries to find ways to produce more food without increasing GHG emissions (SHAFER et al., 2011). Therefore, the division of the selected articles in these three-time intervals aims to verify the influence of these key publications on the confidence level of the chambers used on studies in Latin America.

The six characteristics of the chambers evaluated in this work were related to the details of the chambers design and deployment procedures, that were: height, area, and perimeter of the chamber, insertion depth of the chamber base into the soil, duration of deployment, and the number of samples taken during the deployment time. To verify the quality of the chamber method, its characteristics were evaluated according to the criteria developed by Rochette and Eriksen-Hamel (2008), which indicate the values or ranges of values to qualify each one as very good, good, poor, and very poor (Table 1).

Table 1. Criteria used for the evaluation of chamber quality

Chamber Characteristics	**Unit**	**Qualification** Very Poor (0)	 Poor (1)	 Good (2)	 Very Good (3)
		Criteria			
Chamber height index	cm h^{-1}	< 10	10 to < 20	20 to < 40	≥ 40
Base insertion index	cm h^{-1}	< 5	5 to < 8	8 to < 12	≥ 12
Area/perimeter ratio	cm	< 2.5	2.6 to < 6.25	6.26 to < 10	≥ 10
Duration of deployment	min	> 60	> 40 - 60	> 20 - 40	≤ 20
Number of samples	Nº	1	2	3	> 3

Chamber height index: ratio of height (cm) to duration of deployment (h); base insertion index: ratio between insertion into the soil (cm) by duration of deployment (h). area/perimeter ratio: ratio of the area of the chamber (cm^2) to the perimeter (cm) (if the shape is cylindrical, the diameter is used; with the rectangular shape, the length and width are used). For the deployment duration and number of samples per deployment period, the exact numbers described in the study were used. The numbers between parenthesis are the score for each qualification class. Source: Rochette and Eriksen-Hamel (2008).

Therefore, each characteristic received a score that was linked to its quality according to Table 1, which was: very good = 3; good = 2; poor = 1; and very poor = 0. From that, the scores were averaged for all studies found in each time interval to release a general score for each characteristic from the measurement protocol, which where: 0-0.74 = very poor; 0.75-1.49 = poor, 1.50-2.24 = good; and 2.25-3.0 = very good.

Besides evaluating the characteristics individually, weight was also placed on each of them according to the importance of each characteristic for the confidence level of the chamber. For instance, the base insertion into the soil (cm h^{-1}) is classified as a "primary" characteristic, so received the highest weight (0.3 - Table 2), due to this characteristic having a more significant impact on soil gas leaks, depending on the soil type (ROCHETTE & ERIKSEN-HAMEL, 2008). The "secondary" characteristics as the number of samples, area/perimeter ratio, and chamber height index received the weight of 0.2, and the duration of deployment received the weight of 0.1.

It was possible to obtain a global score for each chamber used in each study, by multiplying the score received by the numerical characteristic to the weight referring to it. Therefore, static chambers had their reliability classified into four levels: very low (0-0.74), low (0.75-1.49), medium (1.50-2.24), and high (2.25 -3.0). It was possible to obtain the percentage of studies that were classified in each level for all three-time intervals.

RESULTS AND DISCUSSIONS

A total of 90 studies passed through the screening criteria and were selected for the chamber evaluation. For all the analyzed periods (2000-2008, 2009-2015, and 2015-2020) it was possible to observe the highest concentration of studies at the medium confidence level. Also, it was possible to notice the number of studies with low-confidence decreasing and the percentage of high-confidence studies increasing with time.

Considering the publications from 2000 to 2008, 62.5% of the studies presented a medium level of confidence, 37.5% a low level, whereas no studies obtained a high level. For the time interval between 2009 and 2015, 8.3% of the studies were classified as of high confidence level, 75.0% medium level, and 16.7% low level. For the 2016 and 2020 studies, this proportion was 17.4% with high levels of confidence, 71.7% with medium level, and only 10.9% with low level (Figure 1).

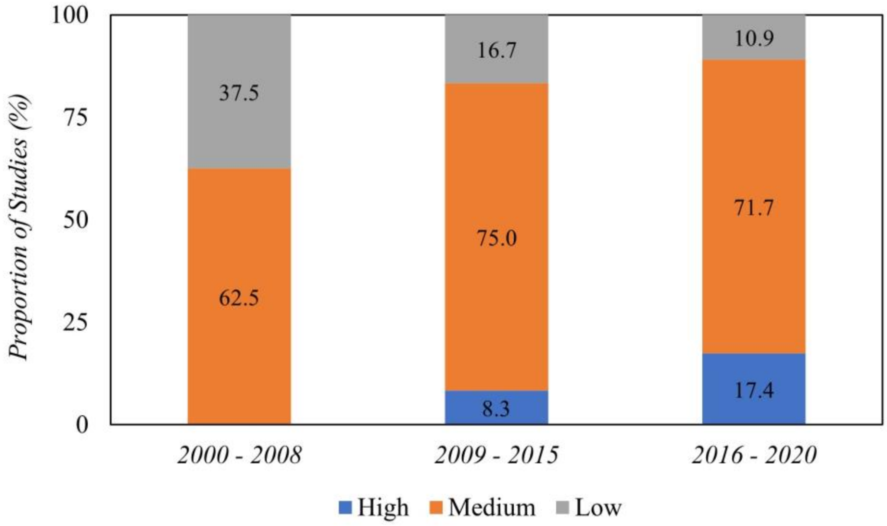

Figure 1. Proportion of studies associated with each level of confidence for each time interval.

From an analysis of studies from all over the world, Rochette and Eriksen-Ramel (2008) concluded that the level of confidence of the GHGs flows in 60% of these studies was low or very low due to the low scores of the characteristics or lack of reporting of methodological details. Thus, in that study, the confidence level increased with time, as the proportion of studies with high or medium confidence increased from 29% of the studies in 1990 to 50% after 2005. Besides that, the number of studies with very low confidence levels decreased from 46 to 9% between 1990 and 2005, respectively. Around 57% of all studies, they considered received very poor or poor scores for more than half of the characteristics. The characteristics that have slightly improved were chamber height and number of samples taken, from 1980 to 2007. But Latin American studies were considered weaker when compared to other regions, and this situation motivated the present work to evaluate what happened with chamber studies after 2008. Latin America is a key continent for food production in the world, making the characterization of production systems necessary with reliable analyzes of the impacts and development of mitigation strategies (CLARKE et al., 2016; SÁ et al., 2017).

was also observed that over the years, the proportion of Latin American studies about GHGs using static chambers with a high confidence level has increased while the proportion with a low confidence level has decreased. This indicates the improvement of the chambers used in the studies after the publications of standard protocols that clarify the best conduct of this methodology (ROCHETTE & ERIKSEN-HAMEL, 2008; DE KLEIN & HARVEY, 2015). The continuous improvement of the confidence level in the studies carried out after 2008 and after 2015 is a strong indication that these publications and international recommendations had contributed to improving the researches with static chambers in Latin America.

CONCLUSIONS

The evaluation made by this paper was only about the design and deployment chamber characteristics, and to determine the confidence of the complete method (storage, analytical technique, and flux calculation) it is necessary to evaluate characteristics from other important practices too. In general, there was an increase in the number of studies that had a high confidence level over the three periods evaluated. Besides, the number of studies with low confidence levels had been reduced, evidence of gain in data quality. It is recommended that researchers continue to follow the GRA protocols when working with static chambers, especially the most updated ones.

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GREENHOUSE GAS EMISSIONS BY CATTLE REARED IN AN INTEGRATED CROP-LIVESTOCK SYSTEM AND FINISHED IN FEEDLOT

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ABSTRACT

Beef cattle is one of the main sources of GHG in the agricultural sector, however, it is possible to implement improvements in this segment to mitigate GHG emissions. Beef production in an integrated crop-livestock system can achieve a positive carbon balance, but feedlot systems generally offers both lower area requirements and GHG emissions per kilogram of meat produced than traditional systems. In this way, beef cattle production systems that associate well-managed grass systems, with the supply of diets in the finishing phase is an alternative to increase the productivity of the system, in addition to contributing to the reduction of GHG emissions per kg of meat produced. Cattle excreta are also sources of GHG emissions to the atmosphere, mainly nitrous oxide (N_2O) and methane (CH_4), but considerably less is known on their environmental impact. Thence, the objective of the study was to evaluate the enteric methane production from two breed compositions as well as GHG emissions from beef cattle excreta in a feedlot system. Methane production (kg/period) was 19% lower in Nellore (NEL) than Angus x Nellore crossbred (AN) in grazing, and no difference was observed in feedlot. The NEL had less CH_4 intensity (CH_4/BW) in grazing but greater CH_4 per unit of ADG in the feedlot compared to AN. Breed composition did not influence the CH_4 yield (CH_4/DMI) in either phase, despite the difference in feedlot DMI (kg day^{-1}). Regarding to the GHG emission from excreta deposition, the occurrence of rainfall was determinant of very high N_2O fluxes either for urine or feces. Individual excreta were characterized by a period of small but significant fluxes, followed by a period of indistinguishable fluxes at the background level, and then a third period after rainfall portrayed the large impact of excreta on GHG emissions from the feedlot.

Key words: Enteric methane; Beef cattle; Bovine excreta

INTRODUCTION

Emissions of greenhouse gases (GHG) caused directly by Brazilian agriculture and livestock represent 28% of the total (ALBUQUERQUE et al., 2020) and are mainly derived from animal and plant production. Beef cattle is one of the main sources of GHG emissions in the sector, followed using nitrogen fertilizers, the deposition of animal excreta and the decomposition of cultural residues, among others (EMISSÕES ..., 2018). In recent years, agriculture has been recognized for its potential in reducing GHG emissions through the adoption of sustainable use and mitigation practices. Beef cattle is the sector with the greatest margin for implementing improvements in its production system, mainly related to increasing the efficiency of the use of pastures in Brazil (EMISSÕES ..., 2018). The relationship between efficiency in the production of agricultural systems and the reduction of emissions in the sector is an opportunity to achieve the growing demand for livestock products and providing a positive carbon balance (MANZATTO et al., 2019; SOUZA et al., 2019).

Beef production in feedlot systems generally offer substantially lower area requirements and lower GHG emissions per kilogram of meat produced than traditional extensive systems. However, GHG emissions in grazing systems can be considerably less than previously thought, since the use of rotated, more productive, and better-quality pastures, as in crop-livestock systems (CLS), has the potential to increase carbon sequestration in the soil, thus negating emissions by animals. Beef cattle production systems that associate grazing well-managed in the initial growth phase of the animals, with the supply of concentrated diets in the finishing phase seems to be an alternative to increase the productivity of the system, in addition to contributing for the reduction GHG emissions per kg of carcass produced. Another alternative that has been frequently used to increase the weight gain of animals is the genetic improvement in beef cattle. The crossing between *Bos indicus* and *Bos taurus* animals can improve the production rates of purebred cattle, in addition to having the potential to reduce methane emissions per kg of meat produced.

Cattle excreta are also sources of GHG emissions to the atmosphere, mainly nitrous oxide (N_2O) and methane (CH_4). Some studies have quantified the emission of N_2O by the beef cattle excreta in pastures, but little is known about these emissions in feedlots, especially in tropical conditions (SORDI et al., 2014; LESSA et al., 2014). The GHG emissions from the soil due to the deposition of animal excreta can be influenced by different factors such as climate, species, type of diet and the management system (BROUCEK, 2018), and some aspects present in feedlot can increase N_2O emission, such as high animal density, soil compaction and absence of vegetation (VAN GROENIGEN et al., 2005). Studies indicate that the emission of N_2O in feedlots is small (BAI et al., 2015), but the production of beef cattle in feedlots has been expanding in Brazil, and greater attention should be given to the emission of GHG by deposition of urine and feces. According to the IPCC (2006), the emission factor for N_2O (amount of N lost as N_2O) is 2% for the animals' excreta in pasture or in feedlot, without distinguishing between urine and feces. However, studies show that there is a difference in the emission factor between urine and feces (LESSA et al., 2014; SORDI et al., 2014).

From the above, the objective of the study was to evaluate the enteric methane production from two breed compositions in pasture and in feedlot where, also, the emissions of gases from the excreta of these animals were measured.

MATERIAL AND METHODS

Site description and experimental design

The study was conducted in an integrated crop-livestock system (CLS) installed in the Embrapa Maize and Sorghum experimental field, located at the geographical coordinates 19°29'4.37"S and 44°10'25.66"W, at 755 m altitude. The local and predominant climate in almost the entire Cerrado region is classified, according to the Köppen classification, as Aw - Type A: megathermic (tropical humid) - with average temperature of the coldest month above 18 °C and subtype w, dry winter and maximum summer rainfall (MACENA et al., 2008). The average annual coverage is 1350 mm, distributed between the months of October and March. The soil is a Oxisol, dystrophic Red Latosol according to the Brazilian Soil Classification System (SANTOS et al., 2013), clayey and smooth wavy relief.

The 22.0 ha area was divided into four 5.5 ha plots where, each year, the plots are rotated as crops for the production of grains (soybeans and corn) or silage (corn and sorghum) associated with grasses *Urochloa* (Syn. *Brachiaria*) or *Megathyrsus* (Syn. *Panicum*) and in the fourth field is the *Megathyrsus* pasture (Figure 1).

Figure 1. Sequence of annual crop rotation (Soybean; Corn + Urochloa; Sorghum + Megathyrsus) and Megathyrsus pasture conducted in the CLS plots. Photos: R. C Alvarenga.

Bovine animals with an average age of seven months were introduced in the system in July of each year and remained in it for twelve months. In the finishing phase, the animals were transferred to the feedlot where they were finished over approximately 110-120 days and slaughtered at the age of 22-23 months.

Trials were conducted in the years 2016/2017 and 2017/2018. At the beginning of each rainy season (October/November), the steers (10 months old) were divided into two groups, according to the breed: Nellore (NEL) and Angus x Nellore crossbred (AN) and grazed only the *Megathyrsus* grass, which was subdivided into five paddocks of approximately 1.1 ha each, used as a rotational grazing system with approximately seven days of grazing and 28 days of rest. Subsequently, these animals were finished in feedlot, with a 65:35 concentrate:silage ratio diet.

Evaluation of methane emission in beef cattle in CLS and in feedlot

During the grazing and feedlot period, enteric methane (CH_4) emissions from the animals were evaluated. The CH_4 emissions were measured using the sulfur hexafluoride (SF_6) tracer gas technique as reported by Johnson et al. (1994). Ten days before the start of each measurement, an SF_6 permeation tube was introduced directly into the rumen of each animal through the esophagus. Exhaled gases were collected from eight animals from both breed composition with a sampling apparatus containing a collection canister made of polyvinyl chloride (PVC) equipped with a capillary tube. The gases expired by the animals were sampled once a day until at least five samples were obtained per animal (Figure 2). The analyzes of the concentrations of CH_4 and SF_6 were determined by gas chromatography at the Gas Chromatography Laboratory of Embrapa Dairy Cattle, Juiz de Fora, Minas Gerais, Brazil.

Figure 2. Detail of the sampling apparatus used to collect enteric methane in cattle in feedlot (left) and pasture (right). Sete Lagoas, MG. Photos: S. T. Guimarães (L) and I. C. F. Maciel (R).

Evaluation of nitrous oxide and methane emission by the excreta of beef cattle in feedlot

In addition, N_2O and CH_4 emissions from the deposition of feces and urine on the surface of pens were also assessed in the feedlot. GHG emissions from excreta were measured using a closed static chamber technique, and the methodology was based on previously published studies (SAGGAR et al., 2004; LUO et al., 2013, 2015; VAN DER WEERDEN et al., 2016). Two weeks before the experiment, a base of the chamber (dimensions of 60.5 cm long x 40.0 cm wide) was inserted 8.0 cm into the soil in each plot and left for the entire experimental period.

The urine and feces of Nellore steers (n = 25, BW = 393 ± 31kg) were collected on days 34 and 35 of the feedlot. The excreta application was performed once, at the beginning of the experiment, in the dry season (winter 2017). Feces weight and urine volume were 1.3 kg and 1.3 L, respectively. Feces and urine were applied separately to the center of the base of the static chambers used for the measurement of GHG. A control treatment, without the addition of excreta, was included in the study. A trough was made around the top of the frame and filled with water at the time of gas monitoring to ensure the seal after coupling the top portion of the chamber to the base. The top portion was covered by an insulating material to avoid large differences between internal and external temperatures.

Gas samples were collected manually from each chamber and measurements were taken daily during the first four days after application (DAA) of excreta to account for possible instantaneous excreta emissions and, subsequently, every 2 and 3 days in the second and third weeks, respectively, and then weekly thereafter until 92 DAA. Air samples inside the chamber were collected at 0, 15, 30 and 45 min after closing the chamber using a 60 mL syringe and transferred to a 20 mL Exetainer flask with vacuum (Labco, Lampeter, United Kingdom). Extra samplings were performed when the precipitation exceeded 10 mm in 24 h. On each sampling day, gas measurements were taken once between 9 am and 10 am. Nitrous oxide and methane concentration were analyzed by gas chromatography. For more details on the execution of the GHG experiment of bovine excreta, see Maciel et al. (2021).

RESULTS AND DISCUSSIONS

Methane production (g day^{-1} and kg year^{-1}) was lower for NEL animals than for AN in both pasture and feedlot systems ($P<0.01$). Considering the entire period, NEL emitted 19% less methane than AN on pasture, but no differences between breed composition in feedlot were observed. Although AN have a higher daily methane emission, the total methane emission during the feedlot was the same for both breed compositions, because the period that the crossbred animals remained in feedlot was shorter than the NEL animals.

There was no difference in the dry matter intake (DMI) between breeds on pasture (5.9 vs. 6.23 kg DM per day for NEL and AN, respectively), however, in the feedlot, AN had greater DMI (12.4 kg day^{-1}) than NEL (9.3 kg day^{-1}). Despite the difference in DMI, breed composition did not influence the methane yield (g CH_4 per unit of DMI) neither in pasture nor in feedlot.

Regarding the methane emitted per unit of ADG, there was no difference between the two breed compositions on pasture (119.5 and 140.0 g of CH_4 per kg of ADG for NEL and AN, respectively). However, in feedlot, CH_4/ADG or CH_4/carcass ADG was significantly lower ($P<0.01$) in AN than NEL animals. Previous research has focused on the use of feedlots as a strategy to reduce methane emissions per kg of meat produced compared to the grazing system. However, most studies have evaluated continuous grazing systems, or have not considered the carbon sequestration by plants. In addition, in these studies, ADG is generally below what can be achieved in well-managed intensive grazing systems. A substantial reduction in net GHG emissions can occur in intensive grazing systems, even when requiring twice as much land as in feedlot systems, because of increased animal performance and carbon sequestration.

The results for GHG emission from the excreta showed significant effects of interaction between excreta type and days. Fluxes of N_2O were predominately low owing to the dry conditions throughout the monitoring period, exception made to a few days after excreta application (DAA), and principally after the three-day rainfall from 67 to 70 DAA. When comparing excreta treatments within each day of gas monitoring, the application of urine resulted in a significantly higher fluxes than those measured from feces or control. In the following day, N_2O flux from urine decreased, but was still higher than the control. From 3 to 69 DAA, N_2O fluxes were practically basal and similar between excreta treatments, coinciding with the increase in temperature. During this period, the soil was probably too dry. With the three consecutive rainfall events, starting at 67 DAA, soil N_2O fluxes started to increase. The CH_4 fluxes were around zero or negative for most of the time, but an initial flux from feces, of relatively low magnitude was significantly higher than from urine or control. This happened again at 10 DAA. As observed for N_2O, the rainfall events also induced high CH_4 fluxes.

Over the 92 DAA (winter/spring) of gas monitoring, three distinct periods could be withdrawn based on the gas flux trends and principally on the significant differences that were observed among treatments within each gas sampling date. A first period would comprehend the first 10 DAA, during which urine induced high N_2O fluxes (first two days) and CH_4 fluxes were produced in feces at days 1 and 10. We called this period “excreta inductive period”, or EIP, as all changes in fluxes were virtually associated to own excreta, more than the environment. From 13 until 56 DAA was the period of low fluxes, when no differences between treatments could be observed. This was called “dry period”, or DP. A third period was mostly associated to the effects of rainfall on both gas fluxes which lasted from 69 DAA to the end of monitoring, which was called “after rain induction period” or ARIP. On average of whole monitoring period, N_2O fluxes presented mean values of 180.4, 249.4 and 297.3 μg N m^{-2} h^{-1} for control, feces, and urine, respectively. The highest mean flux of 650.7 μg N_2O-N m^{-2} h^{-1} was observed for ARIP, followed by a mean flux of 47.2 μg N_2O-N m^{-2} h^{-1} for EIP, when excreta were fresh. The mean flux for DP was 29.1 μg N_2O-N m^{-2} h^{-1}.

CONCLUSIONS

The potential for mitigating and neutralizing greenhouse gases is one of the benefits arising from the use of CLS, already recognized by science in Brazil. These reduce net GHG emissions per kg of carcass produced, which contributes positively to the role of the agricultural sector in climate change. The estimate of the carbon balance in CLS systems can provide added value to production, adding competitiveness to the sector in the face of market demands and is in line with the Brazilian GHG reduction policy in the country.

Excreta GHG emission data indicate that urine results in a prompt emission of N_2O and that occasional rainfall has potential to dramatically enhance the process. The CH_4 emissions seems to be of lower importance when dry conditions prevail, but the rainfall effect on emissions can be also relevant.

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EVOLUTION OF THE SOIL ORGANIC MATTER CONTENT AFTER 15 YEARS OF CROP LIVESTOCK SYSTEM

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ABSTRACT

Soil organic matter (SOM) is sensitive to changes in land use and is a key indicator of soil quality. This work evaluates the evolution of the organic matter of an oxisol under a crop-livestock integration system (CLS) installed in 2005 and located in the Cerrado Biome, in Sete Lagoas, Brazil. The CLS system consists of four plots of 5.5 ha each, which in the spring/summer were cultivated in annual rotation with the crops of soybean+ intercropping Urochloa, corn+Urochloa consortium, sorghum+Megathyrsus consortium and Megathyrsus pasture. In autumn/winter, after crops' harvesting, succession pasture was used with beef cattle grazing. An area of native savanna ("cerrado"), above the experimental site, is used as a reference site. The organic matter content was measured by the method of wet digestion. The SOM values under CLS showed a tendency to approach the soil under native Cerrado. There was no significant difference in the global average levels and the analysis of the time series shows a general trend of increasing values under the CLS. There was a stability of SOM after 2012, with an average value of 4%.

Key words: Soil carbon stock; Sustainability; Soil quality

INTRODUCTION

The integrated systems are, beyond their technical and economic benefits, a way to achieve the goals of the sustainable development commitments signed by the government. The crop livestock and crop livestock forest systems (CLS/CLFS) are production systems included in the public policies' strategies for the agriculture aiming to achieve the COP 15 commitments for the climatic change mitigation (UN, 2015). For that goal, the federal law 12.187 and the decree 7.390 (National Policy for Climate Change) were done, and the Sector Plans for Mitigation and Adaptation, which include the CLS/CLFS in the top six methods concerning Brazil's Low Carbon Agriculture Plan (ABC Plan), a sector plan for the consolidation of the low carbon emission economy in agriculture and livestock). It aims to mitigate 133.9 to 162.9 million ton of CO_{2eq} emissions, through to recovering 15 million ha of degraded pastures and to increase in 4 million ha of CLS/CLFS. The measurement of some soil parameters is necessary to evaluate the efficiency of these systems, and to help their management strategies (RODRIGUES et al., 2010). The soil organic matter (SOM) is one of these parameters that is sensitive to land use changes (BALDOTTO et al., 2015; CONCEIÇÃO et al., 2005; NIAZ et al., 2017), and is a key indicator of soil quality (CONCEIÇÃO et al., 2005). The soil organic matter and its components are used as to evaluate the crop systems and their conversion to more sustainable ones. The conversion of degraded pastures to CLS system led to the increase of the biological components and of the organic carbon levels in the soil ecosystem (MUNIZ et al., 2011). This work presents and discuss the results of the evolution of the soil organic matter in a CLS experiment, along its 15 years since the implantation, compared to a native reference soil (cerrado).

MATERIAL AND METHODS

The soil was sampled in four experimental fields in the Technological Reference Research Unit of Crop Livestock Integrated Systems, started in 2005 in the Embrapa Milho e Sorgo's experimental station, at 19º 28'S, 44º 15'W and 732 m ASL. The unit is 22 hectares in area, split in four fields of 5.5 ha. A native savanna ("cerrado") area, in the upper area close to the experimental site, is used as a reference site. The soil of the area is a Typic Haplustox with high clay content. The samples were taken in the years of 2005, 2006, 2008, 2009, 2010, 2012, 2014, 2015, 2017, 2018 and 2019, through hand augering. Twenty single samples were taken for each compound sample, by random walking in the areas. In 2005, the samples were taken from the 0 to 20 cm and 20 to 40 cm soil depths. In 2006, 2009, 2010 and 2012, from 0 to 10 cm, 10 to 20 cm and 20 to 40 cm. in 2008, the sampling depths were at 0 to 10 cm and 10 to 20 cm, but the lines and the in-between lines were samples separately, and the results presented separately. In 2014 and 2015, the sampling depths were at 0 to 5 cm, 5 to 10 cm, 10 to 20 cm, 20 to 40 cm and 40 to 60 cm. From 2017 to 2019, the sampling depths were at 0 to 10 cm, 10 to 20 cm, 20 to 40 cm and 40 to 60 cm. The soil organic matter content was measured by the wet digestionmethod (TEIXEIRA et al., 2017). The results were subjected to the statistical analyses using the R system's (R Core Team 2018) packages "MASS" (VENABLES; RIPLEY, 2002) and "data.table" (DOWLE; SRINIVASAN, 2021).

RESULTS AND DISCUSSIONS

The values of SOM of the experimental fields under CLS showed a trend to get closer to the native soil references, and were related to the crop planted in the year of sampling. The experimental fields were cropped in a no-till system, and as it was consolidated, the deposition of crop residues was stabilized and the vertical distribution of the SOM followed the standard decrease with depth (Figure 1). The surface values were in the "good" level, according to standard recommendations and relatively high at 50 cm depth (CFSEMG, 1999), with no difference to the references. Also, no significant difference was found in the global average leves. The time series analysis of the fields shows a general trend to the increase of the SOM values under the CLS, and a no clear trend of the native reference, as the reference "cerrado 1" had increasing values and the "cerrado 2" decreasing values (Figure 2). It seems that a stable state was achieved after 2012, with an SOM average value of 4%. This result indicates that tha CLS has potential to capture carbon in the soil, with an adequate management. It also helps to improve the overall soil quality, as the SOM is a key factor to many soil properties and is a good indicator of soil quality. The comparison among the years indicates that the fields present different trends, and that the native references do not show clear trends, which may suggest that the variations here found are natural fluctuation along the time (Figura 5). The field "gleba 3" presents the higher SOM rise, while the "gleba 4" remained similar to the references without any apparent trend, which is coherent to its neighborhood plots to them. The natural spatial variability sums to the management effects on the total SOM values before the beginning of the experiment.

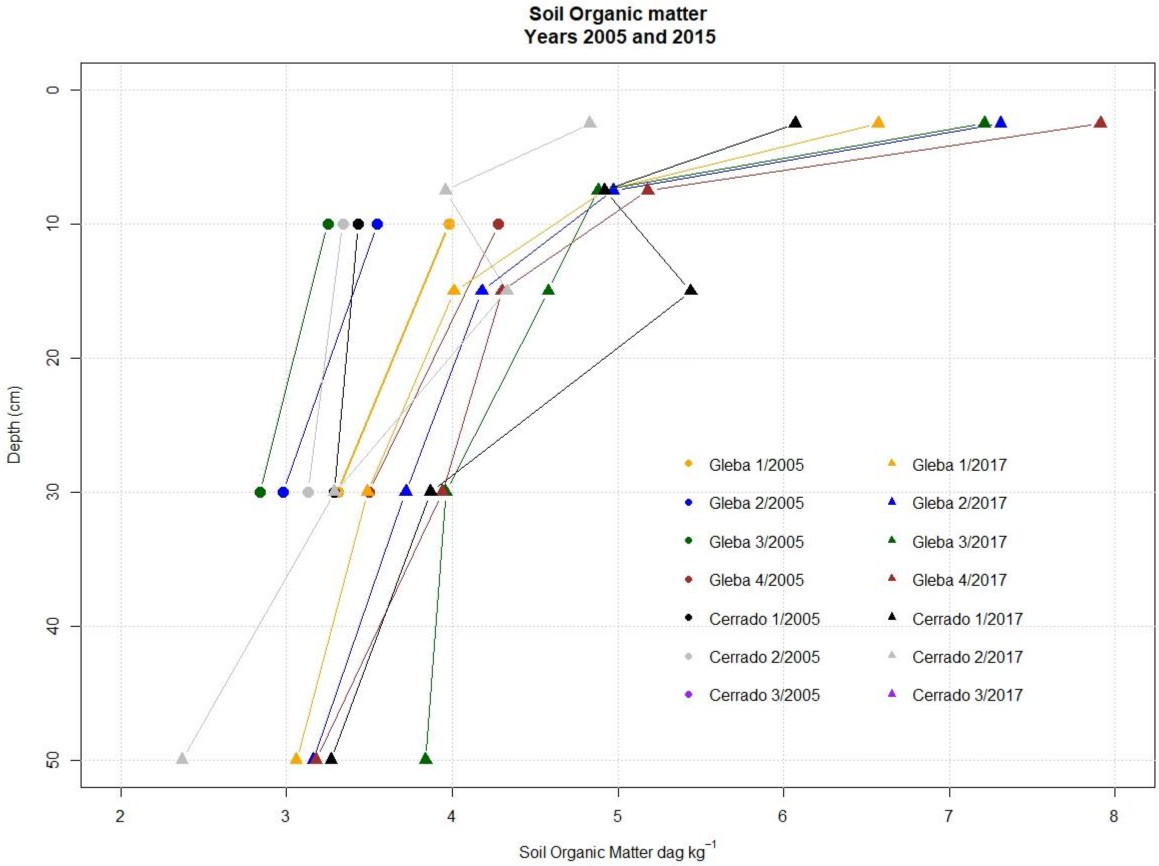

Figure 1. In-depth distribution of all samples collected in the plots sampled in the CLS and in Cerrado.

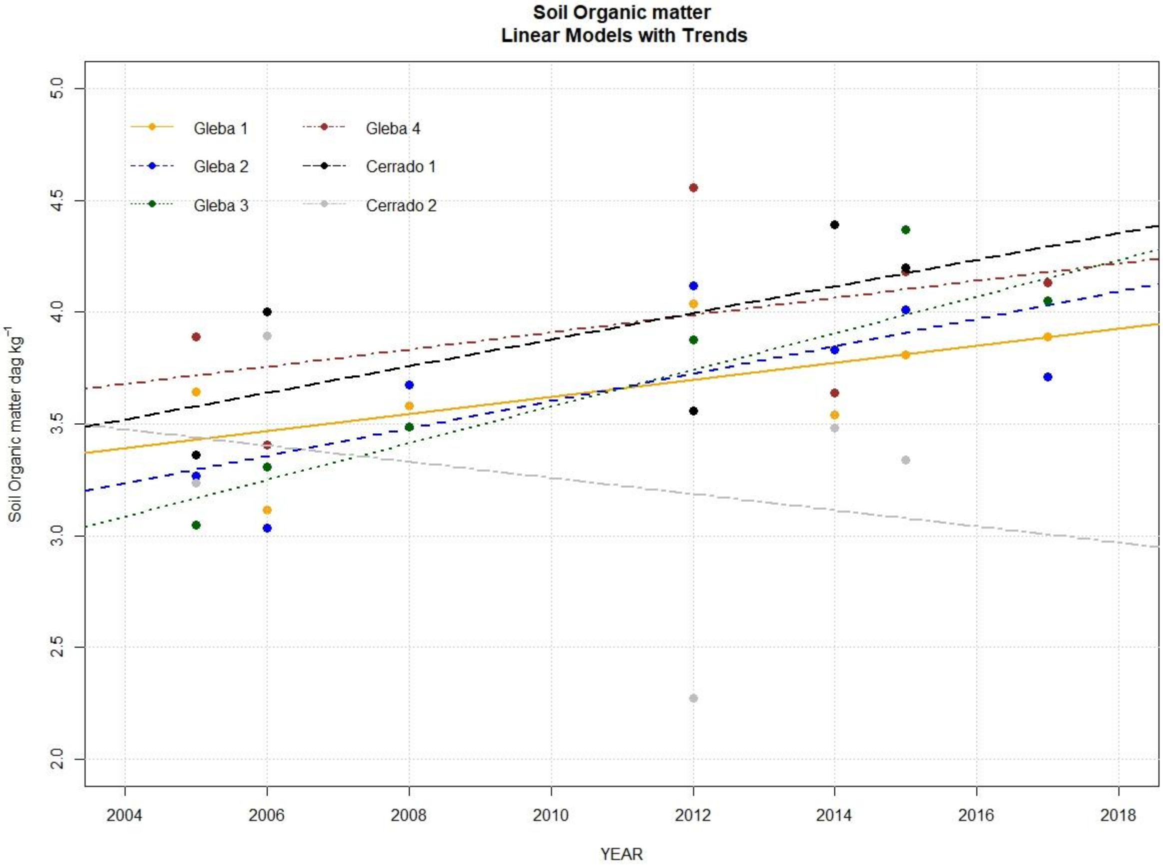

Figure 2. Linear regression models with the general trends of variation for the organic matter values (MOS) of the plots sampled in the CLS and in Cerrado.

CONCLUSIONS

The results of the monitoring of the soil carbon in the experimental long term CLS system indicates the it was able to increase the soil organic matter content, compared to the native reference. The system fields showed a general trend to accumulate SOM in the initial years and to stabilize these values afterwards, indicating the benefits of the CLS to them. The continued monitoring of the SOM in this experiment shows the importance of the long-term experiments with periodic sampling, to the adequate evaluation of the intensified crop systems as tools to achieve environmental goals, concerning its capacity to work as carbon sink. The result also shows the adequacy of the inclusion of the CLS/CLFS in the strategies for the public policies for the agriculture aiming to achieve the COP 15 commitments for the climatic change mitigation.

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CHANGE IN SOIL CARBON STOCK AFTER FOREST CONVERSION IN PASTURES AND AGRICULTURE AREAS IN THE AMAZON REGION

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ABSTRACT

Tropical soils contain large stocks of carbon stored in it, which when disturbed alter their dynamics. The aim of this study was to evaluate the concentration and stock of soil C, in different land uses, in the arc of deforestation in the Amazon. Where the pasture area used for soil collection was composed of *Brachiaria brizantha* cv. Marandu, the area corresponding to agriculture hadblack pepper cultivation *(Piper nigrum)* and forest area was composed of Amazonian biome. The concentration of C in the agricultural system was lower than in the other ($P<0.05$). The concentration of C in the pasture system was lower than in the forest system only in the surface layers. The stocks of C and in the pasture and forest systems did not differ from each other and presented a higher stock than the area of agriculture ($P<0.05$), for depths of 30 and 100 cm. Our results show that with the conversation of the in well-managed pasture systems and agriculture, for aspects related to soil parameters, pasture systems conserve C in soil and in agricultural systems c perch occurs over the years.
Key words: Amazon biome; Stocks of C; land use

INTRODUCTION

Tropical soils contain large stocks of carbon stored in it, which when disturbed alter their dynamics. In the Brazilian Amazon, after deforestation, the predominant destination of its lands has been the conversion into pastures, where maintenance of stock C in pastures depends on the stability of the organic matériderived from the old vegetation, the replacement rate of the organic matter of the implanted crop (NEILL et al., 1997) and the history of management of the area. Considering the expansion of Brazilian agriculture and the role played by the Amazon biome in soil C dynamics, there is a great demand for data on soil C stock under pastures compared to those under native vegetation.

Currently agriculture has also gained more and more space in the Amazon region, according to FAESPA (2017) Pará is a leader in the national production of açaí, pineapple, cocoa, oil, cassava and black pepper and in the last 10 years soybean production has increased by 700%.

Due to this growing position of the North region in national agriculture, intense changes in land use have occurred and it is important to understand how this alters the stock of soil C. Therefore, this study aims to evaluate the stock of soil C, after land use changes (agriculture, livestock and forest) in the arc of deforestation in the Amazon.

MATERIAL AND METHODS

Soil samplings were carried out in the municipality of Nova Esperança do Piriá (Amazon biome), Pará, Brazil (2°15'47" S, 46°58'41" W; altitude 73 m). Areas with different land use, but with similar soil characteristics were selected. The different collection sites were distant from each other within a radius of approximately up to two kilometers. The Köppen classification of the region is Am, and this climate is present in 27.5% of the Brazilian territory (ALVARES et al., 2013). The rainfall of theannual average of the municipality is 2104 mm and with an average annual temperature of 26 °C. Soil characteristics at the collection sites were classified as Yellow Latosol (GAMA et al., 2020).

An experiment was carried out with three treatments consisting of different land use systems (forest, pasture and agriculture) and four replications. Where the forest area was composed of Amazonian biome, the pasture area was composed of *Brachiaria brizantha* cv. Marandu, the area corresponding to agriculture has the cultivation of black pepper (*Piper nigrum).* The selected areas have similar soil characteristics and within each land use treatment.

In October 2019, soil composite samples were collected in four trenches per treatment (areas of 1 x 1 x 1m). The samples were taken in the medium interval (5 cm central) of depths 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm as described by Santos et al. (2019). For the analysis of soil organic carbon (OCD) and C stocks at 30 and 100 cm depth, subsamples were taken from each trench wall, in the eight depth intervals described, generating a depth sample with four replications per treatment. The samples for apparent density analysis were taken by means of chamfered stainless-steel rings of 5 cm in diameter (5.2 cm in length and 100.6 cm^3 in volume) at the same depth intervals previously described, in two opposite walls of each trench, totaling 16 samples per trench, the soils were removed, dried at 110 °C for 72 hours and weighed, as described by Sisti et al. (2004).

After fine grinding of the subsamples (roller mill), the OCD was determined by isotopic analysis performed at the Stable Isotopes Center of the Paulista State University - UNESP, Brazil. Soil samples were dried in an oven at 50 ºC for 48 hours. An aliquot of 1.0 to 1.5 mg of each sample was weighed in tin capsule using a scale with a resolution of 1 µg (XP6, Mettler Toledo, Switzerland). The capsules were analyzed in an isotopic mass spectrometry system by CF-IRMS continuous flow ratio using an IRMS (Delta V, Thermo Scientific, Germany) coupled to an elementary EA analyzer (Flash HT, Thermo Scientific, Germany) by means of a gas interface (ConFlo IV, Thermo Scientific, Germany). The CF-IRMS determined the isotopic ratio of *Carbon R* ($^{13}C/^{12}C$) and the values were expressed in relative difference of theisotopic ratio ($\delta^{13}C$), in ‰, from the V-PDB pattern (Coplen, 2011). The standard uncertainty of THE CF-IRMS was estimated at ±0.15‰ (n=10) and the results were normalized from the nbs-22 certified reference standard. The CF-IRMS determined the OCD percentages present in each sample using the Thermal Conductivity Detector (TDC) of the EA calibrated with the certified reference standard Nicotinamide (P/N33840009, Thermo Scientific, Germany). The standard uncertainty of OCD values was estimated at ±1.0% (n=10) for samples with OCD between 0.5% and 5%.

C stocks were determined by multiplying the C content by soil density corresponding to each depth (all eight profiles). The stocks of C were corrected for the same reference soil mass (forest at 30 and 100 cm deep). Nthis procedure is assumed that soil compaction due to grazing, or machinery, is only representative in the surface layers, fearthat in the calculation of c stock was subtracted the c content present in the extra weight of the soil in the deepest layers, 20-30 and 80-100 cm (Sisti et al., 2004).

All statistical analyses were performed with the statistical program R Core Team (2020). To test the normal distribution, in all parameters we used Cramer-von Mises and when ANOVA was significant for land use levels, the Student-Newman-Keuls test was used to distinguish the means ($p<0.05$). Treatment effect levels were defined as land use (forest, pasture and agriculture).

RESULTS AND DISCUSSIONS

The concentration of C (Fig. 1) in the soil decreased with depth in all profiles, regardless of the system. The concentration of C in the agricultural system was lower than in the other ($P<0.05$), regardless of soil depth. The concentration of C in the pasture system was lower than in the forest system only in the surface layers (0-20 cm).

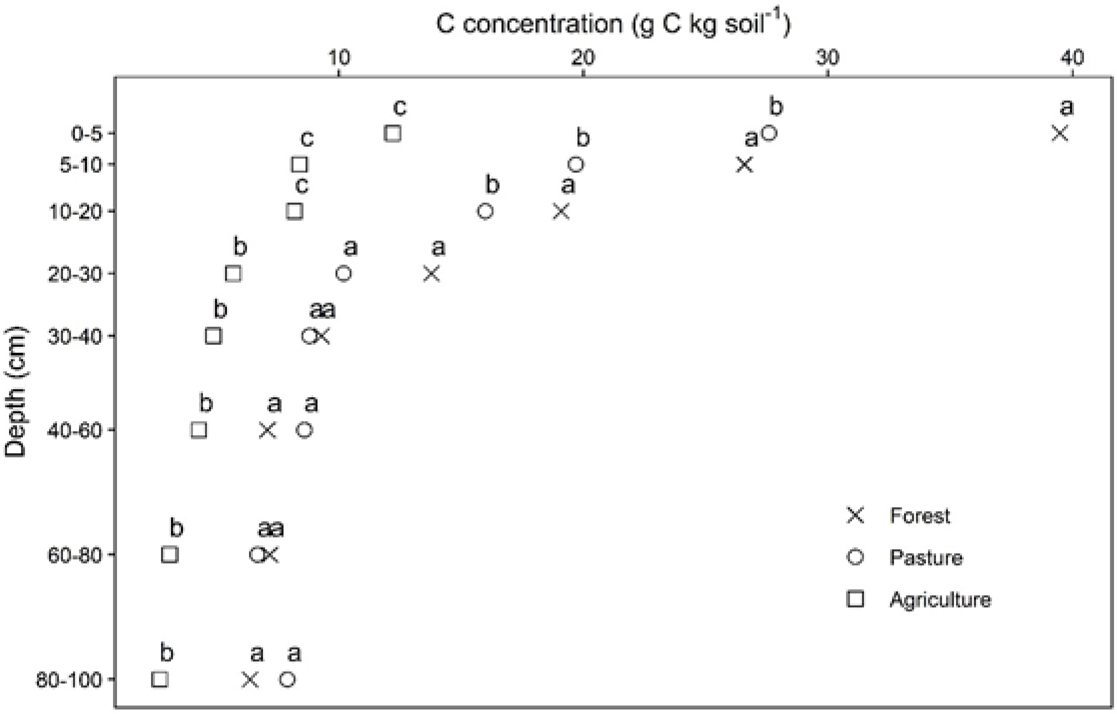

Figure 1. Organic carbon concentration in soil profile (g C kg soil^{-1}) of 0-100 cm depth under different land uses in the Amazon region. Averages in the same line followed by the same letter are not significantly different ($P<0.05$).

The higher C contents of forest and pasture systems that the agricultural system at all depths can be explained by the root system of the pasture and by the greater renewal of its tissues that favor pasture in relation to the agricultural system. The absence of soil operations and the entry of sawdust into forest systems explain their higher C content than in the agricultural system. Another strong trend is in the pasture systems and forests in the surface horizons the carbon content is higher, being this caused by the entry of litter, this would no longer be so evident in the agricultural system. These results are consistent with other authors who reported that most of the biomass of *Brachiaria brizantha roots* is found in the upper 30 cm and the first 10 cm are strongly affected by the entry of litter (BRAZ et al., 2013; SANTOS et al., 2019).

The stocks of C and in the pasture and agriculture systems corrected for the same soil mass relative to the forest area at depths of 30 and 100 cm presented the same pattern. The pasture and forest systems did not differ from each other and presented a higher stock than the agriculture area ($P<0.05$). Since the c stock for the depth 30 cm did not follow the same trend of C concentration for the forest and pasture systems, since, when the stock was corrected for density, both systems did not differ in both depths (Tabshe 1). Regardless of the system, the stock of C presented between 47 and 57% of its total quantity in the initial 30 cm of the soil profile.

Table 1. Stocks[1] of C in the soil profile at 30 and 100 cm depth under different land uses amazon region.

	Forest	Pasture	Agriculture	CV[3] (%)
	Carbon stock (Mg C ha^{-1})			
30 cm	77.1 A[2]	67.6 A	36.4 B	7.7***
100 cm	137.5 A	144.8 A	63.9 B	4.2***

[1] Stocks of C corrected for the same reference soil mass (forest at 30 and 100 cm depth).

[2] Averages in the same line followed by the same letter are not significantly different ($P<0.05$).

[3] Coefficient of variation.

The higher carbon stocks of forest and pasture systems were already expected due to lower operations in the soil, the largest litter inlet and better soil cover of their roots than the agricultural system.

It should be highlighted that the favorable conditions of climate, temperature and pasture management under the evaluated conditions favored the carbon stock of the pasture system. According to Braz et al (2013) evaluating different areas in the Cerrado region with four different sites of coletas concluded that the clay content and the history of the area have great influence on soil carbon stocks. In our study, the average clay contents for pasture, agriculture and forest areas were 29.5, 26.5 and 36.5%, within the expected for yellow latosol. The work of Freitas et al. (2020), which evaluated the C stock at 30 cm depth, in soil with 65.6% of clay, under different land uses, low productivity pasture, intensified pasture (100 kg ha^{-1} N), livestock crop integration (ILPF) and native vegetation (Cerrado Biome, Curvelo-MG), where the respective treatments had C stocks of 59.3, 65.9, 71.8 116.2 Mg ha^{-1}, demonstrates the need for research evaluating intensified pasture systemsand ILPF in the Amazon biome and its different climatic zones.

CONCLUSIONS

Our results show that with the conversation of the Amazon Forest in well-managed pasture systems and agriculture, for aspects related exclusively to soil parameters, pasture systems conserve C in soil and in agricultural systems c perch occurs over the years. Research is needed to assess intensified pastures and ILPF, as both systems have the potential to sequester carbon, increase the region's productivity and prevent more areas from being deforested.

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CHANGE IN THE CARBON ORIGEN AFTER FOREST CONVERSION IN PASTURES AND AGRICULTURA AREAS IN THE AMAZON REGION

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ABSTRACT

The Brazilian territory is constantly expanding and in recent decades much of the advance of agriculture has been in relation to the North direction, causing change in land use. Therefore, this study aims to evaluate the origin of soil C, in different land uses, in the arc of deforestation in the Amazon. Soil samples were collected to evaluate the abundance of ^{13}C and the origin of C. In the pasture area, the abundance of ^{13}C of soil was significantly ($P<0.05$) less negative than the forest area at all depths. The agriculture area presented c4 remaining indicative of the old crop less negative than the forest area only at depths of 0-5 and 20-40 cm. The pasture system, despite having a similar c content than that of forest, demonstrated a substitution of C3 by c4 derived from grass. The agricultural system demonstrated that even after 8 years of its implantation remnants of the grass are still in the soil. Our results show that with the conversion of pastures in agricultural or livestock systems occurs the substitution of forest carbon by that of the new crop, being more evident in the surface layers.

Key words: abundance of ^{13}C; C origin; land use

INTRODUCTION

Land use changes are responsible for the higher proportion of GHG emitted, either by deforestation, degradation of areas or by the application of fertilizers. This is due to the country's economy turning around agribusiness, and the production of ruminant animals occur mainly in pastures.

The Brazilian territory is constantly expanding, where in recent decadesmuch of the advance of the agricultural frontier has been towards the Northern region of Brazil (FREITAS; MENDONÇA, 2016). Thestate of Pará, which has increased its herd in the last 10 years of 21.67%, totaling 20,510,169 million head and achieving the second largest growth and the fifth largest herd in the country (ABIEC, 2020). Currently, agriculture has also gained more and more spacein the Amazon region, according to FAESPA (2017) Pará is a leader in the national production of açaí, pineapple, cocoa, oil, cassava and black pepper and inthe last 10 years soybean production has increased by 700%.

When a change in land use occurs, the amount and proportion of soil organic matter will also change. The organic carbon derived from the use of the original land will decomm and will gradually be replaced at a higher or lower rate by the organic carbon derived from the new land use. The determination of soil abundance of ^{13}C provides a precise technique to evaluate the course of c decomposition derived from forest soils (predominantly calvin c3 photosynthetic pathway vegetation) and the contribution of C derived from the new photosynthetic pathway crop C4 (CERRI et al., 1985; SANTOS et al., 2019).

The growing position of the North region in national agriculture has caused an intense change in land use, evidencing its potential to alter soil C (NEILL et al., 1997). Therefore, this study aims to evaluate the origin of soil C in different land uses (agriculture, livestock and forest) in the arc of deforestation in the Amazon.

MATERIAL AND METHODS

Soil collections were carried out in the municipality of Nova Esperança do Piriá (Amazon biome), Pará, Brazil (2°15'47" S, 46°58'41" O; altitude 73 m). Areas with different land use, but with similar soil characteristics were selected. The different collection sites were distant from each other within a radius of approximately up to two kilometers. The Köppen classification of the region is Am, and this climate is present in 27.5% of the Brazilian territory (ALVARES et al., 2013). The average annual rainfall of the municipality is 2104 mm and with an average annual temperature of 26 °C. Soil characteristics at the collection sites were classified as Yellow Latosol (GAMA et al., 2020).

An experiment was carried out with three treatments consisting of different land use systems (forest, pasture and agriculture) and four replications. Where the forest area was composed of Amazonian biome, the pasture area was composed of *Brachiaria brizantha* cv. Marandu, the area corresponding to agriculture has the cultivation of black pepper (*Piper nigrum).* The selected areas have similar soil characteristics and within each land use treatment.

In October 2019, soil composite samples were collected in four trenches per treatment (areas of 1 x 1 x 1m). The samples were taken in the medium interval (5 cm central) of depths 0-5, 5-10, 10-20, 20-30, 30-40, 40-60, 60-80 and 80-100 cm as described by Santos et al. (2019). For the analysis of the estimation of carbon in the soil profile (C_3-C and C_4-C) and abundance of ^{13}isotopic C, subsamples of each trench wall were taken, in the eight depth intervals described, generating a sample by depth with four replications per treatment.

Isotopic analyses were performed at the Stable Isotopes Center of the Paulista State University - UNESP, Brazil. Soil samples were dried in an oven at 50 ºC for 48 hours. An aliquot of 1.0 to 1.5 mg of each sample was weighed in tin capsule using a scale with a resolution of 1 μg (XP6, Mettler Toledo, Switzerland). The capsules were analyzed in an isotopic mass spectrometry system by CF-IRMS continuous flow ratio using an IRMS (Delta V, Thermo Scientific, Germany) coupled to an elementary EA analyzer (Flash HT, Thermo Scientific, Germany) by means of a gas interface (ConFlo IV, Thermo Scientific, Germany). The CF-IRMS determined the isotopic ratio of *Carbon R*($^{13}C/^{12}C$) and the values were expressed in relative difference ofisotopic ratio ($\delta^{13}C$), in ‰, from the V-PDB pattern (COPLEN, 2011). The standard uncertainty of THE CF-IRMS was estimated at ±0.15‰ (n=10) and the results were normalized from the nbs-22 certified reference standard. The CF-IRMS also determined the percentages of total organic carbon (OCD) present in each sample using the Thermal Conductivity Detector (TDC) of the EA calibrated with the certified reference standard Nicotinamide (P/N33840009, Thermo Scientific, Germany). The standard uncertainty of OCD values was estimated at ±1.0% (n=10) for samples with OCD between 0.5% and 5%.

All statistical analyses were performed with the statistical program R Core Team (2020). To test the normal distribution, in all parameters we used Cramer-von Mises and when ANOVA was significant for land use levels, the Student-Newman-Keuls test was used to distinguish the means ($p<0.05$). Treatment effect levels were defined as land use (forest, pasture and agriculture).

RESULTS AND DISCUSSIONS

The abundance of ^{13}C of the soil under forest areas gradually increased, becoming less negative with depth increase (Fig. 1). According to Santos et al. (2019) this gradual increase in the abundance of ^{13}C of soil is something natural and is not considered due to the presence of C4 in the forest area but rather because the total value of the plants is enriched or exhausted with ^{13}C. Therefore, the more decomposed the material in depth in the soil profile can be more or less enriched at ^{13}C than on the surface.

In the pasture area, the abundance of ^{13}C of the soil was less negative($P<0.05$) than the forest area at all depths (0-100 cm), indicating that there was deposition of C4 derived from the roots derived from the grass in the entire soil collection profile. These differences were more evident in the ranges of surface depths (0-20 cm), indicating a marked c-derived entry from the pasture. Santos et al. (2019) evaluating two different *Brachiaria* cultivars (Arapoti and Xaraés), after 16 years of implantation, determined that up to 30 cm deep there are entries of 24.3 and 28.2 Mg C ha^{-1}, respectively.

The area of agriculture, after 8 years of pasture substitution, showed c4 indicator remaining from the old crop less negative than the forest area only at depths of 0-5 and 20-40 cm, and in the interval of 0-5 cm the agricultural area was less negative than the forest and more negative than the pasture, at depths of 20-40 cm the pasture area was equaland in the other depths did not differ from the forest area.

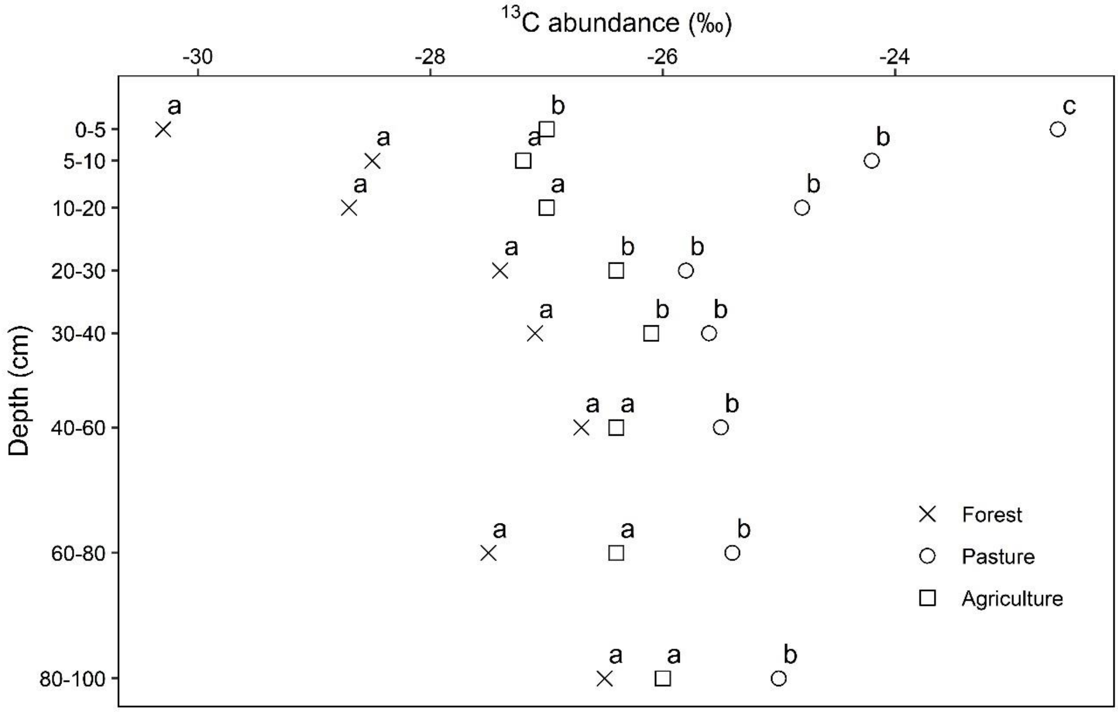

Figure 1. Abundance of ^{13}C in the soil profile of 0-100 cm depth under different land uses in the Amazon region. Averages in the same line followed by the same letter are not significantly different ($P<0.05$).

The proportions of c derived from plants C3 and C4 in the different systems was estimated using the abundance data of ^{13}C of the soil and the content of C (kg C m^{-3}) of each soil depth interval (Fig. 2). The pasture system, despite having a similar C content than the forest system, demonstrated a substitution of C3 by C4 derived from grass. This substitution of C3 by C4 was more intense in the surface layers (0-40 cm), but occurred throughout the soil profile analyzed. The agricultural system (C3) demonstrated that even after 8 years of itsimplantation remnants of the grass are still in the soil. This effect is more evident in the surface layers (0-40 cm).

The data show that in the pasture system there is a decrease in c derived from the forest (C3) and that this decrease is more evident in the surface layers, but this decrease was offset by the carbon derived from the pasture (C4). In the agriculture system, the data show more clearly in the surface layers that there are still remnants of carbon from the old crop previously cultivated in the area (pasture), but in this system there was a total carbon reduction. Probably the largest soil operations that occurred in this system and the higher proportion of soil area discovered contributed to the lower carbon content.

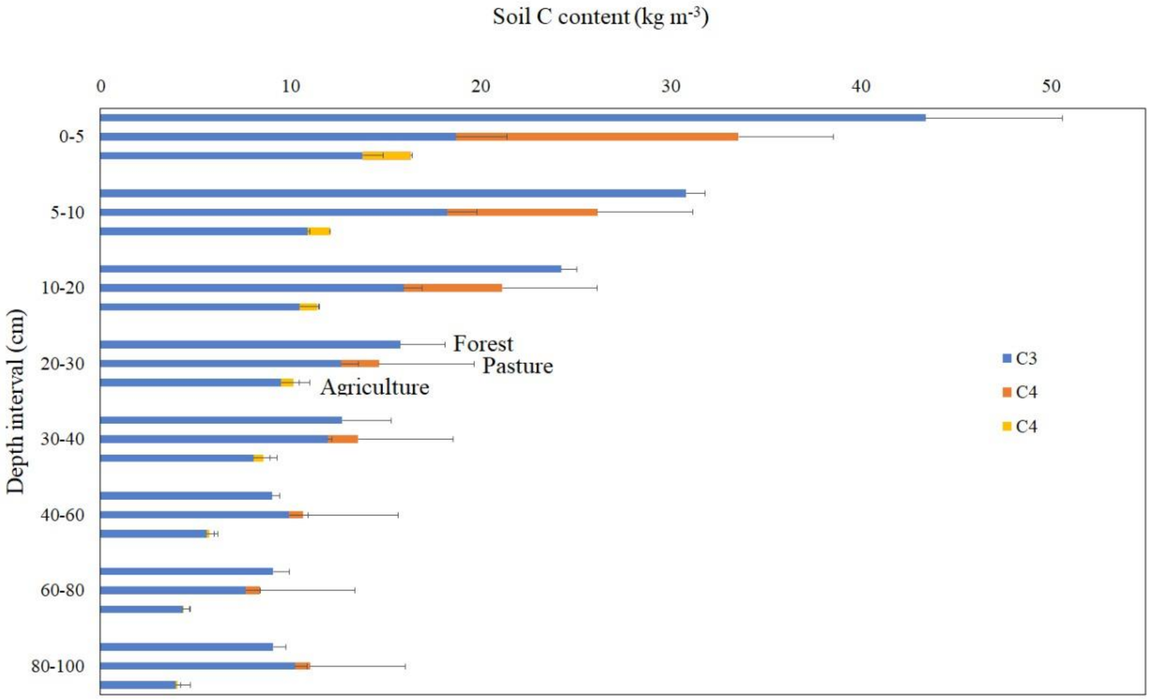

Figure 2. Estimation of carbon in the soil profile of 0-100 cm derived from forest areas (C_3-C), of the black pepper area, which was previously composed of pasture (C_4-C) and pasture (C_4-C). Error bar represents the average carbon error derived from plant C_3-C and C_4-C.

CONCLUSIONS

In the conversion of the forest into livestock systems, or agriculture occurs the partial replacement of the carbon of the forest by that of the new crop in the surface layers. In addition, it is evident that pasture systems are more efficient at mitigating soil carbon than agricultural crops.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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CARBON AND NITROGEN STOCKS IN THE SOIL IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS

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ABSTRACT

The integrated crop-livestock-forest system (ICLF) is a sustainable production strategy that integrates agricultural, livestock and forestry activities. The intensification of land use through systems integrated with trees provides income diversification for the farmer, thermal comfort for animals and the offsetting of greenhouse gas emissions - GHG. The objective of this work is to evaluate the effect of the ICLF system on the stocks of carbon and nitrogen in the soil, with a focus on dairy farming. The carbon stock in the 0-100 cm soil layer under ICLF system was 10.4% higher than the carbon stock in the same layer under integrated crop-livestock system (ICL). The nitrogen stock in the soil under ICLF system was 19.5% higher than the ICL. The ICLF system has great potential for storing carbon through the soil and trees and consequently mitigating GHG emissions.

Key words: integrated systems; dairy cattle; eucalyptus

INTRODUCTION

The crop-livestock-forest integration (ICLF) is a sustainable production strategy, which integrates agricultural, livestock and forest activities carried out in the same area, in intercropped cultivation, in succession or rotation, and seeks synergistic effects between the components of the agro-ecosystem, contemplating environmental adequacy, valuing man and economic viability (BALBINO et al., 2011, VILELA et al., 2011, KLUTHCOUSKI et al., 2015). It is a production system conducive to achieving satisfactory productivity and offsetting GHG emissions from agricultural activity, providing a positive carbon balance (OLIVEIRA et al., 2017). The high content of organic matter on the soil surface is one of the main benefits of integrated systems, when associated with soil management and conservation practices. This is because these practices improve the physical, chemical and biological conditions of the soil, while the cultivation of monoculture under the conventional system for some years causes the loss of organic matter and, consequently, compromises the quality of the soil (ASSAD et al., 2019). In addition, promoting the accumulation of organic matter in the soil is an excellent way to store carbon by removing it from the atmosphere, providing greater sustainability of the agricultural system. As part of the commitments to reduce GHG emissions assumed by the country through the Agricultural Low Carbon (ABC Plan), a goal was adopted for the adoption of four million hectares of ILPF systems with an estimated mitigation potential of 18 to 22 million Mg CO_2 eq (BRAZIL, 2012). In this way, the adoption of ICLF systems aiming at sustainable intensification can converge to a more efficient agricultural production strategy in relation to the carbon footprint, both by increasing the organic matter of the soil and by fixing carbon in the plant biomass of the forest component. The objective of this work is to evaluate the effect of the ICLF system on the carbon and nitrogen stocks in the soil in an ICLF area with a focus on dairy cattle.

MATERIAL AND METHODS

An experimental area of approximately 16 hectares with two systems: crop-livestock integration (ICL) and crop-livestock forest integration (ICLF), with a focus on milk production, was implemented in 2013 in Brasília, DF, at the Dairy Zebu Technology Center (CTZL), Embrapa Cerrados (15º 57' 09''S, and 48° 08' 12" W), altitude of 998 m. The soil of the experimental area is a typical dystrophic Red Latosol. The region's climate is Aw, with an average annual air temperature of 21.1 ° C and an average annual capacity of 1,668 mm, distributed predominantly from November to April. The area of each system is approximately eight hectares. In this work, the ICL system will be considered as a control treatment. The ICLF was implanted with eucalyptus seedlings in February 2013, through 13 simple rows, with spacing of 1.5 m between plants and 25 m between rows, associated with the cultivation of grains and or pasture, totaling about 2000 trees in the total area and about 267 trees per hectare. The fertilization of the implantation of the eucalyptus seedlings was carried out with 300 g of 4-30-16 + Zn, and in June 2013 it was projected in the total area of 2 t/ha of dolomitic limestone, without incorporation. In the experimental area, in February 2013, the sorghum was planted, in 2014 *Brachiaria brizantha* BRS Piatã was planted, in 2015/2016 soy was introduced and in 2017, a species of forage in the areas of ICL and ICLF it was *Panicum maximum* cv. Mombaça that remains in the area today. With the exception of trees, the ICL and ICLF areas suffered the same cultural treatments. The ICLF area comprises 13 lines of eucalyptus, 11 lines of the *Eucalyptus urograndis* hybrid (*E. urophylla* x *E. grandis*) (clone GG100) and a border containing two lines of the *E. urocam* hybrid (E. *urophylla* x *E. camaldulensis*). As for the animal component, in the first three years (2013 to 2015) heifers of the Zebu breed (girolando and gir) were introduced to the area, from the fourth year onwards lactating cows (girolando and gir) were introduced in rotated pasture. In 2018, due to the shading of the trees that hinder the development of forage, thinning of the trees in the area was carried out, with a removal of about 50% of them. For the assessment of soil carbon and nitrogen stocks, three samples of soil up to 1 m deep in the 0-5 cm layers were collected in June 2019; 5-10 cm; 10-20 cm; 20-30 cm; 30-40 cm; (from 20 simple samples); 40-60 cm; 60-80 cm and 80-100 cm (from 5 simple samples). The samples were air-dried and subjected to chemical and physical analysis. For the evaluation of the apparent density of the soil (AD), undisturbed samples were collected in the same layers mentioned above, by opening trenches 120 cm deep. The samples for AD were taken in duplicate in each layer (in the middle of the interval), using two alternating walls of the trench, with thin-walled stainless steel cylinders, 4 to 5 cm in diameter and 5 to 8 cm in diameter. length, according to the Embrapa soil analysis manual procedure (EMBRAPA, 1997). The AD data were used to calculate the carbon and nitrogen stocks. The soil samples for analysis of C and N were ground, passed through a 0.150 mm mesh sieve, and subjected to the determination of the total carbon (C) and total nitrogen (N) content by elementary analysis with dry combustion on Elementar's Macro Vario Cube equipment. The accumulated C and N stock, in each layer of the soil profiles, was calculated using the equivalent soil mass method (SISTI et al., 2004). The analysis of the contents and stock of C and N were carried out using the Mixed procedure of the statistical program SAS 9.4. The means of the ICLF and ICL systems were estimated using the LSMEANS command and were compared using Fisher's least significant difference (LITTELL et al., 2006). The level of significance was set at $P < 0.05$.

RESULTS AND DISCUSSIONS

The stock of C up to 30 cm deep for the ICLF system was 83.4 Mg ha^{-1} and in the 30 to 100 cm layer it was 99.7 Mg ha^{-1}, that is, on average 45% of the carbon was stored in the 0 to 30 cm layer and 55% of the carbon was stored in the 30 to 100 cm layer. Oliveira (2015) studying carbon stocks in ICLF systems in the municipality of Nova Canaã do Norte, MT, found that the 0 to 30 cm layer was responsible for storing an average of 47% of the soil's carbon, while the stock in the 30 to 100 cm was approximately 53%. The results of the present study are similar to the data found by Oliveira (2015). Thus, although the Intergovernmental Panel on Climate Change (IPCC) requires, for carbon credit projects under the Kyoto protocol, the assessment of soil carbon stocks up to a depth of 30 cm, considering a layer of at least 100 cm is important when assessing carbon stocks, especially in areas where tree and grass species with a deep root system are present (OLIVEIRA, 2015). In the ICL system of the present study, results similar to those found in the ICLF system were observed in terms of the percentage of carbon storage in the layers, where 47.5% of the carbon was stored up to 30 cm deep and 52.5% of the carbon was stored in the layer from 30 to 100 cm. The carbon stock in the ICLF system in the 0 to 100 cm layer was 10.4% higher than the carbon stock in the ICL system (Figure 1). The higher accumulation of C in the ICLF system, found in the present study, may have been favored by the high deposition of eucalyptus litter in the soil. Villa Nova et al. (2003) reports that greater spacing allows greater accumulation of nutrients in eucalyptus leaves and branches in relation to trunk biomass. Pulrolnik et al. (2015) studying the ICLF and ICL systems in the Cerrado area at three and five years after the implantation of the system, observed that at three years of age, the C stock values were 137.85 Mg ha^{-1} for ICL and 139.61 Mg ha^{-1} for ICLF and at five years of age the C stock values for ICL were 146.76 Mg ha^{-1} and 146.33 Mg ha^{-1} for ICLF, in both evaluations (at 3 and 5 years of age) there were no significant differences between the two systems. Macedo et al. (2015) found a higher total accumulation of C in the soil in ICL systems after six years, when it obtained higher carbon values compared to ICLF systems with single or double lines of trees, concluding that the ICL system (without trees) had less competition for light, water and nutrients, allowing greater increase of organic matter than the ICLF system. The ICLF experiment under study, however, has the largest spacing, with about 130 trees per hectare, that is, with less competition for water, light and nutrients than the ICLF system of the study by Macedo et al. (2015). The nitrogen stock in the ICLF system was 19.5% higher than that found in the ICL system (Figure 1). However, in his study Oliveira (2015) found a decrease in the N stock in the ICLF with one tree line and an increase in the ICLF system with three tree lines, compared to pasture, both in the 0 to 30 cm layer and in the layer from 0 to 100 cm. Sacramento et al. (2013) observed that the ICLF provided, after 13 years of cultivation, the lowest losses of N in the soil, followed by the ICL and monocultures under a conventional system.

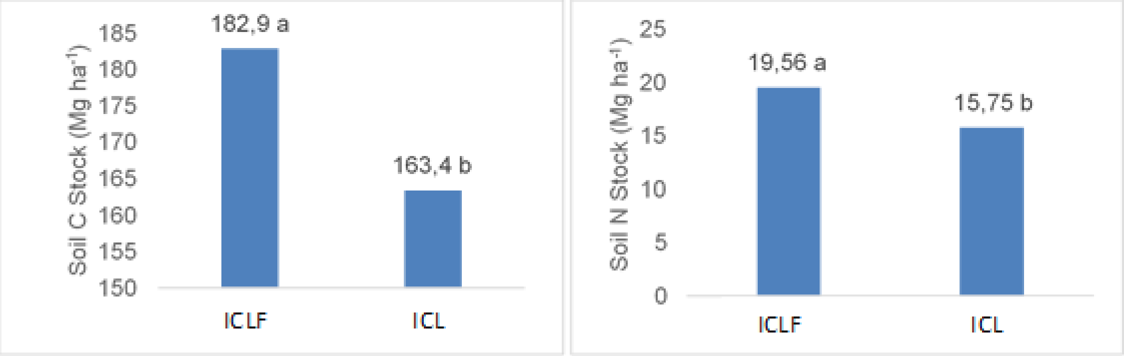

Figure 1. Stocks of soil carbon (C) and soil nitrogen (N) in the 0-100 cm layer in the ICLF and ICL experimental area. Bars followed by different lowercase letters indicate significant differences between systems ($p < 0.05$).

CONCLUSIONS

The carbon stock in the soil under ICLF system up to a depth of 0-100 cm, was 10.4% higher than the carbon stock in the ICL system and the nitrogen stock in the ICLF system was 19.5% higher than the ICL system. In this study, the ICLF system was more efficient in storing nitrogen and carbon through storage in the soil. These results confirm the ICLF system's greatest potential in mitigating greenhouse gas emissions. However, it is important that measurements continue to be carried out in order to assess changes in C and N stocks over time.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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SOIL CARBON STOCKS OF INTENSIVE GRAZING AND SILVOPASTORAL SYSTEMS

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ABSTRACT

Soil has a great potential to accumulate carbon; deforestation and the different managements tend to decrease the soil carbon (C) and generate loss of soil quality and increase CO_2 emission. The intensification of grazing management with fertilization, adequate cattle stocking rate, as well as the systems integration such as livestock and forest (silvopastoral) can increase the soil C stock. In this study were evaluated the soil C stocks at depths of 0—30 and 0—100 cm in pastures with irrigation and high stocking rate (IHS), rainfed pasture with high stocking rate (RHS), rainfed pasture with moderate stocking rate (RMS), degraded pasture under continuous grazing (DP) and a silvopastoral system with native trees. The RHS and RMS showed higher C stocks (139 and 165 Mg ton ha^{-1}, respectively) concerning the other evaluated systems, which was able to incorporate C equally a native forest (148 Mg ton ha^{-1}) and more than the degraded pasture (103 Mg ton ha^{-1}) and silvopastoral system (114 Mg ton ha^{-1}). The results suggest that the intensification of grazing systems can stock more C in the soil than integrated systems.

Key words: Soil carbon storage; Pastures; Integrated systems

INTRODUCTION

The concentration of gases that causes the greenhouse effect (GHG) has increased in the atmosphere, since the industrial revolution, which is associated with the upsurging in the Earth's surface temperature, melting of glaciers and increasing of ocean levels, among other environmental deregulations (IPCC, 2018). The soil has great potential to stock carbon (C) in the organic form, originated from the input of animal residues and plant tissues (LAL, 2004). Deforestation to create different systems for crop and animal production as well as the soil management causes a loss of carbon in the soil, decreasing the quality and productivity. The intensification of grazing systems with adjustment of the stocking rate, use of correctives and fertilizers can influence the quantity and quality of the accumulated C and contribute to stock C and mitigate GHG emissions (FREITAS et al., 2020). In addition to intensive grazing systems, the integration of systems, such as livestock and forest (silvopastoral) can contribute to increase soil carbon storage due to the different C sources in the system.

This study aimed to evaluate the C stock of intensive grazing systems and at a silvopastoral system (SP), in relation to a degraded pasture and an area of native vegetation.

MATERIAL AND METHODS

Five different grazing systems were evaluated, replicated twice for each area: 1) irrigated pasture with high stocking rate (IHS), 2) rainfed pasture with high stocking rate (RHS), 3) rainfed pasture with moderate stocking rate (RMS), 4) degraded pasture (DP), and 5) silvopastoral system with moderate stocking rate (SP). In addition, a semideciduous forest, Atlantic Rainforest Biome, without signs of anthropogenic disturbance was evaluated. Pastures in DP and RMS were established in 1996 with *Brachiaria brizantha* and *Brachiaria decumbens*. Pastures in IHS and RHS were established in 2002 with *Panicum maximum*. The pasture in SP was established with *Brachiaria decumbens* and wooded with native forest species in 2008. Each pasture of the DP consisted of a single paddock (3.3 ha) maintained in continuous grazing and was not managed, limed or fertilized (SEGNINI et al., 2019). The IHS and RHS were divided into 12 paddocks (0.14 to 0.15 ha each) grazed for three days under a rotational grazing system with 33 days of rest. The RMS pasture was divided into six paddocks (0.55 ha each) grazed for six days, and under a rotational system (30 days rest). SP was divided into six paddocks of 0.6 ha each, grazed for six days and with 30 days of rest. The trees in the SP system were native species such as “angico-branco” (*Anadenanthera colubrina*); “canafístula” (*Peltophorum dubium*); “ipê-felpudo” (*Zeyheria tuberculosa*); “jequitibá branco” (*Cariniana estrellensis*) and “pau-jacaré” (*Piptadenia gonoacantha*). Furthermore, “mutambo” (Guazuma ulmifolia) and “capixingui” (Croton floribundus) were planted in an alternating sequence to ensure that these species mentioned above grew straight boles with a minimum of lower branches. The trees were planted in sets of three corridors (distance between trees of 2.5 m), and each corridor in a distance of 17 m, which resulted in 545 trees per ha. In July 2016, trees were thinned, which consisted in cutting 50% of the trees in each external corridor, resulting in 350 trees ha^{-1}.

The soils were sampled in trenches in 2020, in a total of six trenches per area, in a depth of one meter with segmented fractions: 0-5, 5-10, 10-20, 20-30, 30-40, 40-60 and 80-100 cm. In the SP system, the trenches were open in the corridors with tree (referred to as SP T) and between the tree corridors (8.5 m) referred to as SP M. To calculate the C stock, the density of the soil was determined by the volumetric ring method and the total C content by an elemental analyzer (model 2400, PerkinElmer, USA).

The C stocks (Mg ha^{-1}) were calculated by multiplying soil C content (%), bulk density (Mg m^{-3}) and soil thickness (cm). Once soil bulk density of the agricultural systems treatments was higher compared to the forest area, non-corrected C stocks would be systematically overestimated in these treatments. Then, the stocks were corrected by equivalent soil mass, considering native vegetation as a reference, according to the method proposed by Ellert and Bettany (1995).

RESULTS AND DISCUSSIONS

Figure 1 shows the carbon stocks in the depth of 0-30 cm (a) and 0-100 cm (b), which the majority of the accumulated carbon is in depth. Both RHS and RMS pastures showed the capacity to increase carbon storage in relation to DP. The irrigation was not favorable to distinguish the C stock between IHS, RHS, and DP systems. May the abundance of water promoted by irrigation limited the growth of roots, decreasing C entry into the soil (MUDGE et al., 2017; SCOTT et al., 2012). The RMS showed the most potential area to accumulate carbon (165 Mg ton ha^{-1}), which at both depth 0-30 and 0-100 had the same stock of forest. The *Brachiaria* pasture may have influenced a greater entry of vegetal tissues in the soil and vegetation cover, generating a greater C accumulation in relation to the *Panicum maximum* pasture. *Brachiaria* has a high root growth and improves the soil’s physical, chemical, and biological properties with its vegetal cover (BIELUCZYK et al., 2020). Horrocks et al. (2019) demonstrated that *Brachiaria* pasture increased the amount of C in the soil compared to *Panicum maximum* pasture. Although the RHS showed a lower C stock (139 Mg ton ha^{-1}), it is not statistically different from RMS, maybe with time the differences will be more highlighted.

Silvopastoral system did not show any statistical difference in the C stock in proximity to trees (SP T) or between the tree corridors (SP M), in both evaluated depths of 0-30 and 0-100 cm, which suggest that pasture and trees can have the same contribution for C accumulation in the soil. Furthermore, both depths of 0-30 and 0-100 cm showed a C stock inferior to native vegetation, and equally to DP. Thus, in 12 years of native trees integration in the pasture, there was no increase in the C stocked in the soil in relation to DP. Considering the C stocks of all systems, intensive grazing systems (RHS and RMS) shown a greater potential for C accumulation in the soil. Of course, the C accumulated in the trees' growth is not being considered, and just the C accumulated in the soil.

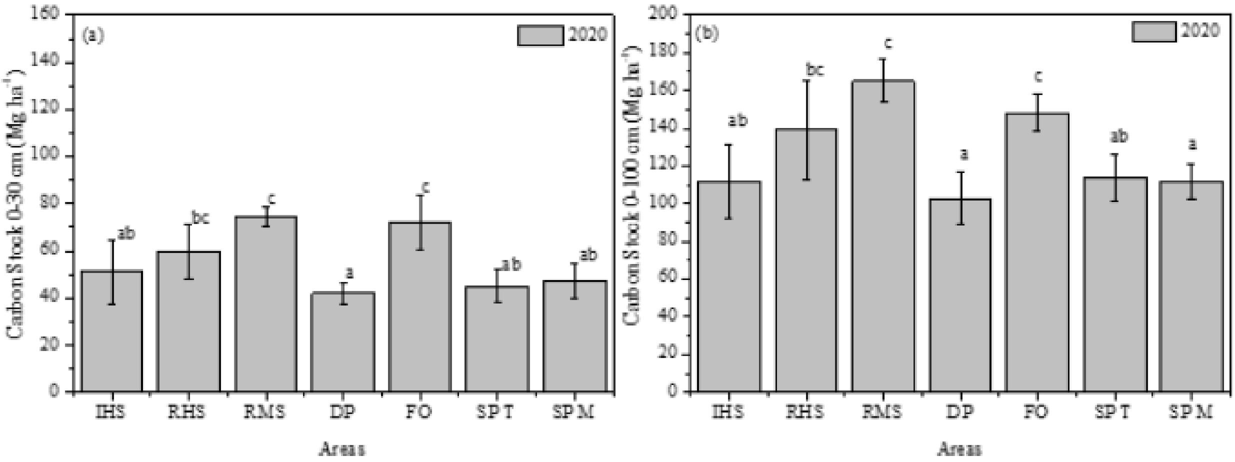

Figure 1. Carbon stocks at a depth of 0-30 cm (a) and 0-100 cm (b) in the different evaluated areas corrected by a native forest area. Different letters mean statistical difference at a level of $p<0.05$ by Tukey pos-hoc test.

Table 1 shows each storage carbon system capacity per year. C stock rates were obtained by a subtraction between stocks from each area in relation to FO and DP, and normalized by the time (years) of each experiment. The C stocks rates data obtained of RHS and RMS systems has shown that were the only one that presented capacity to increase C in relation to FO, while all the evaluated areas showed C stock rates higher than DP.

Table 1. Carbon stock rates (Mg ton ha^{-1} $year^{-1}$) in relation to forest and degraded pasture.

Management System	**Carbon stock (Mg ton ha^{-1} $year^{-1}$) in relation to forest area**	**Carbon stock (Mg ton ha^{-1} $year^{-1}$) in relation to degraded pasture**
IHS	-1.51^{cd}	1.03^{ab}
RHS	0.15^{ad}	2.69^{b}
RMS	0.79^{ab}	2.70^{b}
SP T	-2.90^{c}	0.99^{ab}
SP M	-3.49^{c}	0.32^{a}

*different letters mean statistical difference at a level of $p<0.05$ Tukey pos-hoc test.

CONCLUSIONS

Both high and moderate cattle stocking rate and the different pasture type (*Panicum maximum* and *Brachiaria brizantha)* did not change the C stock between RHS and RMS systems. Furthermore, the irrigation did not help increasing the C stock, as expected.

Intensive grazing systems proved to be more effective in accumulating C in soil than a silvopastoral system with native trees, in which, both RHS and RMS were able to accumulate C in the soil equally to an area of native vegetation.

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SOIL CARBON STOCKS IN INTEGRATED CROP-LIVESTOCK AND CROP-LIVESTOCK-FOREST SYSTEMS IN THE BRAZILIAN CERRADO

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ABSTRACT

Pasture degradation is currently an important problem in livestock production in Brazil. Conventional agriculture, without crop rotation and constant soil preparation, it is a practice that causes loss in soil quality. Soil carbon is a fundamental component for chemical, physical and biological characteristics that assures soil quality. Crop-livestock (ICLS) and crop-livestock-forest (ICLFS) integration systems, combined with crop rotation practices and no-tillage system may be alternatives for recovering and maintaining C levels in the soil, providing adequate soil C stocks, through rates of accumulation that can improve in mitigating greenhouse gases emissions. This work aimed to evaluate different integrated systems, with reference to natural vegetation, as soil management alternatives that could minimize losses and increase soil carbon stocks after the recovery of degraded pastures in the Cerrado region of Brazil. After 8 years ICLS showed highest values of soil C contents, C stocks and rate of C accumulation as compared to ICLF22 and ICLF14, respectively. ICLS system (no trees) had less competition for light, water and nutrients, and provided greater source of organic matter for soil carbon, than grass/pasture combined with trees. ICLS has proved to be a promising system in helping to mitigate greenhouse gases in livestock production.

Key words: Agropastoral; *Brachiaria*; Mitigation

INTRODUCTION

Pasture degradation is currently an important problem in livestock production in Brazil. Conventional agriculture, without crop rotation and constant soil preparation, it is a practice that causes loss in soil quality. Soil carbon is a fundamental component for chemical, physical and biological characteristics that assures soil quality. Crop-livestock (ICLS) and crop-livestock-forest (ICLFS) integration systems, combined with crop rotation practices and no-tillage system may be alternatives for recovering and maintaining C levels in the soil, providing adequate soil C stocks, through rates of accumulation that can improve in mitigating greenhouse gases emissions. This work aimed to evaluate different ICLS and ICLFS systems, with reference to natural vegetation, as soil management alternatives that could minimize losses and increase soil carbon stocks after the recovery of degraded pastures in the Cerrado region of Brazil.

MATERIAL AND METHODS

The experiment was conducted at the National Center of Beef Cattle Research, of EMBRAPA, in Campo Grande, MS, Brazil, in the biome Cerrado, belonging according to the climatic classification of Köppen-Geiger, the transition band between Cfa and Aw tropical humid (KOTTEK et al., 2006), with average annual precipitation of 1,560 mm and characterized by hot and rainy summer and cold winter moderate and dry. The field experiment was carried out in an area of degraded pasture (20^{o}26’S, 54^{o}43’W, 530 m asl) since 2008/09. Local soil is classified as an Oxisol, clayed, acid and with low fertility (SOUSA; LOBATO, 2004). The agricultural practices adopted in the experimental area and the results of forage, agricultural and animal productivity are described in Oliveira et al. (2014), Pereira et al. (2014; 2021). Treatments included ICLS (integrated crop-livestock, no trees), ICLFS14 (integrated crop-livestock-forest with single line of trees, 14 m apart with 357 trees ha^{-1})

and ICLFS22 (lines of trees 22m apart, with 227 tress ha^{-1}) both composed of *Eucalyptus urograndis*, clone H13. Soybeans were cultivated conventionally in 2008/09 and no-tillage in 2012/13. Grazed pastures of *Brachiaria brizantha* cv. BRS Piatã were cultivated between eucalyptus trees, after soybeans. Two transects lines, composed by 10 single soil samples/transect, were taken yearly in May-June, to 20 cm depth, and analyzed for total C in an autoanalyzer (Sumika/Shimadzu). Soil density was measured in all paddocks up to 100 cm in 2014 and 2008 up to 20 cm. An equation to estimate soil density (SD) for all years was established in order to calculate soil carbon stocks and rates. Soil density data were validated using Pearson correlation, which reached over 80% of correspondence. Independent variables were soil pH $CaCl_2$, soil clay and soil carbon contents, as below:

$$SD= 1,2898-(0,0131*Clay) -(0,10868*Carbon) +(0,1240*pH_{CaCl_2})$$

Soil carbon stocks were calculated after soil mass, in 0-20 cm soil layer, be estimated by SD. Data of soil carbon stocks obtained through these calculations were corrected considering the excess of soil mass. It was assumed soil compaction due to tillage and treading by cattle in all imposed treatments. Untouchable soil mass content of the native vegetation (NV), in the same layer, was used for correction in accord with Sant-Anna et al. (2017) and Sisti et al. (2004).

RESULTS AND DISCUSSIONS

Soil chemical and physical characteristics

Results of soil chemical and physical characteristics in 2008 and 2016, after 8 years of soil, crop and animal management are presented in Table 1. It is observed that soil quality expressed by the soil fertility were significantly increased by the management of fertilization in the three systems studied in comparison with the native vegetation (NV). Soil base saturation (V%), as well as the levels of P extractable by Mehlich-1 increased considerably, going on average from 25-28, to 32-41%, while in the NV it remained around 2-4%. The levels of soil P after 8 years of agricultural and livestock exploitation reached 0.6, 1.81, 3.34 and 6.55 mg P dm^{-3} in VN, ICLS, ICLF22 and ICLF14, respectively. This gradient can be explained by forage and animal production presented in the inverse way, as demonstrated in Pereira et al. (2017). Light interception was greater in ICLF14 and demand for water and nutrients among pasture, crops and trees affected its productivity. This behavior reflected directly on remaining soil fertility.

Soil C contents

On the other hand, lower productivity by ICLF14 (PEREIRA et al., 2017) related to forage biomass, and consequently lower root system yield, decreased soil C content, as presented in Table 2. Treatments (systems) were significantly different ($p<0.0001$) as related to soil C contents and was greater in ICLS (no trees) as compared to both with trees (Table 2). Spacing lines of trees up to 22 m improve forage production and soil C content. It was observed also significant effects among years ($p<0.0001$) in soil C contents most probably due to precipitation, temperature and soil management related to crop and livestock operations.

Soil density

Soil density (SD) is presented in Table 2 and showed also significant differences among treatments and years of observation ($p<0.001$) there was no interaction between years and treatments ($p>0.48$). It was observed a gradient in SD among treatments in the field and this was close related to soil texture, being NV more clayed than, ICLS, ICLF22 and ICLF14, respectively.

Soil C stocks and accumulation

In table 2 are presented data of soil C stocks each 2 years from 2008 up to 2016. Treatments and years were highly significant ($p<0.0001$) as interaction between treatments and years ($p<0.004$). ICLS (no trees) reached, in 2016, the highest soil C stock with 43.0 Mg ha^{-1}, as compared to ICLF22 and ICLF14, with 37.8 and 30.3 Mg ha^{-1}, respectively. This latest one had practically no C accumulation along years, as the native vegetation. Higher stocks of C to the ICLS are attributed to longer permanence of forage in full sun, without the presence of trees, and the clayed texture of the soil of 42.6%, which was slightly greater than ICLF22, ICLF14, with 38.6 and 31.1%, respectively. Even with the corrected values of C stock, by soil mass related to natural vegetation, it was observed accumulation of C in the three systems studied. Between 2008 and 2016 accumulated values varied from 3 to 6 Mg ha^{-1}, with the exception of ICLF14 and the native vegetation. The up and down variations observed each two years, both in the production systems, as well as in the native vegetation, are attributed to variations in precipitation, temperature, crop, soil and animal management, and soil sampling as well. These were carefully taken in two assigned transects along each paddock, but it was not enough to avoid some variation. Another explanation for these variations could be the impact of climate and soil management on the portion of particulate carbon that make up the less stable fraction of the total soil carbon, which is more subject to variations caused by these variables. The absolute values of C stock observed in this study are close to those obtained by Braz et al. (2013) who measured C stocks in various soils under pastures, up to 30 cm deep, in different places of the Cerrado. Increased stocks values observed in this study are also similar to those obtained here. Following the same trending of carbon stocks, the rate of C accumulation between 2008 and 2016 in the different systems and native vegetation were greater in ICLS= 0.748 Mg/ha/year, as compared to ICLF22= 0.473 Mg/ha/year and ICLF14= -0.074 Mg/ha/year. These results are in accord with those cited by Urquiaga et al. (2010).

Table1. Chemical and physical soil characteristics in the 0-20 cm layer in different integrated crop, livestock, forest systems and native vegetation, in 2008 and 2016. Campo Grande, MS, Brazil.

System	Year	pH	Ca^{+2}	Mg^{+2}	K^{+}	Al^{+3}	H+AL	CTC	V	m	PM1	Sand	Silt	Clay
		$CaCl_2$	------------------ cmolc/ dm^3					----------------------	------ %	-----	mg/dm^3	--------- %		---------
Nat Veg	**2008**	4.18	0.09	0.11	0.12	1.37	7.24	7.56	4.3	81.0	0.09	50.5	9.2	40.3
	2016	4.32	0.02	0.11	0.08	1.07	8.03	8.21	2.1	86.3	0.65			
ICLS	**2008**	4.68	1.21	0.73	0.08	0.22	5.13	7.16	28.3	9.9	0.42	44.0	13.4	42.6
	2016	5.20	1.94	1.32	0.16	0.06	4.78	8.20	41.6	2.0	1.81			
ICLFS22	**2008**	4.62	0.85	0.67	0.11	0.38	4.83	6.46	25.3	18.9	0.31	49.8	11.7	38.6
	2016	4.94	1.44	0.89	0.19	0.19	5.23	7.76	32.4	7.8	3.34			
ICLFS14	**2008**	4.60	0.99	0.69	0.09	0.42	4.29	6.06	29.1	19.6	0.37	57.7	11.2	31.1
	2016	5.16	1.84	1.00	0.17	0.20	4.88	7.88	38.4	7.2	6.55			

Table 2. Soil C content (C, %), soil density (SD, g/cm^3) and soil C stocks (Mg/ha) in the 0-20 cm layer in different integrated crop, livestock, forest systems and native vegetation, measured yearly in the period of 2008 and 2016. Campo Grande, MS, Brazil.

System	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Mean**
					C, %					
CLS	1.79	1.91	1.95	2.01	2.19	2.10	2.20	2.20	2.03	2.04 A
CLFS22	1.64	1.92	1.80	1.78	2.05	1.88	1.90	1.90	1.79	1.85 B
CLFS14	1.49	1.69	1.53	1.62	1.65	1.70	1.64	1.64	1.43	1.60 C
Mean	1.64 d	1.84 bc	1.76 cd	1.80 bc	1.96 a	1.89 ab	1.91 ab	1.91 ab	1.75 cd	1.83
Nat Veg	2.23	1.99	2.04	2.08	2.19	2.19	2.20	1.98	2.19	2.12
					SD, g/cm^3					
ICLS	1.11	1.13	1.16	1.20	1.16	1.15	1.13	1.13	1.15	1.15 A
ICLFS22	1.18	1.20	1.23	1.25	1.21	1.20	1.18	1.17	1.20	1.20 B
ICLFS14	1.29	1.34	1.35	1.41	1.37	1.34	1.33	1.32	1.36	1.35 C
Mean	1.19 f	1.22 cde	1.25 b	1.28 a	1.25 bc	1.23 bcd	1.21 def	1.20 ef	1.24 bc	1.23
Nat Veg	1.04	1.07	1.08	1.08	1.06	1.04	1.04	1.07	1.06	1.06

	2008	**2010**	**2012**	**2014**	**2016**	**Mean**
			C, Mg/ha			
ICLS	37.1	42.2	46.3	45.8	43.0	42.8 A
ICLFS22	34.0	39.0	43.4	39.7	37.8	38.7 B
ICLFS14	30.9	33.2	35.0	34.2	30.3	32.7 C
Mean	34.0 d	38.1 bc	41.6 a	39.9 ab	37.0 c	38.1
Nat Veg	46.2	44.2	46.4	45.8	46.2	45.7

Note: There is no significant difference between values with same letters in line or column, as estimated by Tukey (p=0.05).

CONCLUSIONS

After 8 years under ICLS this system showed highest values of soil C contents, C stocks and rate of C accumulation as compared to ICLF22 and ICLF14, respectively. ICLS system (no trees) had less competition for light, water, and nutrients, and provided greater source of organic matter for soil carbon, than grass/pasture combined with trees. Grass biomass and animal production were greater in ICLS as compared to systems with trees as reported in cited papers. ICLS has proved to be a promising system in helping to mitigate greenhouse gases in livestock production.

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NET CARBON BALANCE IN TWO SILVOPASTORAL SYSTEMS FOR DAIRY HEIFERS

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ABSTRACT

The objective of this study was to estimate the carbon balance in two silvopastoral systems (SPS) for rearing dairy heifers: Eucalyptus and african-mahogany based. Emissions of GHG were calculate based on IPCC protocols. Carbon stocks in trees were estimated through allometric equations and local references and the estimation of carbon storage in the forest component considered only the wood for solid products and the root system, while the biomass of the root system of the pasture was considered as a carbon pool as well. The net carbon balances of the silvopastoral systems were -137.18 Mg CO_2e ha^{-1} and -47.54 Mg CO_2e ha^{-1} for eucalyptus-based SPS and african-mahogany based SPS, respectively, showing the potential of both systems for mitigating climate change.

Key words: ICLF; GHG; Climate Change

INTRODUCTION

Concerns about global warming and its relation to livestock have increased worldwide in recent years. Consequently, as a major agricultural player and holder of the second largest herd of cattle in the world, the Brazilian livestock sector is under increasing pressure for upholding an environmental friendly, sustainable production.

As signatory party to the Paris Agreement, Brazil has committed to reduce its emissions by 37% in 2025, based on 2005 levels, according to the Intended Nationally Determined Contributions (INDC). To accomplish this target, the government established the “low-carbon agriculture plan” that finances the adoption of sustainable practices such as silvopastoral systems.

Silvopastoral systems have been reported to be an efficient strategy for restoring degraded lands by increasing biomass, improving soil chemical and physical properties, reducing water and soil losses and increasing the stocks of carbon on both biomass and soil pools (DE STEFANO; JACOBSON, 2018).

Albrecht and Kandji (2003) suggested that carbon stocking in integrated crop-livestock-forestry systems depends upon the systems’ structure (arrangement, species), function and management. These authors also consider that in silvopastoral systems intended for wood production, C storage is temporary as biomass is eventually removed and part of the C is released to the atmosphere. On the other hand, if the logs are processed in any form of long-lasting products, a great part of the stored C may last fixed for much longer (ROY, 1999).

The aim of this study was to estimate the carbon balance in two silvopastoral systems for rearing dairy heifers: (i) with eucalyptus and (ii) african-mahogany trees.

MATERIAL AND METHODS

The experiments were conducted between January 2010 and December 2020 at Embrapa Dairy Cattle Research Station in Coronel Pacheco, state of Minas Gerais, south-eastern Brazil (21°33' S, 43°15' W, 470 m a.s.l.) where, according to Köppen's classification, the climate is Cwa (mesothermal).

Both systems were set up on *Urochloa. decumbens* cv. Basilisk pastures already established. System 1 (SPSEUC) was composed by a clone of *Eucalyptus urophylla* x *Eucalyptus grandis* hybrid planted in single rows spaced 20 m and 2 m between trees in the row (250 trees/ha) and System 2 (SPSAFM) is composed by african mahogany trees established in single rows spaced 22 m and 2 m between trees in the row (227 trees/ha). Seedlings were planted in January, 2010. The grazing system and the average performance of crossbreed dairy heifers during the production cycle in this study was assumed to be similar to those reported by Paciullo et al. (2021).

IPCC protocols (2006, 2007) were used to calculate the net carbon balance as per hectare basis, following Torres et al (2017). The carbon pools considered were: the wood for timber, the biomasses of the trees and pastures root systems (FIGUEIREDO, 2017) and the soil organic carbon – SOC (CARVALHO et al., 2010). Carbon stocks of the trees were estimated using SisILPF-Eucalipto and SisILPF-Mogno software (OLIVEIRA et al., 2018).

The study covered a 20 years' production circle for both eucalyptus and african mahogany trees established into two different silvopastoral systems managed with periodic thinnings. For dairy heifers enteric emissions a default enteric fermentation CH_4 emission factor of 39 kg CH4 animal^{-1} yr^{-1}, as proposed by Torres et al. (2017) was used. For converting GHG emissions into CO_2e, the following 100-yr global warming potential were used: 1 for CO_2, 25 for CH_4 and 298 for N_2O, as proposed by IPCC (2006).

Technical thinning age was defined based on maximum productivity in terms of wood volume per unit area (VILLANOVA et al., 2018). As suggested by Resende et al. (2019), GHG removal from the atmosphere through C sequestration were expressed by negative values, while positive values indicate emissions.

RESULTS AND DISCUSSIONS

Over the 20 years study period, the total GHG emission were 30.53 Mg CO_2e ha^{-1} and 30.27 Mg CO_2e ha^{-1} for SPSEUC and SPSAFM, respectively. This result was already expected for both systems were managed almost similarly, differing basically by the specie used.

The most important difference was observed in the wooden pool, that corresponded to 69.3% of the total C stored in SPSEUC and 60.1% in SPSAFM (Table 1). For SPSEUC, the C stored in wood was -116.21 Mg CO_2e ha^{-1} while in SPSAFM was -47.43 Mg CO_2e ha^{-1} and the tree root systems stored -30.70 and -9.58 Mg CO_2e ha^{-1} for SPSEUC and SPSAFM, respectively. This difference between the systems is due to different growing rates of the species. While eucalyptus grew 12.5 m^3 ha^{-1} yr^{-1}, African mahogany showed a growing pace as slow as 3.5 m^3 ha^{-1} yr^{-1}. The estimated carbon sequestration by the pasture and soil pools were -12 Mg CO_2e ha^{-1} and -8.8 Mg CO_2e ha^{-1} irrespective of the system.

Table 1. Systems description and net carbon balance (Mg CO_2e ha^{-1}) of two silvopastoral systems, in Coronel Pacheco, MG.

System	**SSPEUC**		**SSPAFM**	
Year	**Stocking rate (AU ha^{-1})**	**Solid wood m^3 ha^{-1} (thinnings)**	**Stocking rate (AU ha^{-1})**	**Solid wood m^3 ha^{-1} (thinnings)**
1	1.5		1.5	
2	1.5		1.5	
3	1.4		1.4	
4	1.4		1.4	
5	1.3		1.3	
6	1.2	41.3	1.2	3.5
7	1.5		1.5	
8	1.5		1.5	
9	1.4		1.4	
10	1.4		1.4	
11	1.3		1.3	
12	1.2	63.2	1.2	12.1
13	1.5		1.5	
14	1.5		1.5	
15	1.5		1.5	
16	1.5		1.5	
17	1.4		1.4	
18	1.3		1.3	
19	1.2		1.2	
20	1.2	149	1.2	63.5
Emission (Mg CO_2e ha^{-1})	30.53		30.27	
Carbon Stock (Mg CO_2e ha^{-1})	-167.71		-77.81	
Balance (Mg CO_2e ha^{-1})	-137.18		-47.54	

Torres et al. (2017) observed GHG emissions ranging from 2.81 to 7.98 Mg CO_2e ha^{-1}, and a net carbon balance ranging from -18.97 to -192.16 Mg CO_2e ha^{-1} on four agrosilvopastoral systems composed by eucalypt trees associated with *U. decumbens* cv. Basilisk, ageing 3 to 5 years and established in Viçosa, MG, 140 km distant from the experimental site. These values are higher than the ones found in this study for SSPEUC, probably because those authors considered the entire tree volume, whereas only the timber volume was taken into account in this study.

Another study carried out by Resende et al. (2020) in Coronel Pacheco, MG, showed that in 8 years old silvopastoral systems with eucalypt trees and *U. decumbens* for beef cattle reached 26.27 Mg CO_2e ha^{-1} stored on tree biomass (crown+roots, after tree harvest), while GHG emissions were 23.54 Mg CO_2e e ha^{-1} on average, with a net balance of -2.73 Mg CO_2e ha^{-1}.

Unfortunately, the literature about carbon stocks in silvopastoral systems with african mahogany trees are scarce. Warnasooriya & Sivananthawerl (2016) reported about 80 Mg CO_2e ha^{-1} stored by 20 years old african mahogany stand with 400 trees ha^{-1} in Sri Lanka. This result is 30% higher than the one observed in the present study (61.5 Mg CO_2e ha^{-1} if the entire tree volume is considered).

The mean annual carbon balance was -19.39 Mg CO_2e ha^{-1} and -2.88 Mg CO_2e ha^{-1} for SPSEUC and SPSAFM, respectively. It is noteworthy that for both systems, the most important impact comes at clearcutting (at 20 years), when all trees are removed from the site and transformed into solid products (Figure 1). As at this age, tree size allows for a better use of timber for solid products (it was estimated that at least 60% of the volume of the trees was used for this purpose) and the amounts of carbon removed from the atmosphere increased rapidly.

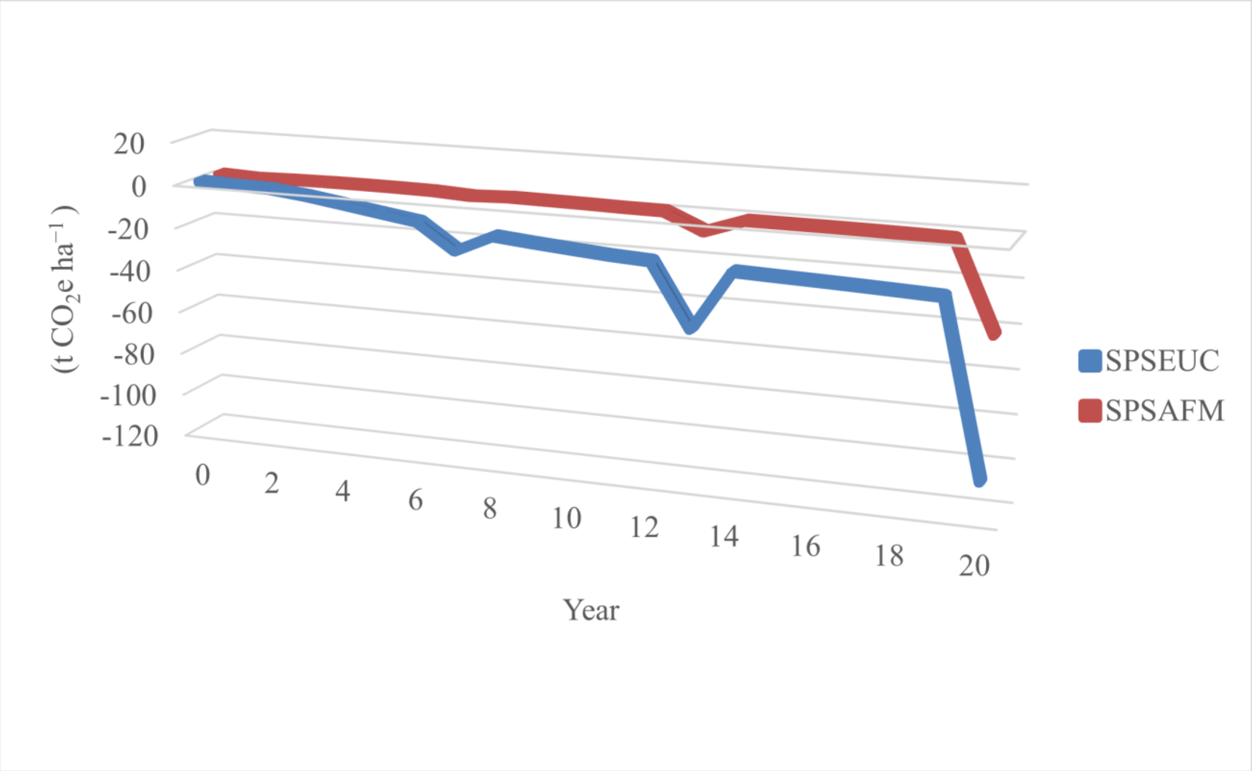

Figure 1. Net carbon balance of two different silvopastoral systems in Coronel Pacheco, MG.

CONCLUSIONS

Silvopastoral system with eucalyptus removes more carbon from the atmosphere than with african mahogany. In spite of significant differences, both systems are negative on net GHG emissions. The clearcutting at the age of 20 years represents 75% and 90% of the total carbon sequestered by the eucalyptus and the african mahogany-based silvopastoral system, respectively.

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BEEF PRODUCTION WITH LOW CARBON EMISSION IN TROPICAL PASTURES: A CASE STUDY FOR THE VALIDATION OF GUIDELINES

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ABSTRACT

The Low Carbon Brazilian Beef (LCBB) concept brand seeks to value livestock systems that do not include the forest component but hold the potential to mitigate greenhouse gas (GHG) emissions, by adopting conservationist production criteria and concepts. At present, there is no commercial production system in Brazil with validated LCBB guidelines. In this scenario, the LCBB Technological Reference Unit proposed to examine beef cattle production in systems with well-managed pastures to validate the guidelines in a commercial environment. The initial results show that by implementing the LCBB guidelines, it is possible to ensure productivity and meat quality as well as increase the profitability of the producer without giving up the maintenance or increase in the soil carbon stock and the mitigation of GHG emission, in addition to the land-saving effect. This is another step towards productive efficiency that takes into account the quality of the product and its environmentally friendly production.

Key words: Low Carbon Brazilian Beef; pasture management; soil carbon stock

INTRODUCTION

Similarly to the Carbon Neutral Brazilian Beef (CNBB) brand values livestock systems that involve the forest component (ALVES et al., 2015, 2017; ALMEIDA et al., 2016), which accounts for around 2% of the cultivated pasture area in Brazil, the Low Carbon Brazilian Beef (LCBB) brand emerges to include livestock systems that do not have the forestry component but hold the potential to mitigate GHG emissions, which represent a higher area percentage in Brazil (BARIONI et al., 2007; BODDEY et al., 2012; ALMEIDA et al., 2013; MEDEIROS et al., 2017).

The guidelines for Low Carbon Brazilian Beef production are part of a set of protocols that contribute to strategies of the ABC (Agricultura de Baixa Emissão de Carbono, or Low Carbon Emission Agriculture) Plan. These guidelines are based on criteria, concepts and practices to value these more efficient livestock systems in mitigating GHG emissions by the herd during its productive cycle through the implementation of adequate practices of herd and pasture management, soil correction and fertilization, intercropping and crop-livestock integrated systems (ALMEIDA; ALVES, 2020). However, to date, there are no production systems in Brazil with validated LCBB guidelines, warranting research in reference areas.

In this scenario, this study presents the results of the first Technological Reference Unit (TRU) of Embrapa for beef production adopting the LCBB guidelines.

MATERIAL AND METHODS

The case study began in May 2019 on the Trijunção Farm, located in Jaborandi - BA, Brazil. The farm is a reference in beef cattle production under the Brazilian Good Agricultural Practices (BPA, 2008), holding structured and sequential data of the entire production system.

According to the Köppen and Geiger classification system, the climate of the region is an Aw type, characterized as hot and dry, with rains concentrated in the summer and an average temperature of 24 °C. The local altitude is 933 m and average annual precipitation ranges from 700 to 1,400 mm, with a pronounced water deficit occurring from late April to October. The predominant soils in the region are Arenosols, Oxisols and Red-Yellow and Yellow Ultisols, in the sand and loam sand or sandy loam textural classes (ALBUQUERQUE FILHO et al., 2020).

The TRU was composed of two plots as well as a native vegetation (Cerrado biome) area that will be monitored, over time, to improve the comparative analysis of the farm's history and to evaluate the areas enrolled in the future LCBB certification process. Both plots are formed by *Urochloa brizantha* pasture, one plot being 115 ha of *Urochloa brizantha* cv. Marandu divided into four paddocks, representing the general farm management (GFM); and another consisting of 85 ha of recovered pasture, with *Urochloa brizantha* cv. BRS Piatã, also divided into four paddocks but managed according to technical guidelines for low carbon meat production in tropical pastures (LCBB), as proposed by Almeida and Alves (2020).

The plots were chosen so as to have similar soil for monitoring and comparing the carbon content. The reference, in this case, was the organic matter content. At the start of the establishment of the TRU (May 2019), the areas were subjected to soil fertility assessments, physical characterization, carbon stock quantification and soil classification (Albuquerque Filho et al., 2020). Soil was sampled from mini-trenches and at georeferenced points, at the end of the rainy season (May 2019). One mini-trench, 40 cm deep, was opened at the central point of each of the four paddocks of the LCBB and GFM plots; and another two were open in the native vegetation (Cerrado). Samples were obtained with a auger at four points arranged in a cross and spaced 100 m apart. Four perforations were made around each point with the auger to form a composite sample at the depths of 0-10, 10-20 and 20-40 cm. Undisturbed samples were also collected from three walls of the mini-trenches, at the indicated depths, using a volumetric ring. These assessments will be repeated every two years to monitor the dynamics of the evolution of fertility and carbon stock in the soil.

The initial soil characterization of the GFM plot revealed the following properties: pH H_2O = 5.9; P, K and S = 8.2, 3.7 and 15.8 mg dm^{-3}; Ca, Mg, Al and T = 1.4, 0.4, 0.0 and 3.0 $cmol_c$ dm^{-3}; base saturation = 50.0%; OM and clay content = 0.8 and 11.9 dag kg^{-1}. The soil profile in the LCBB plot was as follows: pH H_2O = 6.6; P, K and S = 24.9, 52.1 and 8.0 mg dm^{-3}; Ca, Mg, Al and T = 1.8, 0.6, 0.0 and 3.3 $cmol_c$ dm^{-3}; base saturation = 78.9%; OM and clay content = 1.0 and 14.0 dag kg^{-1}.

The pastures of the plot under LCBB guidelines were managed in a rotational grazing system, with the recommended entry of the animals at 30-40 cm, keeping a minimum stubble height of 20 cm for the Piatã grass. Height was monitored every two weeks, using a graduated ruler, by sampling approximately 100 points per paddock along a zigzag walking. The load adjustment in the LCBB field was determined based on this monitoring. In this same plot, two doses of 50 kg ha^{-1} of N were recommended during the summer cycle, applied after grazing in the paddocks, plus one dose of 50 kg ha^{-1} of K_2O based on recommendations by Embrapa (MARTHA JUNIOR et al., 2007) and on the intensification level adopted.

Ground cover, pasture height and forage availability were assessed once per season (rainy; rainy-dry transition; dry; and dry-rainy transition), in all paddocks. Ten georeferenced points were sampled per paddock, using a 1 m × 1 m frame. The ground cover with pasture, within this frame, was visually assessed by at least three people, who assigned coverage scores ranging from 0 to 100%. Additionally, the pasture height was measured in each of the vertices of the square and in its central region. After these evaluations, all the forage was cut close to the ground. The material was packed in paper bags, which were later used for weighing the fresh mass and oven-drying at 65 ºC for 72 h until constant weight to determine the forage dry mass and estimate its availability.

To monitor the animal component, two lots of intact Nellore males at an average age of 10 months were selected to be monitored as tester animals, in accordance with the Ethics Committee for the Use of Animals of Embrapa (CEUA/CPPSul n. 09/2019). The lot in the LCBB plot was composed of 104 animals, whereas the lot in the plot under the Farm management consisted of 72 animals (average weights of 259 and 241 kg, respectively). These animals entered the system in July 2019 and remained on pasture for 346 days in GFM and 354 days in the LCBB management, receiving only mineral salt and being weighed at least once per season. Notes of the date of entry, number of animals, average weight and date of departure were made whenever animals were needed for load adjustment. Based on these data, the average daily gain of the animals and the gain per area were estimated. After this period, the animals were sent for feedlotting on the farm itself for 100 days (GFM) and 95 days (LCBB), ensuring that the final product (meat) would be produced mostly on pasture, under the premise of maintaining the carbon soil stocks fixed, in accordance with the LCBB guidelines.

At the end of the feedlot period, on September 30, 2020, the animals were sent for slaughter. The carcasses of ten animals under LCBB management were evaluated for carcass weight and yield, fatness (score on a scale from 1 to 5 points) and maturity (teeth). After chilling for 24 h, the carcasses were sectioned in the rib region, at the 12th-13th vertebra, to expose the *longissimus* muscle, where backfat thickness and ribeye area were measured. Samples of the *longissimus* muscle were sent to the laboratory for evaluation of marbling (score on a scale from 1 to 18) and shear force (in kg, using a Warner-Bratzler Shear instrument).

Enteric methane emissions were estimated using the equation proposed by Medeiros et al. (2014) and following Alves et al. (2017).

RESULTS AND DISCUSSIONS

Data from the initial characterization (ground zero) of the soil under the LCBB management revealed a carbon stock of 20.59 Mg ha^{-1} in the 0-20 cm soil layer. This value is higher than the 15.18 Mg ha^{-1} found in the native Cerrado vegetation and the 18.16 Mg ha^{-1} found in the pasture under GFM, which is the result of pasture recovery management and which will be monitored over the years. Because these values were obtained in an initial characterization, analyses will be carried out at two-year intervals to follow the evolution of this carbon in the soil of the evaluated areas. However, it is already noted that the soil carbon stock in the LCBB management can be considered appropriate according to the guidelines proposed by Alves et al. (2017).

As shown in Table 1, the average pasture height in the LCBB areas was always very close to the recommended range for the management of Piatã grass, and the minimum recommended height for the cultivar was met throughout the year. Ground cover remained always above 70%, as recommended in the guidelines for forages with a cespitose growth habit (ALMEIDA; ALVES, 2020). This always-high ground cover in the LCBB plot serves to contribute straw to the soil organic matter and carbon retention in the system.

As of January 2020, the pasture in the plot under GFM was taller and, likely due to the presence of green leaves, improved ground cover. However, for both these traits and forage availability, the values were always higher in the plot under LCBB management (Table 1), which made it possible to maintain an average load of 4.34 AU ha^{-1}, versus 1.93 AU ha^{-1} in the plot under GFM.

Table 1. Variables related to pasture monitoring during the first year of applying the Technological Reference Unit (TRU), in pastures under LCBB and GFM management: pasture height (cm), ground cover (%) and forage availability (kg ha^{-1} DM).

Month/year	**LCBB**			**GFM**		
	Height	**Cover**	**Forage**	**Height**	**Cover**	**Forage**
May/2019	39±6.31	86±1.14	5549±154.5	25±3.22	32±5.19	1804±46.07
August/2019	22±3.34	91±3.51	3326±447.9	13±2.21	33±3.21	1464±93.46
November/2019	27±3.45	92±3.12	4976±665.2	18±3.23	41±4.96	2237±48.11
January/2020	42±4.14	90±3.93	4218±1068	23±1.52	75±5.00	2141±108.80
May/2020	36±6.45	80±1.96	2901±704.4	25±1.98	64±4.73	1740±341.2

Mean values per plot at the sampling times.

In compliance with the guidelines, the tester animals were weighed once per season (rainy; rainy-dry transition; dry; and dry-rainy transition) and on June 20, 2020, when they entered the feedlot. Table 2 describes the average lot data. It is important to note that both lots received the same mineral supplementation on pasture. Throughout this first year of evaluation, the animals in the LCBB plot and under Farm management gained an average of 154 kg and 149 kg on pasture, respectively. Therefore, in addition to the higher number of AU ha^{-1}, the animals in the LCBB plot entered the feedlot about 23 kg heavier and reached slaughter weight having spent at least 20 fewer days in confinement than those in the plot under Farm management.

Table 2. Animal production performance during the first year of applying the Technological Reference Unit, in pastures under LCBB and GFM management.

LCBB				**GFM**			
Average live weight (kg)		ADG	Gain per area	Average live weight (kg)		ADG	Gain per area
Initial	Final	(g d^{-1})	(kg ha^{-1})	Initial	Final	(g d^{-1})	(kg ha^{-1})
259±15	414±26	440±170	538±146	241±11	391±71	430±240	166±46

With pasture fertilization, strategic supplementation and pasture management, high body weight production per unit area was ensured in the LCBB plot, whose recorded yield values were above the Brazilian average (ABIEC, 2020). In the field under farm management, although the average daily gain was not very different from that of the LCBB plot, gain per area was below the potential.

In the evaluation of carcass and meat quality of the animals in the LCBB plot, the average slaughter and carcass weights were 573 kg and 306 kg, respectively, which provided an average carcass yield of the order of 53.4%. Additionally, 100% of the carcasses showed type-3 fatness (medium fat) and maturity of two teeth. In the analysis of meat quality, the average marbling score was 7.7, that is, the average marbling was low, with only one animal showing traces (the lowest grade) and 30% of them exhibiting marbling in a higher degree than the observed average. Average shear force was 6.3 kg, varying between 4.87 and 8.17 kg. While none of the animals showed meat considered to be hard (> 9 kg), practically two out of three animals produced meat with a shear force value of less than 7 kg, which could be considered as acceptably tender meat if evaluated by a panel of trained tasters.

Thus, the observed meat quality, marbling and shear force are compatible with the existing production systems in Brazil and meet the market requirements. Similarly, in terms of carcass quality, if these animals were slaughtered and evaluated according to the PROAPE PRECOCE-MS system, they would produce a type-2 product and receive the second highest possible bonus within the program, i.e., this bonus could only be increased if the animals were slaughtered even younger.

Based on the NDF contents of the pasture and the feedlot diet, 74 and 32.4% and 76 and 32.3% for the LCBB management and GFM, respectively, the estimated enteric methane emissions were 169 and 159 g CH_4 day^{-1}, 75.88 and 71.10 kg CH_4 $animal^{-1}$ and 476 and 181 kg CH_4 ha^{-1}, respectively. However, emission intensity did not vary between the management strategies, averaging 6.285 kg CO_2 eq. kg $carcass^{-1}$. The LCBB management allowed a 147% increase in the number of animals ha^{-1} and a 163% gain in kg carcass ha^{-1} relative to GFM. This result indicates an important land-saving effect in addition to the potential for greater carbon incorporation into the soil for the maintenance of the productive condition of the pasture and the mitigation of GHG emissions from the system.

Through planning, adjustments and improvements are also expected to be made in the gains of the area managed under LCBB. At the same time, we expect that the benefits arising from the adoption of the future protocol can be noticeable so that it can be expanded to other areas of the property as well as to contribute to the transfer of this technology in the region.

CONCLUSIONS

The LCBB Technological Reference Unit examined beef cattle production in systems with well-managed pastures to validate the guidelines in a commercial environment that values sustainable production systems. The initial results demonstrate that it is possible to ensure productivity and beef quality so as to increase the profitability of the producer without giving up the maintenance or increase of the soil carbon stock and mitigation of GHG emissions, in addition to the land-saving effect. This is another step towards productive efficiency that takes into account the quality of the product and its environmentally friendly production.

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TREES IMPROVE SOIL CARBON STOCKS IN INTEGRATED CROP-LIVESTOCK-FORESTRY (ICLF) SYSTEMS

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ABSTRACT

Soil organic carbon (SOC, determined with dichromate oxidation) accumulation was evaluated at three ICLF sites of different ages (2, 4 and 11 years) and soil textures (469, 198, 632 $g\ kg^{-1}$ clay) in southern Goiás state of Brazil. SOC stocks were accessed at 0-30, 30-100 and 0-100 cm soil layers under the tree-rows and between tree-rows. SOC stocks were calculated based on equivalent soil mass, using pasture, in which the ICLFs were implemented, as reference. Our objective was to investigate the potential of trees in accumulating SOC in ICLFs. Dunnett's test was applied to check the effect of trees on soil C stocks within each location using the linear mixed model. More SOC was measured under tree-rows at all sites and all soil layers, compared to the alley between the tree-rows, except for the youngest site (Morrinhos) at 0-30 cm. Trees, therefore, are important to maximize SOC accumulation in ICLFs. Further studies are, however, necessary to expand the database to support more robust analysis and to conclude on SOC sequestration (immobilization).

Key words: soil organic carbon; neotropical savanna; Cerrado

INTRODUCTION

Mixed farming systems with trees, annual crops and pasture can be efficient in soil carbon sequestration of clayey Ferralsols in Brazil in a very short term (OLIVEIRA et al., 2018).

ICLF is recommended practices for pasture restoration (MUNIZ et al., 2011; ASSIS et al., 2015; LOSS et al., 2011), improvements in animal welfare (KARVATTE et al., 2016) and higher crop yields (SILVEIRA et al., 2011) with simultaneous reductions on land use impacts such as loss of soil C and net GHG emissions (LEMAIRE et al., 2014). Important C accumulation capacity is associated with ICLF systems due to larger assimilation of atmospheric C in the biomass (MÜLLER et al., 2009) compared to conventional agriculture, and some forestry (monocultures) systems (Tsukamoto Filho et al., 2004) including other integrated systems without trees. Soil C dynamics under ICLF may be very different from that observed in systems without trees. The wood component can directly influence soil C accumulation by the arrangement and density of trees and by the tree species (KUNHAMU et al., 2011). The horizontal stratification of the area, in which rows of trees are alternated with pasture strips or rows of annual crops in the alleys, can efficiently be combined with the use of machinery for grain crops. Indirect effects of the tree component may manifest themselves through its influence on the alley crops (MENDES et al., 2013; FRANCHINI et al., 2014) or pasture (PACIULLO et al., 2011). This zoning effect may alter soil organic C (SOC) spatial distribution. Besides, trees affect the vertical distribution of SOC fractions (HEILE et al., 2010).

The aim of this study was to assess soil C stocks at incremental depths up to 1.0 m in three ICLF sites as affected by the presence of eucalyptus trees. This study, part of the Integra-Carbono Project, is expected to provide relevant baseline data on soil C accumulation of agricultural lands highlighting management practices to increase C sequestration at depth aiming at long-term mitigation of atmospheric CO_2.

MATERIAL AND METHODS

ICLF systems consisted of Eucalyptus tree rows alternated with pasture *Urochloa* sp. grass and were evaluated in three sites in the southern part of the Goiás State of Brazil. In Cachoeira Dourada at the Boa Vereda Farm the ICLF system was 11 years old, while in Quirinópolis at the Santa Bárbara Farm it was 4 years old and in Morrinhos at the Experimental Farm of the Goiano Federal Institute it was 2 years old at the date of sampling. Apart from Cachoeira Dourada in the Atlantic Forest biome, the two other sites were in the savanna (Cerrado) (Figure 1). Between November 2019 and February 2020, soil samples were collected from under the tree-rows and in the middle of the pasture alley. At Cachoeira Dourada sampling was done in five and in Quirinópolis and Morrinhos in four replicates. Horizontally, soil sampling was done in a manner to respect the structure of the sites in terms of the disposition of the tree lines to be able to infer on tree-line effects. Vertically, the soil was sampled to 1 m depth, divided into seven sampling layers (0-10, 10-20, 20-30, 30-40, 40-60, 60-80, 80-100 cm) to be able to study the vertical stratification of soil carbon stocks. The relatively deep sampling of the soil was necessary because even with low C concentration, soil layers below 30 cm can account for over 50% of the total C (e.g. OLIVEIRA et al., 2018). Therefore, it is important to take at least a layer of 1.0 m into account when assessing the effect of soil management and agriculture production systems on SOC stocks, especially when tree species and deep-rooting grasses are grown.

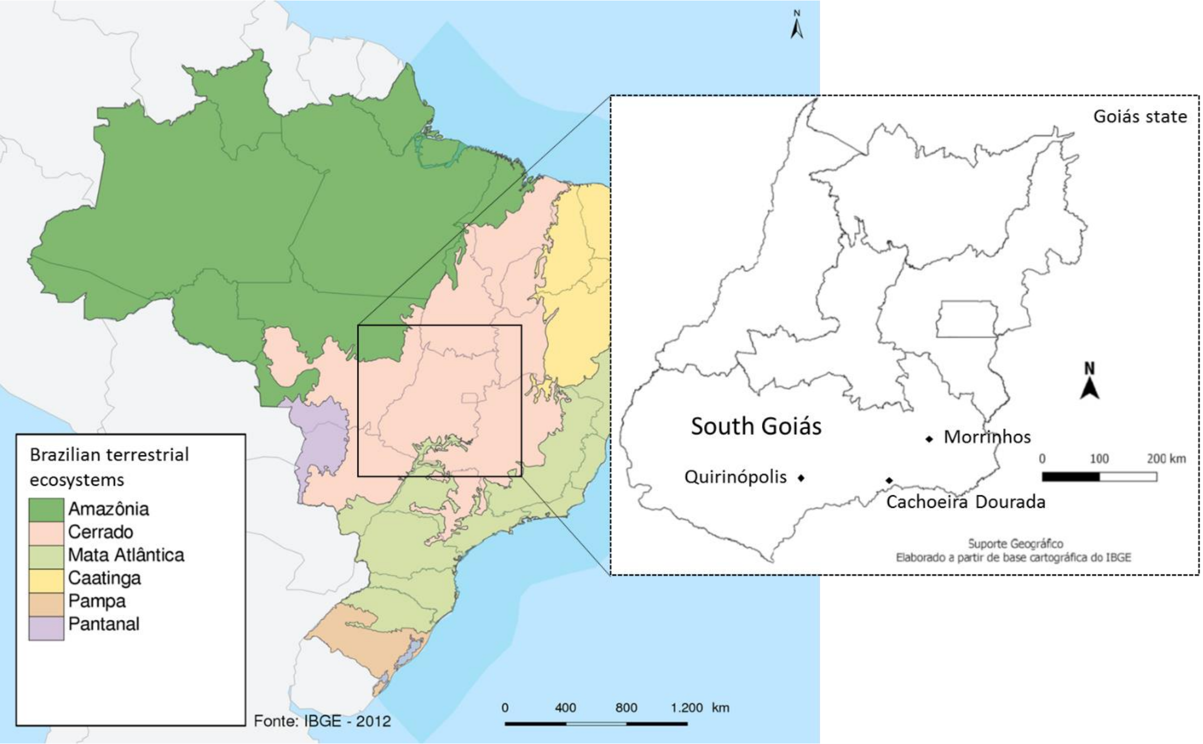

Figure 1. Location of the study sites in South Goiás, Brazil.

SOC was determined by wet dichromate combustion with external heating (we used the data without correcting for soil organic matter, that is, without multiplying the result of the carbon determination by 1.724) modified by Souza et al. (2016), soil texture using the densitometric method (Embrapa 2017), and soil bulk density was measured with the soil core method using Kopecky rings with known volume (EMBRAPA, 2017). Three replicates were taken for each measurement. The samples were taken in the middle of each soil layer. SOC stocks were calculated based on equivalent soil mass, using pasture, in which the ICLFs were implemented, as reference. SOC mas was expressed in Mg ha^{-1}.

Dunnett’s test was applied to check the effect of tree position on soil C stocks by soil depth (0-30, 30-100 and 0-100 cm), within each location. Analyses were performed using the linear mixed model procedure (Proc Mixed) in SAS/STAT (SAS Institute Inc., 2008). Tree position was considered as fixed effect and replicates as random effect.

RESULTS AND DISCUSSIONS

The soil texture at the three evaluated sites were remarkably different. The soil in Cachoeira Dourada featured very clayey texture both in the upper, 0-30 cm (632 g kg^{-1} clay; 221 g kg^{-1} sand), and lower, 30-100 cm (672 g kg^{-1} clay; 170 g kg^{-1} sand), layer. In Quirinópolis the soil was a loamy sand at 0-30 cm (198 g kg^{-1} clay; 770 g kg^{-1} sand) and sandy clay loam at 30-100 cm (247 g kg^{-1} clay; 722 g kg^{-1} sand). In Morrinhos both layers had clay texture (0-30 cm: 469 g kg^{-1} clay, 364 g kg^{-1} sand; 30-100 cm: 475 g kg^{-1} clay, 354 g kg^{-1} sand. Soil texture plays an important role in SOC accumulation.

SOC stocks are shown in Figure 2. Between 35% (Morrinhos) and 50% (Quirinópolis) of SOC was in the top 30 cm layer. In the 1.0 m layer SOC ranged between 77,66 (Quirinópolis) and 133.56 (Morrinhos) Mg ha^{-1}.

Trees affected SOC stocks at almost all depths and all sites, nominal significance levels were between $p \leq 0.3121$ and $p \leq 0.0196$, except at Morrinhos site at 0-100 cm, where no effect was observed ($p \leq 0.9393$). Soil carbon stocks were larger under the tree-rows at different significance levels, independently of soil texture and the age of the ILCF system, however nominal significance level within 5% ($p \leq 0.05$) was detected only at the oldest site in Cachoeira Dourada at 0-100 cm. In Morrinhos, at 0-30 cm the soil under tree-rows contained less SOC than under the pasture alley between tree-rows. There is limited information on subsurface C accumulation under trees in ICLF systems under tropical climate. Accumulation of SOC at the top 0.1 or 0.2 m soil layers was observed in cacao–rubber (MONROE et al., 2016) and coffee-agroforestry systems worldwide (TUMWEBAZE; BYAKAGABA, 2016; THOMAZINI et al., 2015; NOPONEN et al., 2013); however, positive effects of the trees were not observed (or studied) in deeper (>0.2 m) soil layers. Most literature on integrated systems report results obtained from integrated crop-livestock (ICL) systems that lack the presence of the forestry component. However, similar results to ours were observed by Oliveira et al. (2018) for the 30-100 and 0-100 cm layers under the tree-rows and the pasture component between the trees in Nova Canaã do Norte in Mato Grosso state, also with *Eucalyptus sp.*, but they reported no difference at 0-30 cm. They attributed the higher accumulation rate under the tree-rows to the root system of the trees.

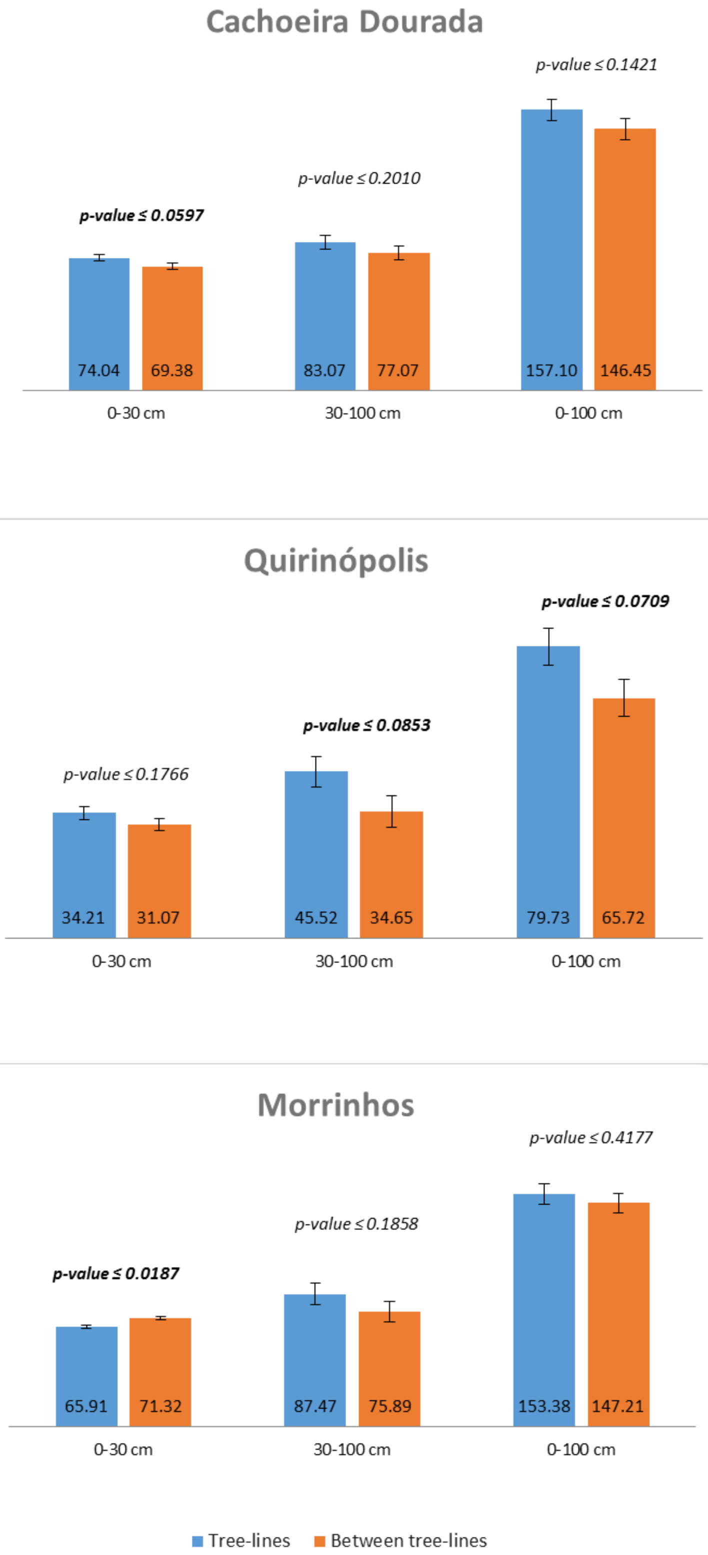

Figure 2. Soil organic carbon stocks (Mg ha^{-1}) under the tree-rows and between tree-rows in three soil depths (0-30, 30-100 and 0-100 cm) at the sites Cachoeira Dourada, Quirinópolis and Morrinhos in southern Goiás state, Brazil. Error bars are standard errors of mean (n=4). Nominal significance level (p-value) of F-tests for the effect of tree-rows by soil depth.

CONCLUSIONS

Trees played a significant role in the increase of SOC stocks in ICLF systems. Trees promoted SOC accumulation, compared to the alley, at 30-100 cm at the two oldest sites within $p \leq 0.15$ significance level and at $p \leq 0.05$ at the oldest site at 0-100 cm. In this work we did not aim to calculate the weighted SOC stock of the ICLFs, but rather compare SOC accumulation as affected by tree-rows versus alley. Further studies are, however, needed to expand the database to support more robust analysis in combination with aboveground C accumulation, greenhouse gas emissions and to identify more conclusive processes involved in SOC sequestration (immobilization).

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SOIL CARBON STOCKS IN INTEGRATED AND CONVENTIONAL PRODUCTION SYSTEMS IN BRAZIL: A LITERATURE REVIEW

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ABSTRACT

Brazil stands out as a major agricultural producer in the world with national and international producers for sustainable food production based on a low carbon (C) policy and that maintain soil quality. Changes in land use or management practices directly affect soil C stocks, making the soil an important source or drain of C into the atmosphere. Among the different production systems, the adoption of integrated systems presents itself as promising alternatives to accumulate carbon in the soil. Thus, the objective of this study was to compile the literature information to evaluate the potential of integrated systems (e.g., crop-livestock, livestock-forest and crop-livestock-forest) to increase soil carbon stocks in comparison with conventional systems (agriculture and pasture) adopted in Brazil. The results indicated that the adoption of this variety of systems results in rates of change of soil C, ranging from -2.04 to 2.85 Mg C ha^{-1} year^{-1}. In this sense, the most promising systems for storing carbon in the soil were sought with integrated systems - ILP, ILF and ILPF - with an average of 0.59 Mg C ha^{-1} year^{-1}.

Key words: Sequestration of C; Crop-Livestock-Forest Integration (ILPF); Agroforestry System (SAF)

INTRODUCTION

Brazilian agriculture has historically been based on the system of expanding new areas for cultivation in order to increase food production, thus establishing food security for the population. However, this mode of production and expansion has resulted in significant changes in the landscape of ecosystems, contributing to the deforestation of native forests and the degradation of natural ecosystems that generate losses of soil organic carbon (DON; SCHUMACHER; FREIBAUER, 2011).

The largest terrestrial carbon reservoir is found in the soil, but conventional production systems contributed to the reduction of biomass in the landscape, and consequently, impacted on the amount of carbon in the soil for agricultural and pasture areas (CARVALHO et al., 2010). Thus, it is necessary to better plan these systems in order to restore balance in nature and, mainly, in the chemical and physical attributes of the soil, such as the carbon and nitrogen ratio (C / N), soil moisture, erosion and consequent GHG reduction (BEILUCZYK et al., 2020).

There are several challenges regarding the improvement of land use and the increase of carbon stocks in the soil, but with them opportunities and initiatives arise. In 2009, the 15th Conference of the Parties (COP15) took place, where Brazil made international commitments on voluntary GHG reduction between 36.1% and 38.9% projected for 2020, which would provide an estimated reduction in the volume of approximately 1 billion tons. of equivalent carbon dioxide (CO_2eq.). In 2011, a plan for mitigating carbon emissions was approved, the ABC Plan (Low Carbon Emission Agriculture) with seven programs: Recovery of Degraded Pastures; Crop-Livestock-Forest Integration (ILPF) and Agroforestry Systems (SAFs); No-Tillage System (SPD); Biological Nitrogen Fixation (FBN); Planted Forests; Animal Waste Treatment; Adaptation to Climate Change, totaling a minimization potential of approximately 150 million Mg CO_2eq. Among these programs is the incentive to ILPF and SAFs with the objective of increasing the area of these systems by 4 million hectares, with a mitigation potential between 18 to 20 million Mg CO_2eq (AMARAL et al., 2011; BRASIL, 2020).

Based on this scenario, Brazil undertook in the Paris Agreement during the 21st Conference of the Parties (COP21) of the UNFCCC audacious commitments to reduce greenhouse gas emissions by 37% and 43% below 2005 levels by 2025 and 2030, respectively (BRASIL, 2015). Among Brazilian actions, the implementation of more than 5 million hectares of ILPF systems by 2030 stands out, precisely because of the potential shown with low carbon agriculture (CONCEIÇÃO et al., 2017).

Integrated systems bring a series of benefits to the ecosystem: they increase the performance of organic matter in the soil (MOS), store carbon in the soil, promote an increase in productivity, improve the physical and chemical characteristics of the soil and decrease fixed and variable costs agricultural production, such as irrigation and agricultural inputs (CONCEIÇÃO et al., 2017).

Due to the importance of the theme, particularly in recent years, it is important to carry out a literature review to compile and discuss works in the area that contemplate aspects involving the quantification of carbon in the soil in different integrated systems compared to conventional systems. Thus, a broad survey of solutions is promoted as alternatives to the problem in question, serving as a source of information for producers, consultants and researchers in the agricultural sector, in addition to contributing to the country to fulfill national and international commitments and to food security. global.

In this approach, the objective of this study was to compile the literature information to demonstrate the potential of integrated systems (crop-livestock, crop-livestock-forest, silviagricultural system, silvopastoral) in the storage of soil carbon in comparison with conventional systems (agriculture and pasture - single systems) adopted in Brazil. The hypothesis is that the adoption of integrated systems increases soil C stocks in Brazil.

MATERIAL AND METHODS

This study was conducted using the systematic literature review as a strategy. Thus, a synthesis approach was adopted through narrative, where the main findings and knowledge gaps identified in the different reviewed articles were synthesized and transcribed in the form of text, table and graph. To achieve the objectives, the literature review sought to answer the following questions:

a) Integrated systems promote an increase in soil C stocks, compared to a reference (agriculture or pasture)?

b) What is the annual rate of accumulation of C in the soil under integrated systems?

The search and compilation of publications were carried out in four stages. In the first stage, the search for the main worldwide research portal “Web of Science” occurred, to assist in this search for publications containing the information necessary for the preparation of the review. Key words described in Table 1 were used, where the results by term can be observed, totaling 76 publications. In the second stage, the literature was collected and filtered to exclude duplicate articles in the searches, this filter also resulted in 42 publications. In the third stage, abstracts were read and articles that did not contain the basic data for the research were excluded, such as the annual rate of C accumulation in the soil. Thus obtaining 32 publications and the year of publication of the literature. In the fourth and last stage, due to time constraints, a random drawing of 32 documents was carried out, resulting in a sample of 14 literature publications (13 scientific articles and a book chapter). The data in these publications were extracted, synthesized and discussed, highlighting the importance of the topic.

For the calculations and average of the rates of stock and loss of carbon in the soil it adopted as a conventional system: i) changes in the use of the land: native vegetation for agriculture; pasture for agriculture; pasture agriculture; native vegetation for pasture and ii) in the same system: agriculture for agriculture and pasture for pasture - in this case, no-tillage versus conventional and extensive pasture versus managed pasture. And for the integrated system, we adopted: i) changes in land use: native vegetation for ILP; agriculture for ILP; pasture for ILP; pasture for ILPF; ILP to ILPF and ii) in the same system: ILP, ILF and ILPF over the years.

RESULTS AND DISCUSSIONS

Soil carbon stock studies in integrated production systems are relatively recent; the results of the majority (44%) were reported between 2017 and 2020. The 14 publications, included in this sample, were concentrated in the Center-South of Brazil, with greater concentration in the states of Mato Grosso do Sul (18%), São Paulo (17%) and Mato Grosso (17%) and Goiás (12%) and Rio Grande do Sul (12%). The same study can present information from more than one state. Most studies involved soils categorized into Oxisols (88%) and Argisols (12%).

The analysis of the literature data from the center-south of Brazil synthesized here showed a wide variation in the rates of carbon values in the soil per hectare per year from -2.04 to 2.85 Mg C ha^{-1} year^{-1}, with positive values for soil carbon accumulation and negative values for soil carbon loss. The values of the average rates of C per author in integrated systems ranged from 2.85 to -1.46 Mg C ha^{-1} year^{-1} and only 26% of the results showed losses of C. In conventional systems, this rate varied from 1.23 to -2.04 Mg C ha^{-1} year^{-1} however 63% of the results showed losses of C (Figure 2). It can be seen that the most promising systems for storing carbon in the soil were obtained with integrated systems - ILP, ILF and ILPF - in changing land use from native vegetation, agriculture and pasture to ILP and pasture to ILPF and within the same system production over the years, either ILF or ILPF, with an average of 0.59 Mg C ha^{-1} year^{-1}. On the other hand, conventional systems (pasture or agriculture) showed an average of -0.31 Mg C ha^{-1} year^{-1} (Figure 1).

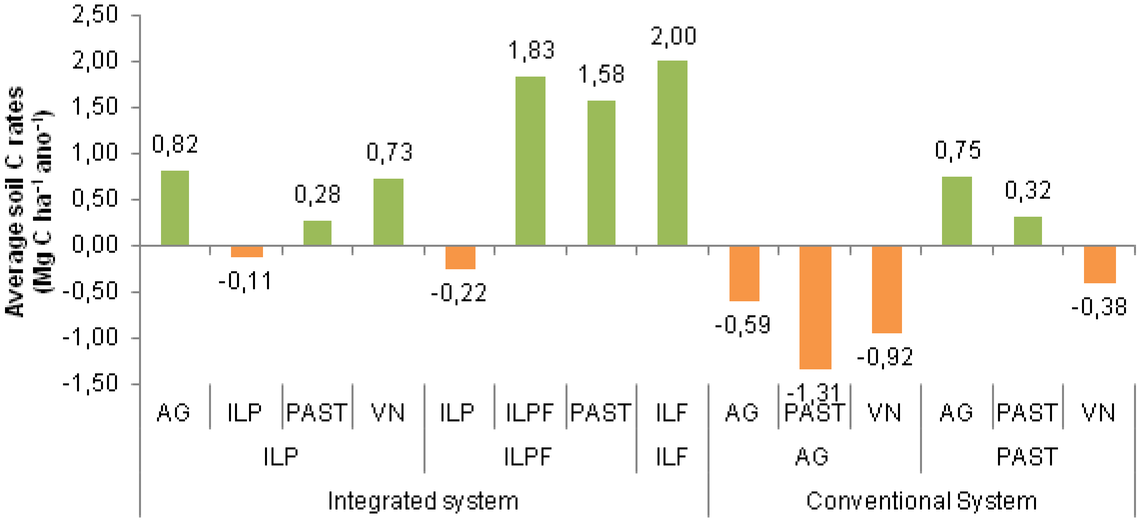

Figure 1. Average accumulation and loss of soil C in the process of land change or in the same system over the years in different agricultural production systems.

Note: The first line of the x-axis refers to the system present in the first year of evaluation of the study, the second line refers to the change of the system or the same over the years, the third in turn is the separation of the integrated systems and conventional systems described herein. AG (conventional agricultural systems and no-till); ILP (Crop-livestock Integration); ILPF (Crop-livestock-forest integration); PAST (Pasture); VN (Native Vegetation).

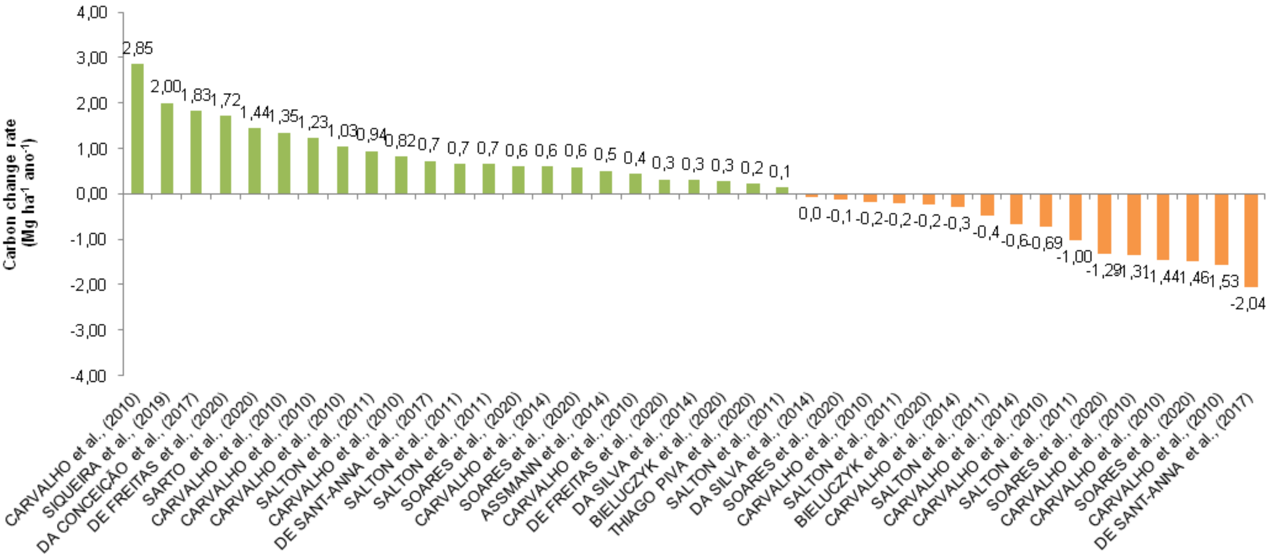

Figure 2. Distribution of the rate of carbon change in soil in decreasing order by author of the publications included in this study**.**

Note: References used to create this figure can be requested directly from the authors.

CONCLUSIONS

This review focused on compiling and synthesizing information on carbon accumulation in different systems in Brazil. The data in the synthesized literature showed that integrated agricultural production systems that combine agricultural, livestock and forestry activities in the same area, whether the three components are present or only two, accumulate more carbon in the soil (0.59 Mg C ha^{-1} year^{-1}) when compared to conventional systems (-0.31 Mg C ha^{-1} year^{-1}), even in managed pasture and no-tillage agriculture.

Integrated systems promote soil C increases, being promising strategies to meet part of Brazil's commitments in the Paris Agreement.

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EFFECTS OF LAND USE CHANGE ON NITROUS OXIDE EMISSION IN SOIL IN THE AMAZON REGION

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ABSTRACT

The change in land use in the Amazon region alters the fluxes of greenhouse gases into the atmosphere. Our objective was to quantify the emission of N_2O in different land use systems (native forest, pasture and agriculture). The design used was completely randomized with five replications. The soils were collected from similar areas with different land use. The methodology used was that of a closed static chamber to quantify the production of N_2O over 25 days and gas chromatography to measure N_2O concentrations. The production of N_2O started on the 8th day after the beginning of the experiment, only in agricultural soils, extending until the end of the evaluations. The peak of production occurred on the 13th, with a production of ~ 681 µg N_2O g^{-1}. An effect of land use was observed ($p = 0.0004$), with the N_2O fluxes being higher in agricultural areas, being 17 and 33 times higher than in native forest and pasture soils, respectively. The production of nitrous oxide in agricultural areas in the Amazon region was higher than in the other areas evaluated.

Key words: agriculture; greenhouse gas emission; native forest

INTRODUCTION

The Amazon is an important global ecosystem that constitutes the richest biodiversity and contributes to the rain cycle and ecosystem services for humanity (CARVALHO et al., 2017; CÓRDOBA et al., 2019). However, there has been a replacement of areas of native forest by areas destined to agricultural production, and this change in land use has effects on the emission of greenhouse gases, directly impacting the climate. Among the main greenhouse gases, nitrous oxide (N_2O) is the third largest contributor to climate change, which has a heating power 265 times greater than carbon dioxide and is involved in chemical processes harmful to the ozone layer, being that the application of fertilizers and the excretion of urine by animals contribute up to 60% of the emissions of this gas to the atmosphere (BORTOLI et al., 2012; IPCC, 2013; WMO, 2015).

The way in which man interferes with nature causes several changes on the Earth's surface, so as the changes intensify, greater attention must be paid to the environment. Land use changes are among the most important human changes to the Earth's surface, since land conversion through cultivation processes, removal of vegetation, burning and degradation can add greenhouse gases to the atmosphere, affecting the environment. global gas cycle (FOLEY et al., 2005; PIELKE, 2005). One of the biggest parameters for regulating N_2O emission in soils is land use, since the botanical compositions of each soil are different, changing the organic matter content in each soil and changing the C: N ratio (ZINN et al., 2018).

Based on this, the objective was to evaluate the effects of nitrous oxide emissions in soils of different land uses.

MATERIAL AND METHODS

The incubation was carried out in the forage sector of the State University of São Paulo “Júlio de Mesquita Filho” campus of Jaboticabal, São Paulo, Brazil. For conducting the incubations, soil collections (0-20 cm) were carried out in three land use systems (native forest, pasture and agriculture) in the municipality of Nova Esperança do Piriá, Pará, Brazil (2°15'47" S, 46°58'41" O; altitude 73 m), distant from each other within a radius of approximately two kilometers.

The native forest area represents the original ecosystem of the region. The pasture area is represented by pastures of *Urochloa brizantha* cv. Marandu formed in 2007, with the last fertilization being carried out in 2018, with the use of reactive natural phosphate. The agriculture area is characterized by the production of black pepper (*Piper nigrum*) formed in 2012, and receiving annual fertilizers, as recommended by the culture.

An experiment was carried out in a completely randomized design with three treatments consisting of different land use systems (native forest, pasture and agriculture) and five replications. The incubations were carried out under controlled conditions: temperature of 25.0 ± 1.0 °C, and soil moisture maintained at 30, 40 and 28% of the water retention capacity of native forest, pasture and agriculture soils, respectively. An addition of 50 kg of N ha^{-1} was made to each soil in the form of a liquid solution, to stimulate the microbial population of the soil.

100 g of soil was added in 500 ml flasks and added to the urea solution according to the moisture content of each soil, the flasks were weighed weekly to correct the soil moisture.

The closed static chamber technique was used to evaluate the fluxes of N_2O. The chambers were pots with 400 mL of free space. The N_2O flux was measured 17 times during the 25-day incubation period (daily for the first week, afterwards, the flux was measured every two days).

In order to measure the N_2O flux, the flask was closed with the lid for a period of 0.5 hours, the time necessary to change the concentration in the empty space of the flask. Gas samples were collected from the flasks, using a 50 mL polypropylene syringe, at the end (T30) of the incubation period. Five samples of ambient gas were collected before closing the chambers (T0), to verify the initial concentration of N_2O, the chambers from which the initial samples were taken were exchanged on each new sampling day.

The gas samples were transferred to pre-evacuated 20 mL flasks for quantitative analysis using gas chromatography to measure N_2O.

A normality Shapiro-Wilk test was performed, then ANOVA of the results was performed, when significant, a Tukey test was applied to distinguish the means ($P = 0.05$), using the SISVAR statistical program.

RESULTS AND DISCUSSIONS

When assessing the effect of land use on N_2O emission, the production of this gas was higher in agricultural treatment, with emissions starting after 8 days of incubation (fig. 1), with the peak of N_2O production happening at 13 days of incubation, with an average fluxes of ~681 µg N_2O g^{-1}. The smallest fluxes were observed in the native forest and pasture soils, which remained constant throughout the incubation days.

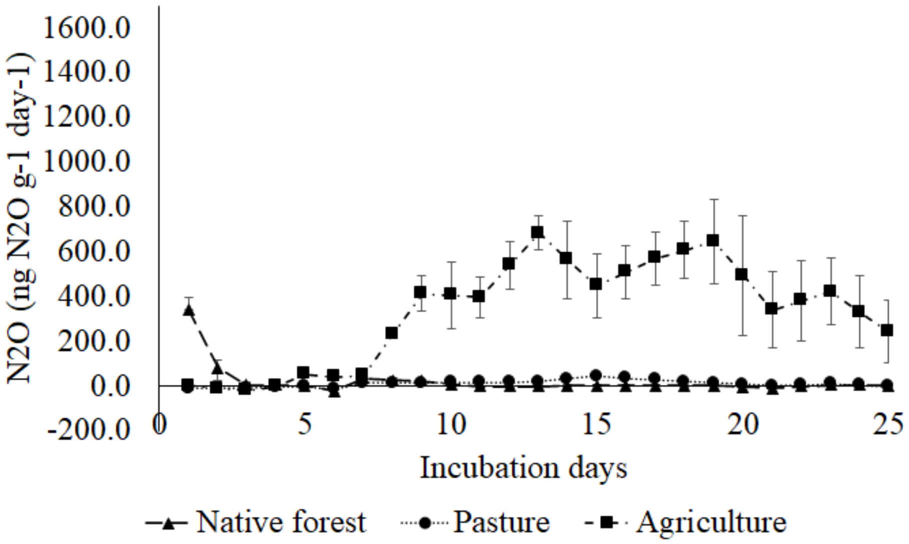

Figure 1. N_2O fluxes (µg N_2O g^{-1} day^{-1} of dry soil) per day of sampling on soils of different land uses.

The start of emissions on the 8th can be explained by the activation of the bacteria, since the soil was previously dry (the environment is not conducive to bacterial proliferation in the soil), and the soil was humidified and nitrogen was added, providing a humid environment and resources. for bacteria to develop, in addition to providing an ideal temperature for their proliferation (WU et al., 2013), however, the same was not observed in other soils, which had a constant N_2O fluxes.

When the total production of N_2O was evaluated, a significant difference was observed (P= 0.0004) due to the different land use systems (Table 1). The N_2O emission in the agriculture treatment presented a higher emission, when compared to the native forest and pasture systems, increasing approximately 17 and 33 times, respectively.

Table 1. N_2O emission (µg N_2O g^{-1} of dry soil) in different land use systems.

Land Use	**N_2O emission**
Native forest	11.74 b
Pasture	5.94 b
Agriculture	199.68 a

Means followed by the same letter, did not differ according to the Tukey test (p = 0.05).

The highest emissions in agricultural soils are due to the fertilization received by the area, since the management is more technical, with fertilization being carried out periodically after each harvest, thus increasing the levels of nitrogen in the soil and, therefore, a higher N_2O emission. (LYIANAGE et al., 2020; RAPOSO et al., 2020; ZANATTA et al., 2010). The spacing observed in the area, of two meters between plants and two meters between lines, makes the area present a large open space. Wachiye et al. (2020) observed higher emissions in areas of beans and corn after harvest, due to the area being without vegetation cover.

Native forests are considered to be mostly resilient areas, that is, they are able to restore their original characteristics after some disturbance, whether internal or external, this characteristic provides native forest areas with the ability to reduce their greenhouse gas emissions (GHAZOUL et al., 2015; PERI et al., 2017). It is observed a lower nitrification action, in relation to the other soils, also explaining the lower N_2O emission from the soil.

The lower fluxes of N_2O in pasture soils can be explained by its age, which is less than 10 years old, emitting 2.8 times less N_2O when compared to pastures over 10 years old, due to the reduction in denitrification rates (MEURRER et al., 2016). In addition to age, the low availability of nutrients (fertilization) explains the low reduction in N_2O emissions, since the last fertilization was carried out in 2017, with only natural phosphate (RAPOSO et al., 2020).

CONCLUSIONS

Areas destined for agricultural production in the Eastern Amazon emit more N_2O into the atmosphere than areas of pasture and native forest.

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METHANE FLUXE IN DIFFERENT LAND USE SYSTEMS IN THE ORIENTAL AMAZON

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ABSTRACT

The Amazon region is characterized by an area with great biodiversity and a sink of methane gas, which due to changes in land use, has become a producer of gas. Our objective was to quantify the CH_4 emission in different land use systems (native forest, pasture and agriculture). The design used was completely randomized with five replications. Soils were collected from similar areas with different land uses. The methodology used was that of a closed static chamber to quantify the production of CH_4 during 25 days and gas chromatography to measure gas concentrations. CH_4 production occurred only on days two and three of the experiment, only on pasture soil, with a production of ~280 µg CH_4 g^{-1}. An effect of land use was observed ($p = 0.0001$), with a higher CH_4 fluxes in pasture areas, with a total production of 470 µg CH_4 g^{-1}, while areas of native forest and agriculture showed a decrease in emissions of CH_4. Methane production in pasture areas in the Amazon region was higher than in the other areas evaluated.

Key words: agriculture; greenhouse gas emission; native forest

INTRODUCTION

The Amazon is an important global ecosystem that constitutes the richest biodiversity in the world and contributes to the rain cycle and ecosystem services for humanity (CÓRDOBA et al., 2019). Despite the great contributions, the region has been going through great changes in its territory, and forest areas have been giving way to areas destined to agricultural production, along with these changes, the emission of greenhouse gases has been changing, among them, the gas methane (CH_4), with heating power 28 times higher than that of carbon dioxide (IPCC, 2013).

These emissions are gradually increasing, since tropical forest soils are considered to be methane sinks, due to their high humidity, however, the changes that have been undergoing make the soils stop being sinks and become considered a source of methane (MEYER et al., 2017).

Thus, it is necessary to have knowledge of the sources of GHG emissions, variables involved in the production of these gases, to adopt measures that help to contain the increase in global warming. And the Amazon region has distinct edaphoclimatic characteristics from the rest of the country, with high levels of precipitation, constant temperatures throughout the year and low fertility soils.

Therefore, the objective of this study is to quantify the emission of methane from the soil in different land use systems (native forest, pasture and agriculture) in the Oriental Amazon.

MATERIAL AND METHODS

The incubations were conducted in the forage laboratory of the State University of São Paulo "Júlio de Mesquita Filho" campus of Jaboticabal, São Paulo, Brazil. For conducting the incubations, areas of similar soil characteristics were selected in the city of Nova Esperança do Piriá, Pará, Brazil (2°15'47" S, 46°58'41" W; altitude 73 m) and collections were carried out. soil at a depth of 20 cm in three land use systems (forest, pasture and agriculture), distant from each other within a radius of approximately two kilometers.

The area of native forest corresponds to a reference of the original ecosystem of the region. The pasture used for soil collection was formed in 2007 after the burning process, and after the implementation of *Urochloa brizantha* cv. Marandu, with weed management carried out annually and the last fertilization being carried out in 2018 with reactive natural phosphate. The area corresponding to agriculture has black pepper cultivation (*Piper nigrum*), the area was opened in 2012 by burning, with a spacing of two meters between plants and two meters between lines, with regular fertilization done annually following the culture's recommendations.

An experiment in a completely randomized design was carried out, with three treatments consisting of different land use systems (native forest, pasture and agriculture) and five replications. The incubations were carried out under controlled conditions: temperature of 25.0 ± 1.0 °C, and soil moisture maintained at 30, 40 and 28% of the water retention capacity of native forest, pasture and agriculture soils, respectively. An addition of 50 kg of N ha^{-1} was made to each soil in the form of a liquid solution, to stimulate the microbial population of the soil.

100 g of soil were added in 500 mL flasks and added to the urea solution according to the moisture content of each soil, the flasks were weighed weekly to correct the humidity. The closed static chamber technique was used to evaluate the fluxes of CH_4.

The chambers were pots with 400 mL of free space. The CH_4 fluxe was measured 17 times during the 25-day incubation period (daily for the first week, after which the flux was measured every two days).

To carry out the measurement of the CH_4 flux, the chamber was closed with the lid for a period of 0.5 hours, time necessary to change the concentration in the empty space of the flask. Gas samples were collected from the flasks, using a 50 mL polypropylene syringe, at the end (T30) of the incubation period. Five samples of ambient gas were collected before closing the chambers (T0), to verify the initial concentration of CH_4. The gas samples were transferred to pre-evacuated 20 mL flasks for quantitative analysis using gas chromatography to measure CH_4.

The Shapiro-Wilk normality test was performed, afterwards the results ANOVA was performed, when Tukey's test was significant to distinguish as means ($p = 0.05$), using the SISVAR statistical program.

RESULTS AND DISCUSSIONS

In the days of incubation of the soil, small variations in the flux of CH_4 are observed in the soils of native forest and agriculture, where in the first days it presented negative flux and in the others they were practically constant, however, in the pasture a peak of approximately 276 was observed and 263 (µg CH_4 g^{-1} day^{-1}), on days one and two, respectively. After the third day of production, the CH_4 flux was similar to that of native forest and agriculture soils.

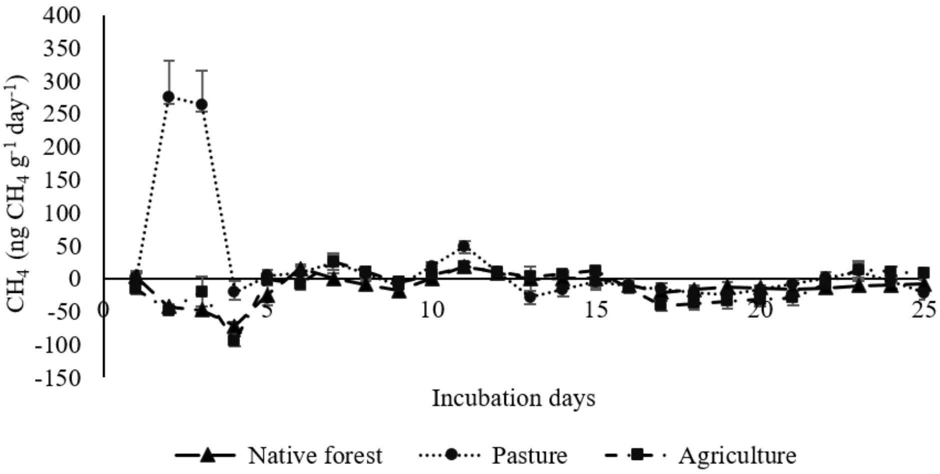

Figure 1. CH_4 fluxes (µg CH_4 g^{-1} day^{-1} of dry soil) per day of sampling on soils of different land uses.

In pasture soils, the presence of animal feces, one of the CH_4 producing agents, is common (CARDOSO et al., 2018). CH_4 is a gas emitted by the faeces, with the passage of time, the faeces dry up and the present CH_4 starts to enter the oxidation process, reducing its fluxes into the environment (SAGGAR et al., 2004). Previously the soil was kept dry until its incubation, as the soil was moistened, the bacteria present in the soil returned to produce CH_4 until the fecal residue contained in the soil entered the oxidation process.

The effect on total methane production (P=0.0001) for land use systems was observed (Table 1). The CH_4 emissions from pasture soils was higher than in native forest and agriculture soils.

Table 1. CH_4 emission (µg CH_4 g^{-1} dry soil) in different land use system.

Land Use	**CH_4 emission**
Native forest	- 303 b
Pasture	470 a
Agriculture	- 267 b

Means followed by the same letter, did not differ according to the Tukey test (p = 0.05).

According to a study carried out by Dalal and Allen (2008), areas of native forest are considered sinks of CH_4, mainly in areas that do not suffer disturbance, as is the case of the native forest in which the soil was collected. In particular, tropical forests are considered to be the most efficient CH_4 sinks, contributing significantly to the reduction of gas emissions into the atmosphere (ZHAO et al., 2019).

The CH_4 is the final product of the decomposition of organic carbon, derived from the decomposition of organic matter in the soil (HAYASHI et al., 2014), however, the soil of the black pepper areas does not have a large deposition of organic matter, since there is large spacing between plants and corridors, and the leaves that come to senescer are placed at the base of each plant, providing a large area uncovered and devoid of organic matter for the soil.

Pasture areas are common for the production of livestock, such as cattle, sheep, goats and buffalo and during grazing time it is common for these animals to excrete in pasture areas, the feces of these animals have a large amount of CH_4 present, which favors CH_4 emissions from soil (CARDOSO et al., 2018).

CONCLUSIONS

The CH_4 emissions from pasture soils are higher than native forest and agriculture soils, possibly due to the deposition of excreta from animals grazing in the area.

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ECO-EFFICIENCY OF BRAZILIAN AGRICULTURE

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ABSTRACT

Eco-efficiency is defined as the relationship between the production value of a firm, industry, agricultural production system, municipality, state or country and the environmental impact of the inputs it uses in the production process Eco-efficiency has also been defined in the literature as a quantitative management tool to study economic and environmental aspects concurrently. Therefore, measuring the eco-efficiency of production units in Brazil can be important for the formulation of public policies aimed at reducing the emission of greenhouse gases. This work evaluated the eco-efficiency of agriculture in 27 Brazilian states using the Data Envelopment Analysis –DEA technique. Two inputs were considered in the model, first the CO_2e emissions resulting from the enteric fermentation of ruminants and the management of manure, the second input are the emissions resulting from the use of the soil, cultivation of irrigated rice and burning of residues. As output, the production value per state was used. An average eco-efficiency of 77.9% was obtained for the 27 states, with 25.9% of the states 100% eco-efficient. An average eco-efficiency of 77.9% is equivalent to saying that eco-inefficient states are emitting 22.1% more CO_2e, given the production value obtained.

Key words: Eco-efficiency; Brazilian agriculture; CO_2e emissions

INTRODUCTION

Many studies have been conducted analyzing the eco-efficiency of agriculture, among which the most recent are those of (CHEN & JIA, 2017) with regions in China and Rybaczewska and Gierulski (2018) and MACIEL et al. (2018) with European Union countries. Eco-efficiency is defined as the relationship between the production value of a firm, industry, agricultural production system, municipality, state or country and the environmental impact of the inputs it uses in the production process (HUPPES; ISHIKAWA, 2007; CHEN et al., 2013). The higher the numerator of this relationship, the more eco-efficient the production system will be. Eco-efficiency has also been defined in the literature as a quantitative management tool to study economic and environmental aspects concurrently. Therefore, measuring the eco-efficiency of production units in Brazil can be important for the formulation of public policies aimed at reducing the emission of greenhouse gases. According to SEEG - the Climate Observation System of Greenhouse Gas Emissions of the Climate Observatory (2019) the country issued in 2018, 1,939 billion gross tons of greenhouse gases, measured in carbon dioxide equivalent (CO_2e). This total, 44% (845 MT CO_2e) came from changes in land use, mainly from deforestation in the Amazon and the Cerrado. Second place was agriculture, with 25% of emissions (492 Mt CO_2e) followed by the energy sector, which includes all activities that use fossil fuels, with 23% (408 Mt CO_2e). The objective of this work was to measure the ecoefficiency in agricultural production in the Brazilian states in relation to the emission of greenhouse gases (CO_2e). Several indicators have been used to measure eco-efficiency or environmental efficiency, the most typical of which is the Life Cycle Assessment Method - LCA (POESCHL et al., 2012; OLANDER et al., 2012; HAWKINS et al., 2013). Through the LCA, energy and material consumed and waste released in production can be identified. In this way, the impact of inputs and products on the environment in production can be identified (MIETTINEN, HAMALAINEN, 1997; CHEN; JIA, 2017). Based on the LCA method, several environmental performance indices have been proposed (CARVALHO et al., 2014). The environmental performance indicators were defined as analytical tools that allow comparing several production units, thus facilitating environmental management and the definition of public policies for them. In this work, eco-efficiency indicators were be calculated using the DEA Method (Data Envelopment Analysis) developed by Banker et al. (1984) and used by Chen and Jia (2017) to assess the environmental efficiency of regions in China and Rybaczewska and Gierulski (2018) to assess the environmental efficiency of European countries.

MATERIAL AND METHODS

Description of the data

Input and output data for the 27 Brazilian states were obtained from SEEG (2019) and MAPA (2020), respectively. The main sources of CO_2e emissions during the agricultural production process according to SEEG (2019) are the cattle herd, which emits high amounts of methane (CH4), by fermentation in the rumen of the animals, the so-called enteric fermentation, and the management agricultural soils, mainly through the application of nitrogen fertilizers, followed by the management of animal waste, cultivation of irrigated rice (which also emits methane and the burning of residues, such as sugarcane straw. CO_2e emissions, these sources werel be used as a proxy for inputs in the model used to measure eco-efficiency and the value of production by state as a product following the model used by Rybaczewska and Gierulski (2018) to assess the environmental efficiency of European Union countries Emissions were divided into emissions of animal origin, adding emissions from enteric fermentation and waste management, from now on called input X1, and emissions plant origin, adding the emissions resulting from agricultural soil management, irrigated rice cultivation and burning of residues, hereinafter referred to as input X2. The production value per state was hereinafter called Y1. Emissions were expressed as CO_2 (t) GWP-AR5. GWP (Global warming Potential) obtained from AR5 (fifth IPCC report. CO_2 (t) GWP interferes with the planet's thermal balance.

Model for assessing eco-efficiency

The Mathematical Programming Model - DEA described by Banker et al. (1984) will be used to estimate the eco-efficiency of agriculture in Brazilian states. The model is represented by equation (1) below. Ecoefficiency was assessed from the perspective of inputs. $\mathrm{Min}_{\lambda\theta}, \theta$ subject to $- yi + Y\lambda j \geq 0$, $E\ xi - X\lambda j \geq 0$, $N1'\lambda j = 1$ $\lambda \geq 0$, (1) Where θ is the eco-efficiency indicator for the j-th state; y_i is a vector (m x 1) of the production value (output y1) of state i; x_i is a vector (k x 1) of CO_2e emissions from state i with two types of emissions: enteric fermentation and manure management (input x_1) and management of agricultural soils, residues and aggregate irrigated rice cultivation (input x_2); Y is a matrix (n x m) of production value for all the j-th Brazilian states considered; X is a matrix (n x k) of emissions from the Brazilian j-th states; z_j is a vector (n x 1) of weights that allow us to obtain the optimized eco-efficiency measures generated by mathematical optimization. $N1'\lambda = 1$ is a convexity constraint, N1 being an N x 1 vector of ones. The convexity constraint ($N1'\lambda= 1$) essentially ensures that the inefficient state is compared with others of the same size. The analysis of eco-efficiency conducted from the perspective of inputs determines constant the value of production and measures the excess CO_2e emissions during the production process, indicating for each state relative to the others the reductions in emissions necessary to become efficient.

RESULTS AND DISCUSSIONS

The descriptive statistics of the input product data used to measure eco-efficiency and efficiency measure are shown in Table 1 below.

Table 1. Descriptive statistics of input-product data used to measure the eco-efficiency of Brazilian states in agricultural production.

	Y_1[1]	**X_1[2]**	**X_2[3]**	**Eco-efficiency[4]**
count	27	27	27	27
mean	2,602.5869	2.6851	3.1373	0.7786
standard deviation	2,137.6640	1.0518	2.3499	0.1958
minimum	287.61	1.3216	0.3076	0.39
maximum	8,151.1324	5.4627	11.1544	1

[1] Production value R$/ hectare; [2] Enteric and manure emissions in tonnes / hectare; [3] Emissions from land use and management in tonnes / hectare; and [4] Measure of eco-efficiency in CO_2 emission GWP-AR5 given the value of production.

The average production value per hectare in the states in 2019 was as shown in Table 1 of R$ 2,602, with a minimum of R$ 287 and a maximum of R$ 8,151. The average CO_2e emission resulting from enteric fermentation and waste management was 2.68 tonnes per hectare with a minimum of 1.32 tonnes per hectare and a maximum of 5.46 tonnes per hectare. The average emission resulting from the use of agricultural land, cultivation of irrigated rice and burning of residues was 3.13 tons per hectare with a minimum of 0.30 tons per hectare and a maximum of 11.15 tons per hectare. The average eco-efficiency was 77.86%, that is, on average, the states could have emitted 22.14% less CO_2e than was emitted given the achieved production value. Table 2 shows by state the value of production and the CO_2e emissions observed and the minimum emissions capable of making them eco-efficient given the value of the production presented.

From Table 2 it can be seen, for example, that the state of Acre achieved an ecoefficiency of 40% given the production value, with CO_2e emissions resulting from enteric fermentations and handling of surplus waste of 2.19 tons per hectare and of land use management emissions of 8.66 tonnes per hectare. Explaining the excess emissions by states is outside the scope of this work, requiring detailed specifications of the different aspects of agriculture conducted by each state. However, a positive correlation was estimated ($r = 0.463$) with $p < 0.05$ between the ratio of agricultural area / total area of the state with eco-efficiency. A negative correlation ($r = - 0.511$) with $p < 0.01$, was also estimated between pasture area / total state area with eco-efficiency. The correlation can be explained by the higher CO_2e emission, when the livestock area is dominant in the state, due to the fact that, in these areas, there is generally no integrated crop and livestock forest (ILPF), being the same exploited with extensive livestock with less added value. When the participation of the agricultural area increases in relation to the total area, CO_2e emissions are lower and the eco-efficiency of the state in question increases. The discussions of the results obtained by this work were hampered by the absence of similar studies conducted in Brazil, and in the studies by Chen et al. (1917) and Rybaczewska and Gierulski (2018) there were, respectively, differences regarding the model used and regarding the inputs considered. The 100% eco-efficient states were seven, AP, DF, ES, BA, RR, RN and PR representing 25.9% of the sample and the least eco-efficient and the least eco-efficient (<50%) were AC, RO and AL representing 11.1% of the sample (Table 2).

Table 2. Observed values, target values and excess CO_2 emissions GWP-AR5 in the agricultural production process of the Brazilian states in 2019.

	Observed values			Target inputs		Excess		
States	**Y_1**	**X_1**	**X_2**	**X_1**	**X_2**	**X_1**	**X_2**	**Ecoefficiency**
AC	1,406.99	3.67	11.15	1.48	2.49	2.19	8.66	0.40
AL	2,104.64	4.63	2.07	1.95	0.87	2.68	1.20	0.42
AM	2,498.97	2.33	2.43	1.76	1.49	0.57	0.94	0.75
AP	287.61	1.32	2.76	1.32	2.76	0.00	0.00	1.00
BA	2,035.32	1.59	1.35	1.59	1.35	0.00	0.00	1.00
CE	1,063.69	2.33	1.50	1.66	1.07	0.67	0.43	0.71
DF	6,019.88	3.40	1.77	3.40	1.77	0.00	0.00	1.00
ES	4,250.61	2.39	2.03	2.39	2.03	0.00	0.00	1.00
GO	2,816.27	2.71	3.18	1.87	1.59	0.84	1.59	0.69
MA	1,231.56	2.42	2.67	1.53	1.68	0.89	0.99	0.63
MG	1,813.04	2.05	2.98	1.55	1.75	0.50	1.23	0.76
MS	1,734.76	1.87	3.19	1.54	1.90	0.33	1.30	0.82
MT	3,440.01	2.46	2.31	2.10	1.78	0.36	0.53	0.85
PA	952.16	2.51	4.28	1.42	2.42	1.09	1.86	0.57
PB	934.90	2.29	1.61	1.64	1.15	0.65	0.45	0.72
PE	2,376.73	2.59	1.89	1.80	1.31	0.79	0.58	0.69
PI	1,495.55	1.67	1.30	1.61	1.26	0.05	0.04	0.97
PR	8,151.13	4.42	2.25	4.42	2.25	0.00	0.00	1.00
RJ	1,602.76	2.84	5.19	1.51	2.14	1.33	3.06	0.53
RN	1,205.88	1.86	0.31	1.86	0.31	0.00	0.00	1.00
RO	1,782.42	3.96	9.56	1.55	1.81	2.41	7.75	0.39
RR	800.25	1.37	3.59	1.37	3.59	0.00	0.00	1.00
RS	3,809.46	2.55	3.15	2.23	1.90	0.32	1.25	0.88
SC	7,430.13	5.46	3.86	4.05	2.21	1.42	1.65	0.74
SE	1,361.94	2.13	1.87	1.58	1.39	0.55	0.48	0.74
SP	6,739.70	3.96	2.12	3.73	2.00	0.23	0.12	0.94
TO	923.50	1.72	4.34	1.39	3.37	0.33	0.97	0.81

CONCLUSIONS

Despite the continuous improvement in the productivity of Brazilian agriculture, it carries the challenge of reconciling high productive performance with better environmental performance. This study reveals that only 25.9% of the states are eco-efficient, with the other states needing to align the value of their production with CO_2e emissions. Practices for integrating crop and livestock forestry should be accelerated, including with the rotation of legumes such as soybeans, alfalfa and pigeon pea integrated into eucalyptus reforestation in livestock, legumes can reduce emissions resulting from the use of nitrogen in pastures and in the production of corn and cotton. The massive introduction of forests to pastures can in a short time mitigate methane emissions from the enteric fermentations of ruminants. The DEA technique can be a good tool to support efficient environmental management by identifying eco-efficient and eco-inefficient systems.

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METHANE EMISSIONS AND MILK YIELDS FROM DAIRY COWS UNDER INTEGRATED SYSTEMS

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ABSTRACT

Integrated systems have been shown to be viable technology for increase agricultural yields and reduce environmental impact. The enteric methane emissions and milk yields were assessed in crossbred grazing cows in the Cerrado region of central Brazil. Treatments were allocated in a completely randomized design and consisted of two dairy production systems based on *Megathyrsus maximus* cv. Mombaça cultivated in Integrated Crop-livestock (ICL) or Integrated Crop-livestock-forestry (ICLF). The treatment means were compared using the F test at 5% probability of error. Mombaça grass presented the same forage yield and 22% more CP (P=0.0105) in ICLF. Treatments did not differ for any enteric methane emission variable; however, the cows' fat milk content and fat corrected milk yield (FCM) were, respectively, 7.3% and 9.7% higher in ICLF (P<0.05). In conclusion, crossbred dairy cows produce more FCM in ICLF, with the same methane intensity and production when grazing Mombaça grass under ICL or ICLF systems.

Key words: cattle; Girolando; greenhouse gas

INTRODUCTION

Integrated/mixed systems has shown to be a viable strategy to increase agricultural yields with more efficient use of natural resources and lower environmental impact. Among the benefits, crop-livestock-forestry (CLF) systems have been indicated for dairy production in order to improve animal welfare and yield, especially in tropical conditions. Some traits may be altered in grasses when cultivated in silvopastoral systems and these changes may affect animal production in pasture-based diets (PACIULLO et al., 2009; SANTOS et al., 2018). The milk yield as well as enteric methane – CH_4 emissions are influenced by the pasture nutritional value (PEDREIRA et al., 2009). Therefore, studies that evaluate ruminant production coupled with greenhouse gases (GHG) emissions, in particularly enteric CH_4, are crucial to better characterized the systems efficiency and sustainability. This work aimed to compare the methane emissions and milk yields from grazing Girolando dairy cows under Integrated Crop-livestock (ICL) and Integrated Crop-livestock-forestry (ICLF) systems in the Cerrado region of central Brazil.

MATERIAL AND METHODS

The work was carried out at the Center for Technologies for Dairy Zebu Breeds (CTZL), located in Brasília – DF at 15°57'09" S, and 48°08'12" W, altitude 998m, in a tropical savanna climate (Aw Köppen-Geiger classification). It was used a completely randomized design, with two treatments. Seventeen lactating Holstein x Zebu cows (mostly 1/2 and 5/8 Holstein × Gyr) with 513 ± 60kg liveweight (LW) and 117.5±49 days in milk (DIM) were used as replications (testers), being eight animals for ICL and nine for ICLF. All experimental procedures were approved beforehand by the Ethics Committee on Animal Use at Embrapa Cerrados (protocol nº 533-2541-1/2017). Treatments consisted of production systems based on guineagrass (*Megathyrsus maximus* syn. *Panicum* *maximum* cv. Mombaça) established in succession after soybean under ICL or ICLF with single lines of *Eucalyptus urograndis* trees (east-west orientation, 25m between rows, 130 trees/ha). The trees were planted in 2013 and the pastures in 2016. In 2019, the average eucalyptus trees height was 28m. The trials took place in February, March and May 2019, comprising the rainy, rain-dry transition and beginning of drought periods in Cerrado region, respectively. Cows were kept on pasture with mean daily herbage allowance (HA) ranging from 12 to 14 kg of dry mass (DM) to 100 kg animal LW. Each experimental unit of 8 ha was divided in 12 paddocks managed using rotational stocking at variable stocking rate, with 2 or 3 days of grazing and 22 or 33 days of rest in the rainy or dry season, respectively. Concentrate with 180 g/kg of crude protein and 760g/kg of total digestive nutrients was offered in the proportion of 1 kg of concentrate for every 3 kg of milk produced above 8 kg of milk per animal per day. The concentrate was supplied during the morning and afternoon milking. Water and mineral mix (90 g/kg of phosphorus) were offered *ad libtum*.

The sulphur hexafluoride - SF6 tracer dilution gas technique (JOHNSON et al., 1994) was used to estimate enteric CH_4 emissions during at least four consecutive days per animal in each experimental period. Individual milk production and milk fat content were measured at least once in every experimental week. The daily milk yield was expressed in fat-corrected milk basis (4%FCM) according to (GAINES, 1928). Pre-grazing canopy height was measured in 90 points per paddock in ICL and 120 in ICLF. Pre-grazing forage mass at the soil level was evaluated in 12 points (1 × 1 m) in 3 transects in the ICLF and 9 points (1 × 1 m) in 3 transects in the ICL treatments. Forage hand-plucked were sampled all over the paddock during grazing days for nutritional value analysis. All forage samples were dried at 55^o C during 72 h to estimate dry matter. After drying, hand-plucked samples were ground in a 1 mm screen Wiley mill and estimates of crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) and *in vitro* dry matter digestibility (IVDMD) were obtained by near infrared reflectance spectroscopy (NIRS). The Proc GLM was used to analyze data from animal performance and PROC MIXED (SAS, 1998) to analyze data from pasture. Type of production system and trial were considered as fixed effects, animal as random effect and pasture traits as repeated measures over time. The treatment means were compared using the F test at 5% probability of error.

RESULTS AND DISCUSSIONS

The pasture canopy variables did not differ between treatments (Table 1), pointing that Mombaça grass presented same yield when cultivated both in ICL or ICLF systems. This is a desirable trait when choosing a grass to be cultivated under shading. In some silvopastoral systems pasture intercropping may be not feasible due to the competition with trees for water and nutrients and by low light availability (OLIVEIRA et al., 2007). Therefore, the arrangement and management of trees are of great relevance for animal performance in ICLF systems. According to Santos et al (2016) planting trees in the east-west direction orientation, setting the spacing between rows greater than 22 m and establishing simple lines of trees may favor pasture production. In the present study the ICLF arrangement with a lower density of tress (130 trees/ha) did not impair the pasture production. When it comes to nutritive value, treatments differ only for CP (P=0.0105). Mombaça grass cultivated in ICLF presented 22% more CP than in ICL. Santos et al (2018) founded CP content 28.9% higher for Piatã grass (*Urochloa brizantha, syn. Brachiaria brizantha*) cultivated in ICLF system with 22m between rows and 417 trees/ha. Highest CP contents in pastures under shade compared to ones in full sunlight access are commonly found in literature and can be explained by dilution effect, delay in forage maturity stage and higher nutrient cycling in silvopastoral systems (LEMAIRE; CHARTIER, 1992; PACIULLO et al., 2007; BELESKY et al., 2011).

Table 1. Pre-grazing forage mass and canopy height and nutritive value of *Megathyrsus maximus* cv. Mombaça cultivated in ICL and ICLF systems from December to May 2019, Brasília, DF, Brazil.

Variable	**ICL**	**ICLF**[1]	***F Prob***
		Pasture Canopy Variables	
Pre-grazing forage mass (kg/ha)	4,600	4,800	0.7885
Canopy height (cm)	73	66	0.1028
		Forage Nutritive Value	
CP (g/kg)	112	137	0.0105
IVDMD (g/kg)	645	658	0.1265
NDF (g/kg)	621	621	0.9394
ADF (g/kg)	348	344	0.1898

[1] *Eucalyptus urograndis*, single lines, east-west orientation, 25m between rows, 130 trees/ha. CP = crude protein, IVDMD = *in vitro* dry matter digestibility, NDF = neutral detergent fiber, ADF = acid detergent fiber.

The quantity and nutritional value of pasture available can affect feed intake and animal performance. In the present study, either for ICL or ICLF systems, the pre-grazing forage mass with 12% to 14% allowance and the pasture average levels of CP and IVDMD assured adequate conditions to animals express its milk production. Despite the absence of differences in terms of forage fibrous fraction and IVDMD contents, the highest CP and probably better animal welfare may have affected the cow's intake behavior and, consequently, increased 7.3% individual milk fat (P=0.0008) content and 9.7% fat-corrected milk production (P=0.079) in ICLF. The production level affects the enteric CH_4 emissions. In general, the milk yield improvement results in more enteric CH_4 production (g/d) although the CH_4 intensity (g/kg FCM) tends to decrease. Emission intensity may be an indicator of systems efficiency since higher livestock products yields associated to lower CH_4 emissions are desirable. The differences in milk production and composition did not impact (P>0.05) any enteric CH_4 emissions variables (Table 2). Thus, ICL and ICLF did not differ in terms of CH_4 production and intensities. The systems average CH_4 production (438.9 g) was higher than the observed for Primavesi et al. (2004) (331 g/d) and Pedreira et al. (2009) (314g/d) for crossbred cows producing 13.3 and 11.5 L/d and grazing *Urochloa decumbens* and *Megathyrsu maximus* cv. Tanzânia, respectively. These differences might be explained mainly by the highest production level of the cows and the energy content of the forage in the present study. Nevertheless, in terms of CH_4 intensity the average value (27.3 g/L FCM) was close to 25.3 g/L reported by Primavesi et al. (2004) and 27.3g/L by Pedreira et al. (2009).

Table 2. Milk yields, milk fat and enteric methane (CH_4) emissions from crossbred cows grazing *Megathyrsus maximus* cv. Mombaça cultivated in ICL and ICLF systems. Brasília, DF, Brazil.

Variable	**ICL**	**ICLF**[1]	***F Prob***
Milk yield (L/d)	16.2±5.1	17.3±5.2	0.1647
Milk fat (%)	4.1±0.6	4.4±0.6	0.0008
Fat corrected (4%) milk yield – FCM (L/d)	16.4±5.0	18.0±4.9	0.0079
CH_4 (g/day)	441.5±196.0	436.4±191.0	0.7026
CH_4 (gCH_4/L FCM/d)	28.5±12.0	26.1±13.7	0.1043

[1] *Eucalyptus urograndis,* single lines, east-west orientation, 25m between rows, 130 trees/ha.

CONCLUSIONS

Data indicated that crossbred dairy cows grazing Mombaça grass produce more FCM in ICLF compared to ICL system, with the same CH_4 production and intensity.

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ANTHROPIC INTERFERENCE ON CARBON CAPTURE THROUGH EUCALYPTUS PRODUCTION IN ALAGOAS, BRAZIL

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ABSTRACT

The intensification of global warming caused by the increase in greenhouse gas (GHG) emissions, mainly resulting from deforestation and inadequate use of the soil for agriculture, contribute to the greenhouse effect and the degradation of the soil's organic matter. On the other hand, adequate management practices accumulate carbon in the soil-plant system and mitigate these effects. In Alagoas, the cultivation of eucalyptus culture has been intensifying. The aim of this study is to analyze the interference of anthropic action on carbon sequestration through eucalyptus production, in Alagoas. The methodology corresponds to the computerized delimitation of the three eucalyptus areas in the study area using geographic information system software, followed by the verification of these delimitations in comparison with previous data through Cohen's Kappa coefficient (κ). After that, GHG emissions were compared between the years of 2013 and 2019 and the carbon stock in the biomass of these plantations was estimated. The results showed that the delimitation was accurate with $k > 85\%$, and the areas of planted eucalyptus in Alagoas have grown over the years, and so did the volumes of carbon captured by them: the difference is over 600% between 2013 and 2019.

Key words: Carbon capture; Land use change; Greenhouse gas emissions

INTRODUCTION

The increase in the atmospheric concentration of greenhouse gases (GHG) has aroused the interest of governments and society in search of measures to mitigate these concentrations, mainly those of carbon dioxide (CO_2) and other greenhouse gases (GHG), such as methane (CH_4) and nitrous oxide (N_2O). The intense generation of GHG arising from anthropic interference has caused a series of changes in the terrestrial landscape and also in the atmosphere, thus contributing to climate change, causing impacts that make vulnerable, directly or indirectly, both society and the environment (IPCC, 2014). Thus, the agricultural sector, especially agriculture, has an important role in increasing these gases over the years. Anthropic activity has been converting from native ecosystems to agrosystems, and added to agriculture currently contribute approximately 24% of global CO_2 emissions, 55% of CH_4 emissions and 85% of total N_2O emissions to the atmosphere (IPCC, 2007; COSTA, 2017).

In Brazil, due to the great importance of the agricultural sector, most of the GHG emissions come from land use change and agriculture, representing around 44% for land and forest change and 28%

for agriculture, corresponding to 72 % of transfers. On the other hand, in Alagoas, GHG emissions comprise 40% for agriculture and 7% for land use change and forests, that is, they are responsible for 47% of GHG emissions in the State (SEEG, 2019).

Anthropic interference cause changes in the terrestrial landscape and in the atmosphere and cause an increase in GHG emissions and global warming of the Earth, in addition to increasing strategies to reduce the sources of these greenhouse gases. In some agricultural systems or management conditions adopted, they can enhance or mitigate the emission of GHG into the atmosphere. Thus, the main mitigation strategies derived from anthropic interference are: less use of fossil fuels, reduction of deforestation and burning of plant material, inappropriate use of the soil and strategies to maximize carbon sequestration (C) in the soil and in vegetation (CARVALHO et al., 2010; SANTOS et al., 2017).

The original Atlantic Forest biome, in Brazil, occupied an extensive area in the territory extending over 17 states of the country. However, this area has undergone high fragmentation and alteration of its original ecosystems, due to human occupation, deforestation of its forests, degradation, urbanization and waterproofing of its areas for the implantation of agriculture, livestock and industrialization (VILELA; CALLEGARO; FERNANDES, 2019). According to IBGE (2020), the Atlantic Forest biome occupies 12.6% of the Brazilian territory and is the most threatened biome in the country, being the only biome whose predominant class of land use is not of natural cover and only 27% of its original forest cover is still preserved. Currently, this biome has several land uses, including: remaining forest, planted forest (mainly pine and eucalyptus), pastures (focus on silviculture), permanent crops (coffee, citrus, cocoa and bananas) and annual crops (BODDEY et al., 2006).

During the process on carbon storage in the atmosphere, forest ecosystems are essential. This importance is given because the reforestation areas can collaborate in this process and reduce the extractive pressure on native forests (AZEVEDO et al., 2018). The reforestation of deforested areas increases carbon sequestration and storage and becomes a mitigating option for GHG emissions in the Atlantic Forest biome. The restoration of deforested areas provides biodiversity conservation and when it comes to the Atlantic Forest, it remembers the high levels of species diversity, endemism, number of species threatened with extinction and reduction of its original area (JOLY et al., 2014).

The proportion of carbon (C) immobilized by forests correlates with the growth and age of these plants. In this way, forests remove C, in the form of CO_2, mainly in greater proportions when young and in the growth phase. Thus, when they reach maturity and growth stabilizes, CO_2 absorption decreases and this vegetation enters a dynamic equilibrium stage (CIESLA et al., 1995). In the study by Paixão et al. (2006), in an eucalyptus stand there was an average increase of C in the order of 12 Mg ha^{-1} $year^{-1}$, in which the aerial part responsible for 67% of this stock, the roots for 21% and 12% of the soil organic matter (SMO) humidified. In view of this, it demonstrates the contribution of reforestation practices and, or, maintenance of the remaining forests to the mitigation of GHG emissions and C sequestration in the soil-plant-atmosphere system. On the other hand, in the agricultural sector, the use and proper management of the soil promote an increase in carbon stocks in the soil, in vegetation and act in reducing the emission of GHG into the atmosphere, attenuating the effects of global warming (CARVALHO et al., 2010).

In Alagoas, since the Portuguese invasion and during the colonial period, its territorial formation was marked by the presence of sugarcane, where extensive fertile areas of Forest Zone and Coast were suitable for monoculture with a primary and highly dependent economy the sugar-energy sector. However, in the last decade, due to the crisis in the sector, there was a decrease in the cultivated area and in the amount of tons of sugarcane, with idle areas and, consequently, it was a great time for the beginning of eucalyptus culture in the State, with a vertiginous growth of cultivated hectares (LIMA; BARBOSA, 2019).

In 2018, the areas of Alagoas with the most hectares of eucalyptus planted are: Maceió, Flexeiras and Atalaia (IBGE, 2019a). On the other hand, it is still a monoculture and eucalyptus plantations are associated with the contamination of water sources by the drift of pesticides and by the decrease in the biodiversity of fauna, flora and soils (ESKINAZI; SOUZA, 2013). However, eucalyptus forests can help to minimize excessive heat exchanges by animals, as the shadows of trees reduce the solar radiation that affects animals, providing animal comfort due to shading and reducing heat stress. The integrated crop-livestock-forest (iCLF) system is set up that contributes to carbon capture, which generates expectations for the implementation of a Reducing Emissions from Deforestation and forest Degradation (REDD+) project, with the aim of increasing forest cover, conservation and Sustainable Forest Management (ZANETTI, 2012).

Considering the scarcity of studies related to carbon fixation in forests in the process of restoration belonging to the Atlantic Forest biome, this study was carried out with the aim of analyzing the interference of anthropic on carbon sequestration through eucalyptus production, in the State of Alagoas. As well as, compare greenhouse gas emissions at the beginning and end of the study period; perform an estimate of the carbon stock in the biomass of eucalyptus plantations delimited using satellite images.

MATERIAL AND METHODS

Study area

The research was carried out in the counties with the three largest eucalyptus plantations in Alagoas: Maceió, Flexeiras and Atalaia, these areas have more than 1000 hectares of planted area with eucalyptus (ESKINAZI; SOUZA, 2013). All of these areas are inserted in the Atlantic Forest biome.

This research was developed in two main steps: the delimitation of eucalyptus' areas in the years of 2013 and 2019 using geographic information systems software, and historical images obtained from satellites; and the estimates' analysis of greenhouse gas emissions in Alagoas, derived from the change in land uses and forests and agriculture (SEEG, 2019).

Satellite delimitation and evaluation

In this research, two orbital images captured by sensors installed in Landsat satellites were used, all made available by the United States Geological Survey (USGS), a North American Scientific Agency created to monitor natural and human interactions with the planet Earth, and provide relevant information for taking scientific decisions (USGS, 2020).

These images were captured by the Operational Land Imager (OLI) sensor, orbit 214, point 67, installed on the Landsat 8 satellite. The selected images have a six-year time span (june of 2013 and july of 2019), and the choice of these specific images is due to the fact of them present the lowest indexes of presence of clouds over the study region at the time of research.

Vector files obtained from the digital database of the Brazilian Institute of Geography and Statistics (IBGE, 2019b) referring to the limits of the Federation Units, counties limits, hydrography, and highways available in the scale 1: 250,000 were used.

This material is available in SIRGAS 2000, an incompatible format with the Datum of the aforementioned Landsat images. In order to allow the interaction between both, the acquired vector files were converted to WGS84 using the Esri ArcMap 10.8 ™ software.

The delimitation of the eucalyptus areas was produced with supervised classification techniques based on region, and with Bhattacharya's distance to calculate the statistical difference between seven classes, the acceptance margin was 99%. This procedure was divided into seven major classes: native forest, agricultural land, forestry, developed land, water bodies, shadows and clouds.

The evaluation of this classification's accuracy was calculated with Cohen's Kappa coefficient (κ) between our delimitation and previous data from SNIF (2021).

Carbon capture calculation

Based on previous studies and the delimitated eucalyptus areas, the amount of carbon and CO_2eq (in tonnes) were calculated using the following equations (IPCC, 2006):

$$CO_2 capture = capture factor \times area of eucalyptus \quad \text{Eq. (1)}$$

$$Ccapture = \frac{CO_2 capture}{3,67} \quad \text{Eq. (2)}$$

Both 2013 and 2019 carbon capture were calculated then compared to evaluate the impact of studied eucalyptus plantations in neutralizing GHG emissions.

RESULTS AND DISCUSSIONS

The first image (Figure 1), presents the results of the eucalyptus plantation delimitation in the study area for both 2013 and 2019. the eucalyptus vegetation cover in 2013 was equivalent to 1,502 and 350 hectares in Maceió and Atalaia, respectively. Flexeiras did not present any plantation of eucalyptus in 2013.

The expressiveness of eucalyptus is perceptively larger in 2019, with 8,000; 1,900 and 2,000 hectares in Maceió, Atalaia and Flexeiras, respectively.

The areas that now have eucalyptus were basically occupied with sugar cane plantations, and the substitution of one plantation for another happened incisively in this period of six years.

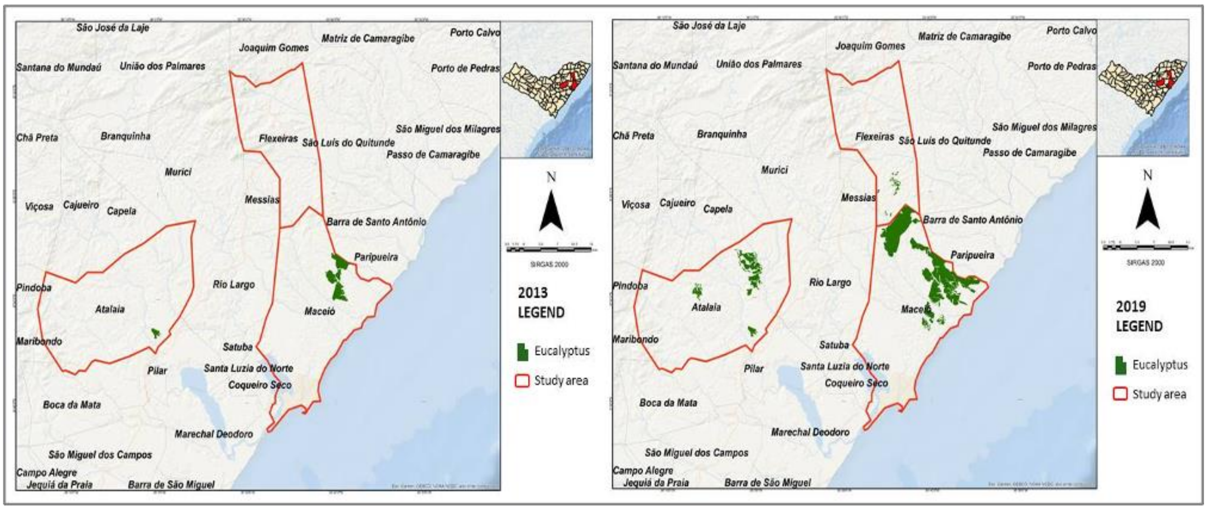

Figure 1. Eucalyptus plantations in Alagoas in 2013 and 2019.

After the delimitation, the results were compared to SNIF (2021) information to validate them statistically. Both classifications were considered excellent according to Cohen's Kappa coefficient that presented values greater than 85%.

Then, as described previously, the volumes of carbon capture (CO_2 and C) in each one of the three cities in the study area were calculated. The results are presented in Table 1.

Table 1. Carbon capture values in the study area through eucalyptus production (2013-2019).

Region	IPCC Capture factor	Eucalyptus plantations in 2013 (ha)	CO_2 capture (t) in 2013	C capture (t) in 2013	Eucalyptus plantations in 2019 (ha)	CO_2 capture (t) in 2019	C capture (t) in 2019
Maceió	25.9942	1,502	39,043.28	10,638.49	8,000	207,953.60	56,663.10
Atalaia	25.9942	350	9,097.97	2,479.01	1,900	49,388.98	13,457.48
Flexeiras	25.9942	0	0	0	2,000	51,988.40	14,165.77
Total	25.9942	1,852	48,141.25	13,117.50	11,900	309,330.98	84,286.35

Results showed that in 2013 over 48,000t of CO_2 and over 13,000t of C were captured in the study area due to eucalyptus plantations. In 2019 as the planted areas grown, so did the volume of carbon captured, as expected.

The increase of capture CO_2 in the area between the six years of this study was of 168,910.32t in Maceió, of 40,291.01t in Atalaia. Flexeiras did not present any eucalyptus in 2013. These numbers reaffirm the discrepancy between 2013 and 2019 verified on Figure 1.

In general, adding the values captured by the three areas, it was found that there was an increase of about 260,000t of CO_2 and 70,000t of C between 2013 and 2019. These numbers represent over 600% less emissions in six years.

CONCLUSIONS

Anthropic actions cause successive changes in the environment, but they don’t have to be negative. As shown in this research, the eucalyptus production in Alagoas has reduced the amount of greenhouse gases emissions, by increasing the capture of carbon. Larger effects of this carbon capture can happen if the continuity of growth of eucalyptus plantations keeps rising in the area of study.

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3. Integrated systems and sustainability assessments

MICROORGANISMS ABUNDANCE IN GRAZED AND NON-GRAZED SOIL

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ABSTRACT

Cattle grazing confers several benefits when present in production systems, but careful handling is needed to maintain the soil quality. We evaluated the total fungal propagules in soil from two integrated crop-livestock systems (ICLS) compared to a non-integrated control. The method consisted of a twice soil sampling submitted to dilutions and culture media evaluation for total fungi growth. Results showed greater colony-forming units per plate in the soil from the non-grazed control, independently of the sampling time. We conclude that grazing influences the soil microbial attributes, probably by changing the quantity and quality of residues in the soil.
Key words: microbial biomass carbon; soil quality; suppressiveness

INTRODUCTION

Cattle grazing is long and fairly incorporated in grain production systems, with or without the inclusion of trees, aiming to better explore the natural and economical resources, diversify incomes, reduce risks, etc. (RYSCHAWY et al., 2012). It is expected that intensified production systems return several benefits to farmers, but the management of production factors is more complex as more diversified the system is. An example is the management of cattle grazing, its requisites (e.g.: grass quantity and quality), and its consequences in the soil quality, as measured by microbiological attributes.

The crop-livestock system with cattle grazing on oats and ryegrass in the winter and soybean and corn as grain crops in the summer is very common in the South Brazil (MORAES et al., 2014) and the soil quality in pasturelands is a great issue for the agricultural development in the recent years (GIL et al., 2015). With this concern, the present work evaluated the abundance of cultivable fungi in three different production systems in a long-term experiment of integrated crop-livestock systems (ICLS) in the Region of Campos Gerais, Brazil: agropastoral, agrosilvopastoral, and a non-integrated control system.

MATERIAL AND METHODS

Soil samples (eight per plot) were collected for microorganism's quantification in a long-term ICLS experiment in the Ponta Grossa County, Paraná State, Brazil in August (winter) and November (spring) 2014. The experiment was put in place in 2006, and had three production systems: agropastoral (AP) system, agrosilvopastoral (ASP) system, and a control (CO) with a non-integrated crop treatment, arranged in randomized blocks with 3 replications. All production systems had summer crops of soybean and corn on alternated crop seasons. The winter grazing in all production systems consisted of black oat and annual ryegrass intercropped. Cattle grazing occurred for an uninterrupted period of 90 to 120 days every winter in AP and ASP systems, and the stocking rate was managed to maintain the pasture with 20 cm height.

Summer crops and winter pastures were established by direct seeding (no-tillage). The tree component of the ASP system was composed of eucalyptus (*Eucalyptus dunnii*) and silver oak (*Grevillea robusta*) alternated in single rows, with 4.5 m between trees and 14 m between rows. Each plot had an area of about one hectare, except CO plots, which were established within the AP plots in 2010 and sized at 100 m².

Soil samples from zero to 15 cm depth were collected randomly from each plot. The soil was stored at 4 ºC in capped acrylic pots, until use. An aliquot of 10 g of soil was diluted in 90 mL of sterile distilled water and stirred for 90 minutes at 170 rpm on an orbital flask shaker. Suspensions were diluted to a concentration of 10^{-3} and 0.5 mL was then spread on Petri dishes containing potato dextrose agar (PDA) medium added with 0.8 ml L^{-1} of lactic acid to avoid bacterial growth, with four plates per sample. The plates were incubated in the dark at 22 to 26 °C and evaluated after 5 days by visual quantification of colony-forming units per plate.

A generalized linear mixed model structure was used for data analysis, with a Poisson distribution for the response variable and adding a random effect to account for measurements (Petri dishes) taken at the same experimental unit (soil sample). Statistical analyses were performed using R software (R Core Team, 2017) with models fitted by the function glmer from the add-on package *lme4* (BATES et al., 2014), and glht from the package *multcomp* (HOTHORN et al., 2008).

RESULTS AND DISCUSSIONS

Total fungi capable of cultivation in PDA, a rich culture medium, were more abundant in the non-grazed CO treatment than in the grazed ones: AP and ASP (Figure 1). This is in accordance with Vargas Gil et al. (2009), who observed also a prevalence of Actinomycetes, *Trichoderma* spp., and *Gliocladium* spp. in non-grazed treatments, while Salton et al. (2014) found little or no differences in soil microbial-biomass carbon and basal respiration between grazed and non-grazed treatments. The soil samples were collected at the beginning (August) and just after (November) grazing when vegetal residues were abundant in the soil. A probable reason for the greater microorganism density in non-grazed plots is the abundance and quality of available residues in the soil, as the grazing process reduces the abundance of residues and returns it to the soil after processed by animals. This is in accordance with previous observations (VARGAS GIL et al., 2009; XUN et al., 2018).

The number of colony-forming units was also lower in the ASP treatment, where the tree component intercepts light and competes with the grasses and grain crops for other growth factors. Previous work in the same experimental area found a greater abundance of *Fusarium* spp. propagules in non-grazed treatments, while *Trichoderma* spp. were more abundant in CO and ASP treatments (ROESE et al., 2018), but the authors discuss that the greater diversity of vegetal species increased the *Trichoderma* spp. in ASP plots.

Cattle grazing play an important role in soil microbial ecology, and incorporating grazing in the grain production system requires careful planning and monitoring of the soil quality. It is important to mention that the soil samples were collected during and just after the grazing phase when the abundance of residues in non-grazed plots influenced the results. The temporal effect is also shown by the greater abundance of microorganisms in August than in November. Certainly, the correct (equilibrated) management of trees, grasses, cattle stock, and fertilization is the key to maintain the soil quality in intensified production systems, as pointed by Carvalho et al. (2010) and Pontes et al. (2017).

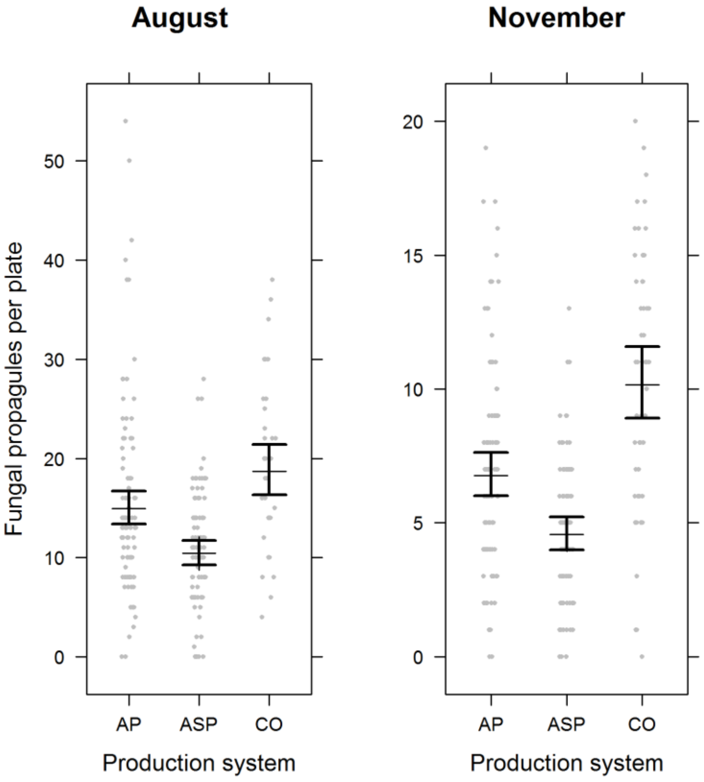

Figure 1. Total colony-forming units in Potato Dextrose Agar medium from soil samples collected twice (August and November) in three production systems: agropastoral (AP), agrosilvopastoral (ASP), and a non-integrated control (CO) in 2014 in the Region of Campos Gerais, Paraná State, Brazil. Bars shown the 95% confidence interval, the line crossing the bar is the estimated average and the points are the raw data.

CONCLUSIONS

Cattle grazing significantly influences the soil microbiota.

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HERBAGE MASS AND NUTRITIVE VALUE OF THE IPYPORÃ GRASS DURING ITS ESTABLISHMENT IN SILVOPASTORAL SYSTEMS IN SOUTHERN AMAZON

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ABSTRACT

The tolerance to the shade is the first characteristic to be observed in the choice of forage to form an integrated system with trees. This work aimed to evaluate the production and quality of forage in the establishment of *Ipyporã* grass in silvopastoral systems in southern Amazon. The experiment was carried out at Embrapa Agrossilvipastoril - MT - Brazil. Five treatments were evaluated: without trees; double rows eucalyptus in a density of 260 trees ha^{-1}; triple rows of 340 trees ha^{-1}; double rows in a density of 130 trees ha^{-1}; simple rows with a density of 120 trees ha^{-1}. In the Ipyporã grass formed under the treatments was evaluated the herbage, leaf, stem, and dead material mass, leaf protein, crude protein, NDF, ADF, canopy height, and volumetric density. The integrated system with the highest density of trees decreased the herbage and leaf mass, and increased the content of protein in the leaves. Crude protein, ADF, height, and leaf volumetric density were somewhat affected by the shade in the integrated systems and not only the tree density seemed to influence on them, but also the tree arrangement. Thus, tree density and arrangements should be carefully planned to better establishment of pasture in integrated systems.
Key words: Crude protein; iCLF; shading

INTRODUCTION

The ICLF strategy, in its several modalities, has sustainable agricultural technologies for the production of food with less environmental impact (ALMEIDA et al., 2019; BEHLING et al., 2013). In one of its modalities, the silvopastoral system, trees are included in the pasture, bringing improvements in microclimate and animal welfare, in the quality of forage and soil and in the mitigation of greenhouse gases (ALMEIDA et al., 2019). However, the trees alter the quantity and quality of the light that reaches the undergrowth, promoting changes in the establishment of the grass (PEZZOPANE et al., 2020). Information on the tolerance of materials available to the shading is still limited (ALMEIDA et al., 2019), and testing them in such conditions is essential for the correct management of forages in ICLF systems.

The forage tolerance to the shade is the first characteristic to be observed in the choice of a forage to form an integrated system with trees (ALMEIDA et al., 2019). The stage of establishing the pasture is the phase in which forage grasses are more sensitive to shading, however, grasses of the genus *Urochloa* can tolerate up to 50% of shade, maintaining satisfactory production (ALMEIDA et al., 2019). Thus, this work aimed to evaluate the production and quality of forage in the establishment of Ipyporã grass in silvopastoral systems in southern Amazon.

MATERIAL AND METHODS

This work was carried out at the experimental field of the Embrapa Agrossilvipastoril, Sinop, state of Mato Grosso – Brazil. The climate of the region following the Köppen classification is Aw. The soil was classified as Hapludox (Soil Taxonomy, 1999), with clay textures, in flat relief.

The evaluated treatments were: A – Control (without trees); B - double rows of eucalyptus (*Eucalyptus urograndis* clone H13) in a density of 260 trees ha^{-1} planted at the edges of the pasture with 50 m between the double rows of eucalyptus; C - triple rows of eucalyptus spaced 15 m apart at a density of 340 trees ha^{-1} within the pasture; D - double rows of eucalyptus in a density of 130 trees ha^{-1} planted at the edges of the pasture with 50 m between the double rows of eucalyptus; E - simple rows of eucalyptus spaced 21 m apart, with a density of 120 trees ha^{-1} within the pasture (Figure 1). The eucalyptus trees were planted in 2011.

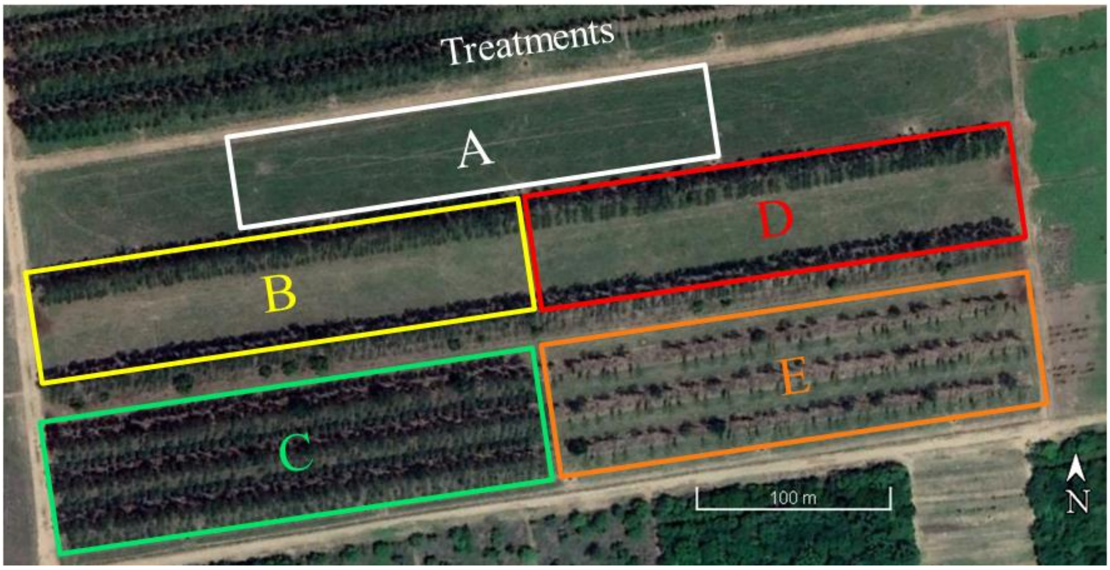

Figure 1. Distribution of treatments assessed in one of the experimental blocks.

The Ipyporã grass (BRS Ipyporã) is a hybrid developed by crossing *Urochloa ruziziensis* with *Urochloa brizantha* (VALLE et al., 2017). It was sowed in no-tillage between the last week of January and the first week of February, 2020, with spacing between rows of 0.45 m and sowing rate of 7 kg ha^{-1} of viable pure seeds, according to the minimum recommendations contained in Valle et al. (2017). The fertilization in the sowing line was 16 kg ha^{-1} of N, 56 kg ha^{-1} of P_2O_5, and 36 kg ha^{-1} of K_2O.

The experimental design was a complete randomized block with two replicates. Each plot of 1.5 ha was divided in 5 paddocks. Two samples of the forage mass from 1 m² template were collected in the 3 central paddocks of each treatment, making 12 samples for each treatment (2 blocks x 2 samples per paddock x 3 paddocks). The height of the grass at the time of the sampling was measured from 20 points per paddock with the aid of a graduated ruler. The forage collection was carried out at 15 cm (residue) from the soil surface at 70 days after the sowing of the grass, before the animals entered for uniformization grazing. The mass from 1 m² was weighed in the field with the aid of a digital scale, thus obtaining the green mass. A subsample was collected, taken to the laboratory, and separated into leaf, stem, and dead material, which were submitted to 65 °C until constant weight in a forced air circulation oven. Leaf and stem were subsequently milled at 1 mm of mesh size in the Willy mill and submitted to analysis for the determination of Protein, using the Dumas combustion method (SWEENEY, 1987), and NDF and ADF, according to the methodology described by Silva and Queiroz (2002). Data were subjected to variance analysis and means were compared by the Duncan test at 0.10 level of probability.

RESULTS AND DISCUSSIONS

The production of herbage mass was higher in A, B, and D treatments and the C showed the lowest value, around 3,000 kg DM ha^{-1} (Table 1). The highest value of herbage mass was around 3,600 kg ha^{-1}. Values like those also were observed by Echeverria et al. (2016) with the same material in pasture without trees. In the treatment C, a system with a higher density of trees, also had the lowest leaf production in relation to another treatments, and also lower stem production compared to the Control. The amount of dead material did not differ between treatments.

Table 1. Herbage, leaf, stem, and dead material mass, leaf protein, NDF, ADF, and crude protein of the *Ipyporã* grass in the assessed treatment.

Variable	**Treatment**					**SEM***
	A	**B**	**C**	**D**	**E**	
Herbage mass (kg DM ha^{-1})	3,612 A	3,525 A	2,963 B	3,351 A	3,630 A	99.40
Leaf mass (kg DM ha^{-1})	1,931 A	1,950 A	1,568 B	1,837 A	1,953 A	49.70
Stem mass (kg DM ha^{-1})	1,160 A	1,033 AB	883 B	995 AB	1,048 AB	42.57
Dead mass (kg DM ha^{-1})	521 A	542 A	512 A	519 A	629 A	31.66
Leaf protein (%)	17.3 B	19.5 A	19.2 A	17.8 B	18.0 B	0.24
Crude protein (%)	13.1 B	14.8 A	14.1 AB	13.5 B	13.2 B	0.22
NDF (%)	44.3 A	44.0 A	43.6 A	44.2 A	42.8 A	0.41
ADF (%)	21.4 A	20.4 AB	20.6 AB	20.8 AB	19.9 B	0.22
Canopy height (cm)	48.8 A	44.9 B	44.3 B	44.3 B	44.6 B	0.84
Herbage volumetric density (kg cm^{-1} ha^{-1})	74.4 A	78.8 A	70.1 A	77.5 A	82.0 A	2.44
Leaf volumetric density (kg cm^{-1} ha^{-1})	39.8 AB	43.9 A	36.5 B	42.9 AB	44.4 A	1.31
Stem volumetric density (kg cm^{-1} ha^{-1})	24.0 A	22.8 A	21.1 A	22.7 A	23.4 A	0.95

Means with the same letter in the line are not significantly different by the Duncan test at level of $p<0.10$. *Standard error of the mean.

Treatments Control, D, and E had the lowest leaf protein content compared to the treatments B and C (Table 1). The crude protein content was higher in treatment B, which differed from Control, D, and E. The levels of NDF did not differ between treatments, but the ADF was lower in the treatment E in relation to the Control. The Control was the treatment with the highest canopy height of *Ipyporã* grass, differing from all integrated systems, which presented the same average of height. Herbage and stem volumetric density were similar between the treatments, however, leaf volumetric density was higher in the treatments B and E, differing of the C. Herbage and stem volumetric density did not differ between the treatments, only leaf had different volumetric density in the treatment C compared to B and D.

The mass production of herbage and leaf in the establishment of the *Ipyporã* grass was influenced by shade in the integrated system with more tree density. As almost 10 years have passed since eucalyptus planting, the shade is more present and can affect more the plants growing under it, as here observed. Geremia et al. (2018) assessing the same treatment C, 3 years after eucalyptus planting, observed a decreasing of around 50% in term of herbage mass of *Urochloa brizantha* cv. Piatã under grazing compared to the Control treatment, without shade. Geremia et al. (2018) also observed increase in the crude protein in pasture shaded formed by Piatã, and no difference of NDF between the treatments. The increase in nutritional value of shaded grasses, especially in protein content, has been reported by some researches (ALMEIDA et al., 2019; PEZZOPANE et al., 2020). Treatment E showed the lower value of ADF than the Control, indicating a possible influence of the shade in the decrease of the components of lower digestibility in the Ipyporã grass. Leaf volumetric density indicated that the level of shade may influence the grass structure in terms of leaves, what should be a point of future investigations, mainly its effects on the animal production. The results presented here are initials, collected in a time in which the grass structure is not well-formed. Thus, only future evaluations will allow validating this material under grazing to compose iCLF systems.

CONCLUSIONS

The integrated system with the highest density of trees decreased the herbage and leaf mass of the Ipyporã grass in establishment and increased the content of protein in the leaves. In different ways, crude protein, ADF, and leaf volumetric density were somewhat affected by the shade in the integrated systems, in these cases, not only the tree density seemed to influence on them, but also the tree arrangement. All shaded systems reduced the height of the grass. Thus, tree density and arrangements should be carefully planned to better establishment of pasture in integrated systems.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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PASTURE SHADOWING REDUCES SEARCHES FOR WATER TROUGHS BY DAIRY COWS

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ABSTRACT

Shading pastures alters the animals' routine and may have an influence on their relationship with water. The objective was to assess the behavior of crossbred cows related to shade and the search for water in three systems: Full sun; Moderate shading and Intense shading. The experiment was conducted at Embrapa Agrossilvipastoril (Sinop/MT/Brazil) from summer 2017 to summer 2018. Behavior of dairy cows' observations were carried out in three typical days in each season, from 6 am to 6 pm. Univariate analyzes were performed by SAS® On Demand and multivariate (principal component analysis) by Excel. The full sun system stimulated a higher frequency of animals looking for the water trough and a longer stay around it, as well as a shorter stay in the shade combined with a lower frequency of animals in this location, being more associated with incident radiation than temperature and temperature and humidity index. When there was shade available in the shaded treatments, the observed relationships were just the opposite. Therefore, shading, even if moderate, contributes to lessen the discomfort of dairy cows caused by radiation; this radiation, which encourages animals to frequent and remain around water troughs.

Key words: radiation; shade time; silvopastoral

INTRODUCTION

The adverse climatic conditions of tropical regions may contribute to reduce milk production. In these regions prevail high air temperatures due to the high incident solar radiation associated with other elements like humidity and wind, that can cause heat stress in the animals, affecting their growth, milk production and quality, and reproduction. To relieve the excess of heat, animals make use of available possibilities in their environment, such as increasing water intake and searching for shadow. Therefore, the presence of these components is of paramount importance for soothing the thermal stress of the animal. Agrosilvopastoral systems have a great potential to provide a friendly environment for the cattle in the topics, improving thermal comfort through shading and consequently an ambience with mild temperature; bettering the nutritional value of the pasture; supplying food for animals through grazing or in troughs; reducing the seasonality in forage production and, consequently, increasing milk production. The objective of this study was to know the behavior of crossbred cows, regarding the search and permanence in places with shade and drinking troughs, submitted to two different shade regimes in agrosilvopastoral systems and in full sun pasture, managed under intermittent stocking in Mato Grosso, Northern Brazil.

MATERIAL AND METHODS

The experiment was carried out at Embrapa Agrossilvipastoril in Sinop, Mato Grosso state, Brazil. The experimental period was from December 2017 to March 2019 and the evaluations were conducted in the following seasons: Summer 2017, Autumn 2018, Winter 2018, Spring 2018, and Summer 2018. According to the Köppen-Geiger classification, the climatic type in the region is Aw – Tropical savanna, with presence of two well-defined seasons: rainy (from October to April) and dry (from May to September), and due to the small annual thermal amplitude, with monthly averages varying between 23.5° C and 25.5° C and maximum below 36 ° C, with annual water deficiencies ranging from 243.72 to 307.43 mm and water surpluses of 954.61 and 890.90 mm (MOTA et al., 2013 - Figure 1). The soil is classified as Latossolo Vermelho-Amarelo (SiBCS) or Ferralsol (WRB/FAO) and a flat relief (VIANA et al., 2015).

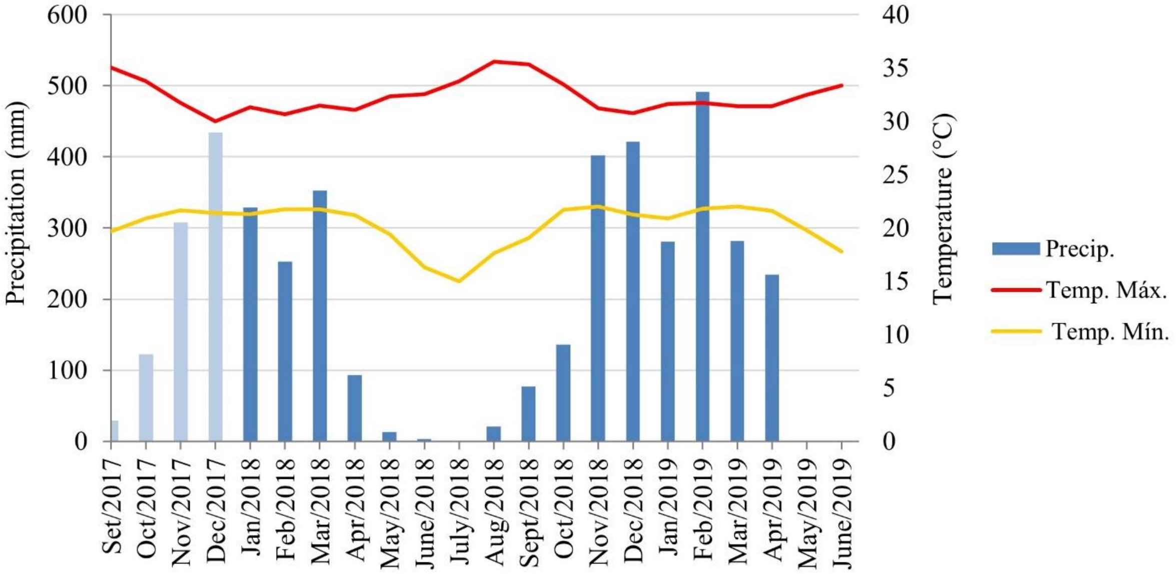

Figure 1. Microclimatic variables at the experiment site from September 2017 to June 2019. Accumulated monthly precipitation (mm), average maximum temperature (°C) and average minimum temperature (°C).

The experimental area of 10 ha was implemented with massai grass (*Megathyrsus maximus* cv. Massai) in three systems: full sun with restricted access to the shade (without trees - FSS), moderate shading (rows of trees spaced 52 m - MSS) and intense shading (tree rows spaced 15 m apart - ISS), with a useful pasture area of 2.4 ha. Eucalyptus (*E. urophilla* x *E. grandis* clone H13) were planted in 2010 (East-West Direction), with densities of 338 and 714 trees ha^{-1} in the moderate and intense shading systems, respectively. To evaluate animal behavior, six lactating crossbred Gir x Holstein cows were used in Summer 2017, Autumn 2018, Spring 2018, and Summer 2018, and eight in winter 2018 in each system. There were 25 observation times in three typical days of each season, from 6 am to 6 pm, every 30 minutes (MELLO et al., 2017). Due to the physiological responses presented by the cows in the full sun system, concomitant with the low relative humidity of the air and cloudiness, these cows were allowed access to the gate with partial shade, during the hottest times of the day (Access to shade: Summer 2017, between 1:00 pm and 2:00 pm; Autumn 2018, between 2:00 pm and 4:00 pm; Winter 2018, between 8:00 am and 9:00 am, and between 11:30 am and 2:00 pm; Spring, between 2:00 pm and 4:00 pm; Summer 2018, between 2:30 pm and 5:00 pm). In this context, it was necessary to consider that the animals of the full sun system had restricted access to the shade during the entire experimental. To assess the environmental conditions, temperature and humidity index (THI) was used and estimated by the equation of Thom (1959): THI = Tb + (0.36 x DPT) + 41.2; where Tb = dry bulb temperature in degrees Celsius; DPT = Dew point temperature (° C). For data analysis of animal behavior, the values of the hourly averages calculated for the season, the mean temperature and photosynthetically active radiation were used, on the days of the evaluation of the animal behavior in the range from 6 am to 6 pm. Microclimate variables were obtained from the averages of the meteorological stations of each system, that is, for the full sun system it was only the information of a station located in the center of the plot, whereas for the moderate shading system the averages of four stations, distributed perpendicularly between the rows were used, while for the intense shading system it was the average information from three meteorological stations, similarly distributed. The statistical analysis of the data was performed using the PROC MIXED procedure of the statistical package SAS® On Demand (SAS INSTITUTE INC, 2020). The data were subjected to analysis of variance using a model of repeated measures over time. In choosing the variance and covariance matrix, the Akaike Information Criterion (WOLFINGER, 1993) was used. The experimental design was in Randomized Complete Blocks with split-plot with the evaluation times being allocated to the subplots and the three sequential days of analysis, considered as replications in time. To assess the relationships between the studied behavior variables (frequency of cows in the shade, length of stay in the shade, frequency of visits to the water trough and time spent in the water trough), and of these with the systems in different seasons of the year in which they were measured, a principal component analysis (PCA) was performed on the data set.

RESULTS AND DISCUSSIONS

The time spent and frequency of cows in the shade were greater in the shaded systems (541 minutes day^{-1} and 63%, respectively, on average) compared to the full sun system (187 minutes day^{-1} and 19%, respectively) ($P < 0.10$). Meanwhile, the time spent at the water trough and the frequency of visits to the water trough were higher in the full sun system (27 minutes day^{-1} and 9.2%, respectively) compared to shaded systems (9.2 minutes day^{-1} and 1.2%, respectively, on average) ($P < 0.10$). Photosynthetically active radiation was higher in the full sun system (6.7 MJ m^{-2} day^{-1}) and intermediate in the moderate shading system (5.4 MJ m^{-2} day^{-1}) than in the intense shading system (3.0 MJ m^{-2} day^{-1}) ($P < 0.0001$). Higher values for average temperature and temperature and humidity index were obtained in winter 2018 (30.9 ° C and 78.7, respectively) ($P_{\text{temp and THI}} < 0.0001$).

From the principal component analysis, the first two components had eigenvalues above the unit and allowed to explain 82.78% of the variability between the observations, whose pattern could be associated with PC1. In turn, it was not possible to identify any pattern, neither for the systems studied nor for the seasons that could be associated with PC2. Considering that the variables associated with PC1 explain 53.82% of the variability, the influence of the shading level on animal behavior was more important than on the microclimate, since PC1 are more strongly associated with the time in the shadow, frequency to water troughs, time in water troughs and photosynthetically active radiation (PAR) and, although the square cosine of the frequency in the shadow was higher for PC2 (0.4821), the value is very close to the 0.4187 obtained for PC1, which indicates that this variable also contributes substantially to this component. The biplot in Figure 2 shows the correlations circle and the observations cloud in the plane of the first two principal components. The variables that showed the greatest contrast between the shading systems with the greatest association with PC1 were time spent in the shade (Shade time), frequency of visits of animals to the water trough (Water Freq), time spent in the water trough (Water time) and PAR. According to the correlation matrix (Pearson), it was found that the higher the frequency of animals in the shade, the greater the number of animals that remained in this location (+0.8732) and the less they frequented water trough (-0.6356), the less time they spent at this location (-0.6129). On the other hand, the more animals sought water trough, the longer they stayed there (+0.9464). Although slightly lower, the correlation between radiation and behavioral variables related to time spent in the water trough (-0.3830) and shade (+0.5069) were still significant, pointing to a tendency for there to be a greater influence of radiation with these animal behaviors than with temperature and THI (less than 0.1500).

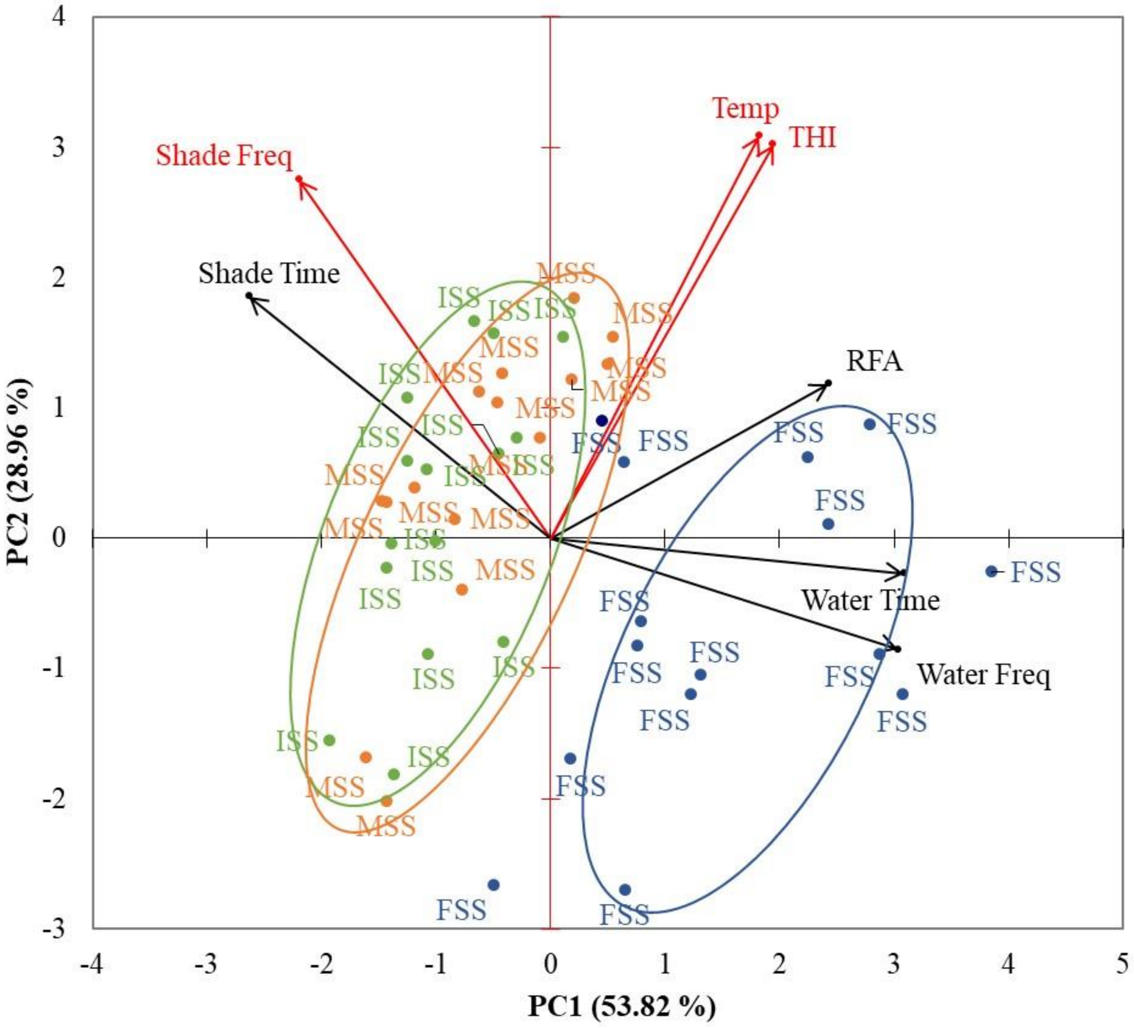

Figure 2. Biplot representation of the Principal Component Analysis (PCA) showing the correlation circle and observations cloud in the plane of the first two principal components. Full sun (FSS-Blue), moderate shading (MSS-orange) and intense shading (ISS-Green).

In the full sun system, animals spent less time in the shade due to restricted access, and having high incident radiation in this environment, more animals sought water troughs and stayed there longer. As the cows that were in the two shaded systems had available shadowing in abundant areas, even in the system with moderate shading, they looked for the places in the system where the shade was more intense and spent more time there. Consequently, the frequency of searching for the water trough was lower and they remained in this place for a short time, only presumably to quench their thirst. The opportunity of animals to search for areas where there was greater shading even in the system with moderate shading may explain the similar results observed in the behavior of animals that were subjected to systems of moderate and intense shading and their distinction with those that were placed in full sun. While, in shaded systems (MSS and ISS) the animals' behavior was similar to each other but opposite along the PC1 axis to the full sun system (FSS) (Figure 2).

The cows that were in the shaded systems showed a reduction of 66.7% in the time (minutes) spent in the water trough and 75% less visits to the water trough compared to full sun (27 minutes and 4%, respectively, on average). From the point of view of behavior, animals in shaded environments may seek more for other activities, being more active than animals in the system in full sun. Mello et al. (2017), also observed, in an experiment in the same place, that heifers in an environment with available shade visited less times the water trough, they stated that heifers visit the water trough more frequently to reduce body temperature, especially during peak hours, due to thermal discomfort, between 10 am and 3 pm. Therefore, shading, even if laterally to the paddock, contributes to alleviate the animals' thermal discomfort and allow an improved ambience for dairy cows.

CONCLUSIONS

Agrosilvopastoral systems by providing shade for animals, mitigate their needs for frequent search for water trough. Solar radiation on animals is a climatic variable that must always be considered in pasture-based dairy farming systems.

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STRUCTURAL FEATURES OF HUMIC ACIDS EXTRACTED FROM INTEGRATED CROP-LIVESTOCK-FOREST SYSTEM

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ABSTRACT

Soil organic matter (SOM) and their humic fractions (e.g., Humic Acids, HA) are considered a relevant soil quality indicator, due to its direct relation with biological, chemical and physical soil properties, permitting to evaluate agricultural management impacts. Soils under Integrated Crop-Livestock-Forest Systems (CLFS) have the potential to capture and sequester carbon, in the form of increasing SOM content, contributing to the mitigation of greenhouse gas emissions from agriculture. In this study aimed was characterization the HA extracted from CLFS and Native Forest (NF) soils using elemental analysis (CHN), fluorescence spectroscopy and electronic paramagnetic resonance (EPR). For this, samples of a dystrophic Red-Yellow Latosol (Oxisol) were collected from the experimental site of a research station called Embrapa Pecuária Sudeste (located in the Southeast of Brazil), five years after the implementation of the agricultural integrated systems. Results showed positive correlation between HA humification index with semiquinone-type free radical present in these soils (R = 0.69). Therefore, these results showed that HA from these integrated systems have a more stable and humified soil organic matter than in native forest, contributing to soil carbon compounds with higher chemical stability and possibly with longer lifetime in the soil.

Key words: Humic Acid; Characterization; Humification

INTRODUCTION

Soils under Integrated Crop-Livestock-Forest Systems (CLFS) potentially can capture and store carbon (C) as soil organic matter (SOM), contributing to the reduction of greenhouse gases[1], but it necessary to increase number of field sites evaluation with long duration experiments as well as to promote deeper soil analysis to better understanding of soil C storage mechanisms and about C compounds lifetime estimate in the systems. In addition, CLFS benefit from the more efficient use of natural and artificial resources, such as: improving soil and water quality, using fertilizers and agrochemicals efficiently, providing greater global productivity of rural properties, diversifying production systems, and minimizing possible negative impacts of climate change[2,3]. According to Minasny and collaborators[4], in the first twenty years after the use of appropriate management systems, soil carbon rates increased compared to the initial C stock. These authors have demonstrated that this system there is a potential to increase soil organic carbon (SOC) on agricultural land. The challenge is to find agricultural technologies that will further improve soil condition and increase C content, enabling sequestration and lowering emissions.

SOM plays an important role in the sustainability of production systems, as it is related to C and nutrient cycling, water retention, among other factors and is, thus, acting directly on issues of global climate change and agronomic studies. The structural features of SOM and their chemical fractions (e.g. humic acids - HA) are essential to understand the cycling and the arrangement of nutrients in the soil, since this matrix accumulates three times more C than the amount in the atmosphere and in the terrestrial vegetation. In this study aimed was characterization the HA extracted from Integrated

Crop-Livestock-Forest Systems (CLFS) and Native Forest (NF) soils using elemental analysis (CHN), fluorescence spectroscopy and electronic paramagnetic resonance (EPR).

MATERIAL AND METHODS

Study area

The field experimental area of 30 ha was in the Research Center of "*Embrapa Pecuária Sudeste*", São Carlos, São Paulo State, Brazil (21° 57'S, 47° 50'W) at 860m altitude, and the soils were classified as Red-yellow Latosol (Haplorthox by Soil taxonomy). The description of the CLFS was implanted with pasture (Piatã grass, *Urochloa brizantha* sin. *Brachiaria brizantha*) with rotating crops (corn, Zea Mays L. var.) every three years, and 333 eucalyptus trees per ha (Eucaliptys urograndis clone GG100). The NF is a reserve area of semi-deciduous Forest (Atlantic Forest, in a transition zone to Savannah biome, called Cerrado, in Brazil). For the CLFS samples, the sampling occurred at distances of 0.0 m and 7.5 m from the tree lines.

Sampling and extraction of the humic acids from soils

Soil sampling was carried out between February and April 2016, after five years of field experiment implantations. Composite samples were prepared at depths of 0–20, 20–30, 30–40, 40–60 and 60–100 cm for isolation of chemical fractions (HA) using the procedure recommended by the International Humic Substances Society[5]. Detailed information regarding fractionation methodology can be found in Tadini and collaborators [6].

Elemental analysis

The elemental composition of the whole soils and HA samples were analyzed by a C, H and N elemental analyzer (Perkin Elmer model 2400).

Fluorescence Spectroscopy

Fluorescence measurements were performed with a luminescence spectrometer (Model LS50B, PerkinElmer), using aliquots of 12.5 mg L^{-1} (pH 8.0) solutions of HA dissolved in 0.05 mol L^{-1} $NaHCO_3$. The methodology proposed by Milori and collaborators[7] was employed for determined the humification index (A_{465nm}). Emission-Excitation model (EEM) was acquired in the scan range between 240-700 nm for emission and 220-510 nm for excitation, according the Tadini and collaborators[6].

Electronic Paramagnetic Resonance (EPR)

The Bruker EMX spectrometer operating in the X band (9 GHz) was used of determining the EPR spectra of the HA samples. The conditions and determination were following recommendation by Simões and collaborators[8].

RESULTS AND DISCUSSIONS

Figure 1 show the C content from whole soil (a) and HA (b) samples from integrated systems (CLFS) and native forest (NF). Figure 1a showed a higher amount of carbon in the CLFS than in the NF, demonstrating the potential for carbon sequestration in these integrated systems as supported and described by Bernardi and co-authors[9]. In Figure 1b observed C content of HA ranges from 45 to 55% of all systems and the distance from the tree line (0.0m and 7.5m for CLFS) did not influence the accumulation of C content in the whole soil (Figure 1a) and the humic fraction (Figure 1b).

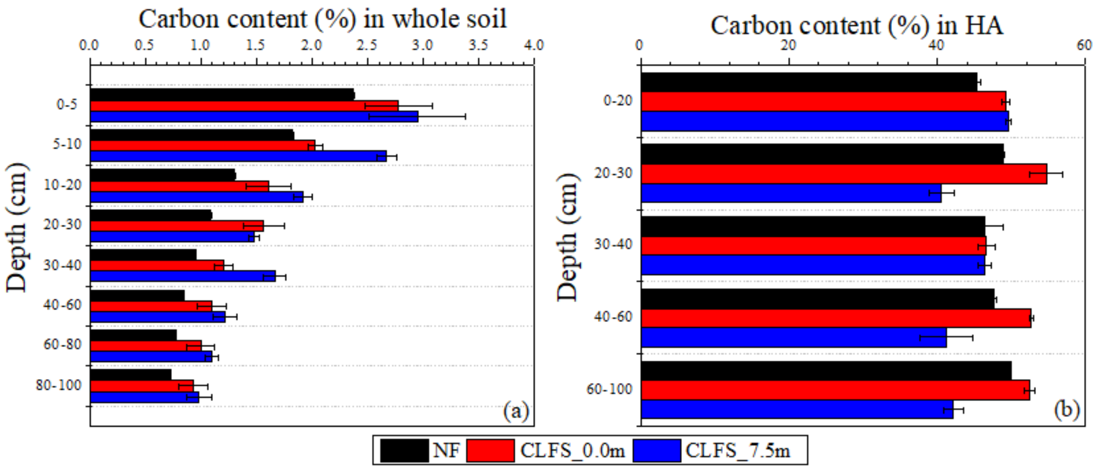

Figure 1. Carbon content (C%) of whole soil (a) and HA (b) samples from Native Forest (NF) and Integrated Crop-Livestock-Forest Systems (CLFS).

The results by EPR showed range from 8.8x10^{+17} to 4.8x10^{+18} g C^{-1} semiquinone-type free radical for all samples evaluated in this study, which the CLFS have more values than NF. In the literature, these values are higher range found in Gonzaléz-Pérez and collaborators[10] for soils of the Oxisol soil and other studies in the literature, which it shown semiquinone-type free radical values ranging from 0.3x10^{+16} to 2.4x10^{+18} g C^{-1} for soil HA[10-12]. Figure 2, showed the positive correlation (R=0.69) with Humification Index (A_{465nm}) vs. EPR (g C^{-1} spin) from CLFS and NF samples. Thus, this result conclude the HA there are more stable organic matter with complex structure (such as aromatic groups) and humified in the deeper layers.

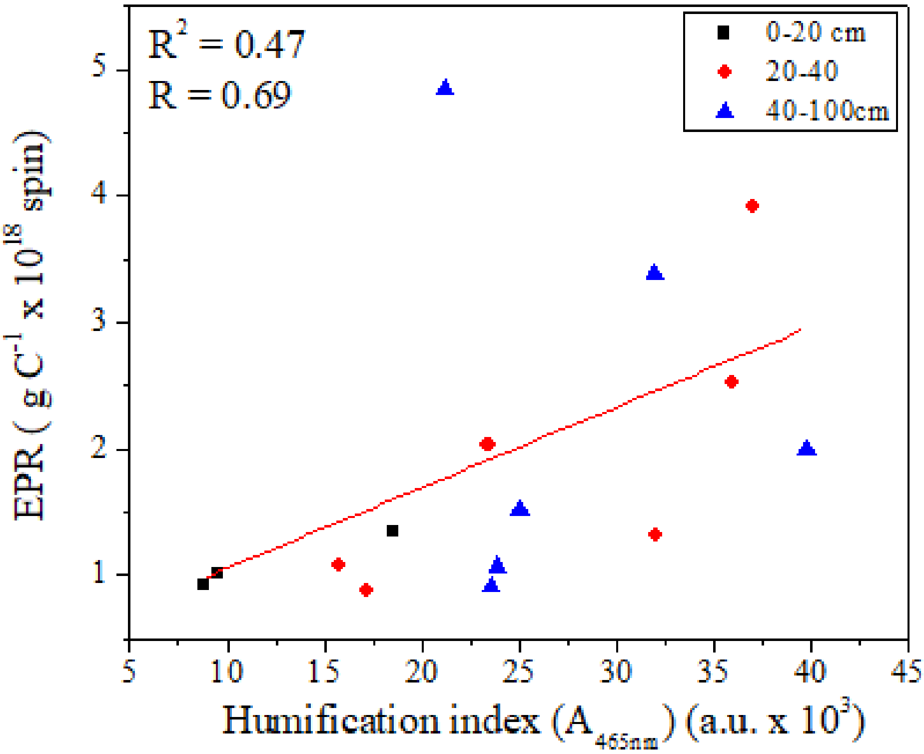

Figure 2. Correlation graph with Humification Index (A_{465nm}) *vs.* EPR (g C^{-1} spin) from HA samples of the NF and CLFS systems evaluated in this study (highlighted square black, red point and blue triangle represent the 0–20, 20–40 and 40–100cm layers, respectively).

CONCLUSIONS

The integrated Crop-Livestock-Forest systems (CLFS) showed positive correlation between HA humification index with semiquinone-type free radical present in these soils (R = 0.69). Therefore, the HA of these integrated systems have a more stable and humified soil organic matter than in native forest, contributing to soil carbon compounds with higher chemical stability and possibly with longer lifetime in the soil.

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INTEGRATED CROP-LIVESTOCK SYSTEM: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

The integrated crop-livestock system (ICLS) allows you to optimize and maximize agricultural, livestock and forestry production. In order to visualize the characteristics of research in integrated systems, a bibliometric analysis carried out in the scientific literature. The data extracted from the Web of Science (WoS) through the selection of specific research fields for ICLS. The articles exported into the VOSviewer software, and a bibliometric map produced with the main clusters and interconnections of application. ICLS1 articles have more frequent fields for systems, growth, dynamics, pasture, plant management, biodiversity and carbon sequestration. Already, the articles of ICLS2, management, system, sustainability, agriculture, livestock and integration. Four clusters formed for ICLS1 and ICLS2 using keyword co-occurrence. The ICLS1 clusters cover topics such as: “growth, characteristics and effects of integration in this system”, “silvopastoral system and climate change, agricultural landscapes and sustainability”, “system and the effects on the soil and plants, especially nitrogen” and “carbon dynamics in the system”. At ICLS2, the studies cover: “dynamics, intensification and farming systems”; "management, systems and sustainability", "performance of the integration system" and "nitrogen, carbon and other soil attributes in planting systems".

Key words: Integration; Interconnections; Sustainability

INTRODUCTION

Integrated systems reach 25 million km^2 worldwide (BELL; MOORE, 2012); they are technological proposals that combine in space-time: agriculture, animals and / or forest, through intercalary, sequential or rotational systems (BALBINO et al., 2011; ASSIS et al., 2017). These allow optimizing and maximizing the production of food, bioenergy, water and forest products, in addition to the environmental and socioeconomic benefits generated (ASSIS et al., 2017).

According to Sulc and Franzluebbers (2014), integrated systems have the potential to provide ecosystem services and profitability. However, to perform them, appropriate technologies, institutional arrangements, support policies and specialization in the activity are required (WRIGHT et al., 2012).

Therefore, this article uses bibliometric analysis to explore ICLS systems in the academic literature; and thus, obtain an overview of the characteristics, dynamics, strengths and deficiencies.

MATERIAL AND METHODS

The research for this review focused on the main aspects involving crop-livestock-forest integration systems (ICLS). For a better understanding of the results, we divided into two structures: ICLS1 that have in the term the forest component (crop-livestock-forest; crop-forest; livestock-forest; silvopastoral; agrosilvopastoral); and ICLS2 as the main term crop-livestock. The data extracted from the Web of Science (WoS) due to its scope in relation to the subject, high quality studies and availability of multidisciplinary academic data (DE SOUZA et al., 2019). In the WoS, for the research, the field called “every year” until August, 2020 (ICLS1) e December, 2020 (ICLS2) used, that is, until the date that can be easily accessed and with relevant information (DE SOUZA et al., 2019). The “advanced search” field accessed; and selected data based on titles, abstracts and keywords (DE SOUZA et al., 2019); restricting the results by studies in "English" and document type "Article".

As a result, 691 articles found for ICLS1 and 1219 articles found for ICLS2. The publications exported in WoS format for further analysis in the VOSviewer software version 1.6.15. In the VOSviewer software, bibliometric maps created using the previous exported database from WoS. The web of the fields of science from which the terms extracted were the “keywords”, and the co-occurrence type analysis was selected with a minimum number of 10 occurrences (DE SOUZA et al., 2019).

To measure the similarity of the keywords based on the number of times they occurred together in different articles, the co-occurrence analysis is used, which provides information on the main other keywords linked to ICLS, and therefore, can be used to assess the knowledge structure of the field (Humboldt-Dachroeden et al., 2020). Thus, through the keywords presented, Figure 1 (ICLS1) and Figure 2 (ICLS2) were generated. Based on the results of bibliometric mapping and during the development of writing, the main application clusters and interconnections described and discussed.

RESULTS AND DISCUSSIONS

The theme “crop-livestock-forest integration systems” has gained strength in the scientific community in recent years. We found 691 articles in the WoS for ICLS1, which are part of most journals such as Agroforestry Systems (186 articles), Cuban Journal of Agricultural Science (27), Agriculture Ecosystems Environment (25), Forest Ecology and Management (16), Tropical Grasslands Forrajes Tropicales (16), Grass and Forage Science (14), Rangeland Ecology Management (10) and others less than 10 articles. For ICLS2, the 1219 articles comprise, most of them, journals such as: Agricultural Systems (121 articles), Agriculture Ecosystems Environement (58), Tropical Animal Health and Production (24), Agroforestry Systems (23), European Journal of Agronomy (23), Brazilian Journal of Soil Science (23) and others with less than 23 publications.

Interconnections observed in the system. Four clusters were formed for ICLS1 and have fields of greater frequency for systems, growth, dynamics, pasture, plant management, biodiversity and carbon sequestration; and these have strong interconnections with other fields of science that appear less frequently. The co-occurrence network formed from these fields leads to studies of “growth, characteristics and effects of integration in this system”, they have 38 forming items and are part of cluster 1. Cluster 2 is about “silvopastoral system and climate change, agricultural landscapes and sustainability” and has 25 training items. Cluster 3 is about the “system and the effects on the soil and plants, especially nitrogen” and has 17 forming items. Cluster 4 is about the “carbon dynamics in the system” and has 15 training items.

For ICLS2, the most frequent fields are management, system, sustainability, agriculture, livestock and integration. Cluster 1 is about “dynamics, intensification and farming systems” and has 60 training items; cluster 2 involves “management, systems and sustainability” and has 47 training items; cluster 3 involves studies of “performance of the integration system” and has 44 training items; cluster 4 is about “nitrogen, carbon and other soil attributes in planting systems” and has 43 forming items.

The integration of crops with agricultural systems can provide improvements in the regulation of biogeochemical cycles, reduction of environmental flows into the atmosphere and hydrosphere through spatial and temporal interactions, a more diversified and structured landscape mosaic to favor habitats and trophic networks, flexibility of all the system for dealing with potential socio-economic risks and crises caused by climate change (LEMAIRE et al., 2014). However, according to the aforementioned authors and, Soussana et al. (2010) and Carvalho et al. (2010) the level that these services provided depends on the local management, types of cultures, edaphoclimatic conditions and management.

ICLS modalities have been strongly used to reverse degradation processes or unproductive areas, however, they can still be used in areas with grain crops in which the introduction of grasses aims at covering the soil for a no-tillage system, making it possible, in off-season, opportunity for use in feeding cattle; pasture-crop rotation areas to intensify land use and synergies in activities; in livestock areas for protection from climatic extremes with the introduction of the forestry component; among other practices that enable sustainability and benefits to the system (VILELA et al., 2011).

The determination of the system will depend on the region's economic and geographical characteristics, access to financial incentives or development programs, agricultural facilities and farmer skills, production techniques, as well as cultural aspects (BALBINO et al., 2011; GALFORD et al., 2013).

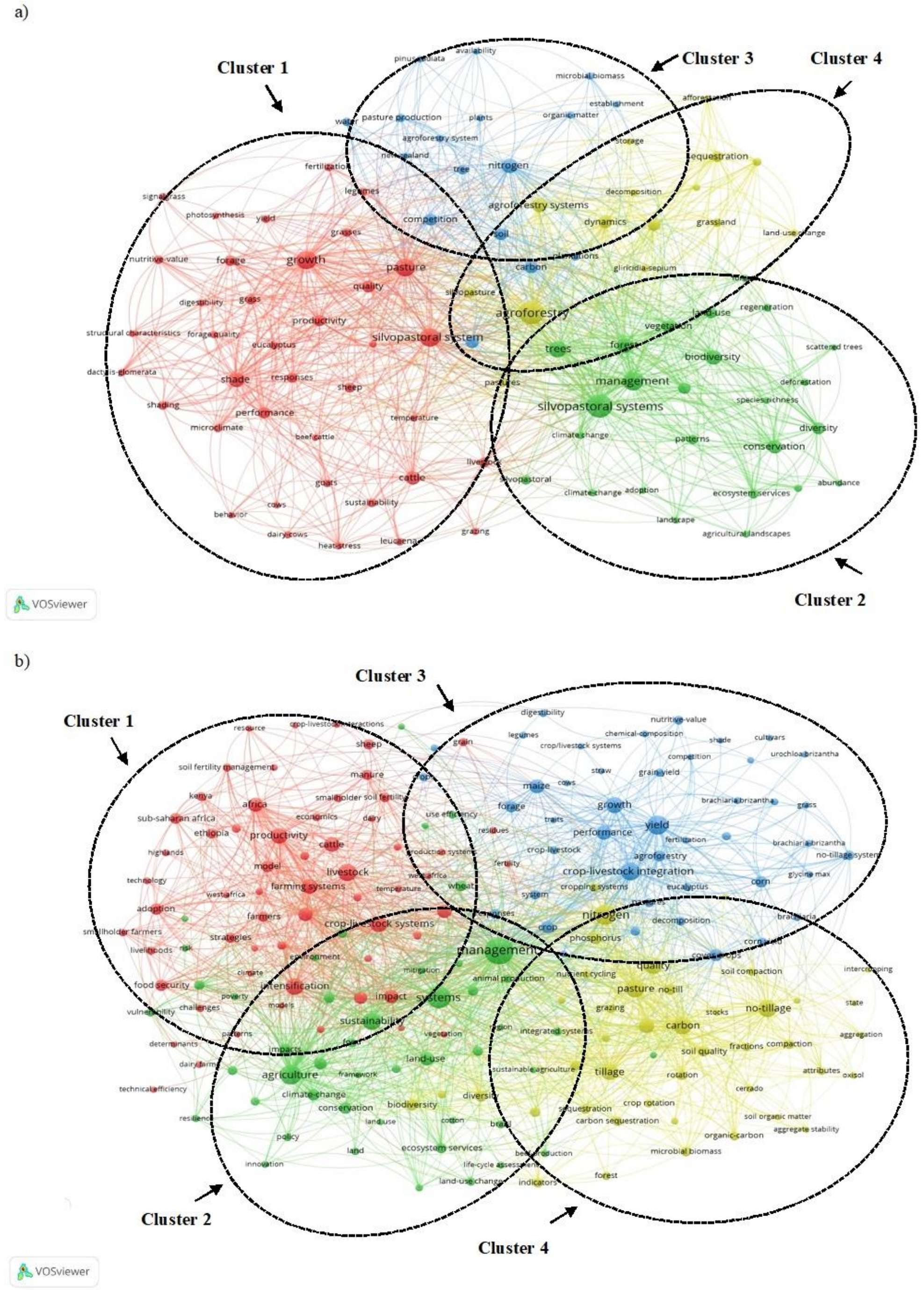

Figure 1. Combined mapping of the most frequently cited author's keywords for ICLS1 (a) and ICLS2 (b) using the WoS database. Source: Prepared from the bibliographic survey at WoS.

CONCLUSIONS

The research focuses on the main aspects involving integrated crop-livestock systems. The availability of multidisciplinary academic data on the Web of Science (WoS) allowed exploring and working on bibliometric analysis. Through this, the generated map and field webs made it possible to explore the main application clusters and interconnections of the theme in question. ICLS1 articles have more frequent fields for systems, growth, dynamics, pasture, plant management, biodiversity and carbon sequestration. Whereas, the articles of ICLS2, management, system, sustainability, agriculture, livestock and integration.

Four clusters formed for ICLS1 and ICLS2 using keyword co-occurrence. The ICLS1 clusters cover topics such as: “growth, characteristics and effects of integration in this system”, “silvopastoral system and climate change, agricultural landscapes and sustainability”, “system and the effects on the soil and plants, especially nitrogen” and “carbon dynamics in the system”. At ICLS2, the studies cover: “dynamics, intensification and farming systems”; "management, systems and sustainability", "performance of the integration system" and "nitrogen, carbon and other soil attributes in planting systems ".

Studies have advanced in recent years to the potential of integrated systems as a means of intensification, carbon sequestration; land use changes; climate change and others; and it showed the capacity of these systems to meet several global objectives.

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AGROFORESTRY SYSTEMS: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

Agroforestry systems are adopted as a way to meet sustainable production. In order to visualize the characteristics of the research in agroforestry systems a bibliometric analysis carried out. The data extracted from the Web of Science (WoS) through the selection of specific research fields for agroforestry systems. As a result, 2.479 articles were found and analyzed in the VOSviewer software, and a bibliometric map was produced with the main clusters and application interconnections described. The 2.479 articles cover most fields such as agroforestry, systems, biodiversity, growth, productivity, biomass and carbon sequestration. Four clusters formed through interconnections: "plant growth and productivity in agroforestry systems", "biodiversity, management and ecosystem services", "carbon dynamics, biomass and nitrogen in the soil" and "agroforestry potential for food security, changes in land use and sustainability”. Studies have advanced in recent years to the potential of agroforestry systems as a means of intensification, carbon sequestration; land use changes; climate change and others; and it showed the capacity of these systems to meet several global objectives.

Key words: Clusters; Environment; Integration

INTRODUCTION

Agroforestry systems have been used as strategies to meet food production, energy generation and land use in a more sustainable way (GEORGE et al., 2012). The combination of agricultural, livestock and or forestry activities translates into greater economic return, positive impacts on edaphic, microclimate conditions and favoring annual carbon sequestration (MBOW et al., 2014; ZOMER et al., 2016; TORRES et al., 2017; CÓRDOVA et al., 2019).

Agroforestry systems assumes important roles in different areas and environments. There are many initiatives to change the use of traditional production systems to more “green” alternatives and with better use of global resources. Research on agroforestry systems integrates several areas and advancing on this multidisciplinarity can be the path to increasingly sustainable gains (ZERMEÑO-HERNÁNDEZ et al., 2016; BROOM, 2019).

This study uses bibliometric analysis to explore agroforestry systems in the academic literature and to visualize characteristics, dynamics, potentials and deficiencies.

MATERIAL AND METHODS

The research for this review focused on the main aspects involving agroforestry systems. The data extracted from the Web of Science (WoS) and the field called “every year” until August 11, 2020 used. The field “advanced search” was accessed; and selected data based on titles, abstracts and keywords. The combination of words was for agroforest * system * restricting the results by the “English” language and “Article” type document (DE SOUZA et al., 2019).

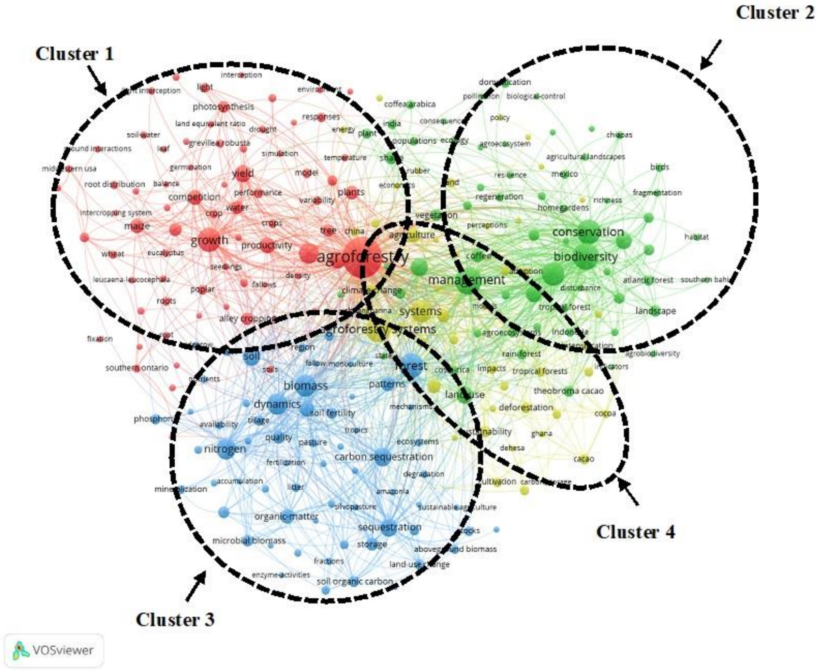
The 2.479 articles found in this search exported in WoS format for further analysis in the VOSviewer software version 1.6.15. In the VOSviewer software, bibliometric maps created using the previous exported database from WoS. The web of the fields of science from which the terms extracted the “keywords”, and the co-occurrence type analysis selected with a minimum number of 15 occurrences of a term, in order to measure the similarity of the keywords based on the number of times they occurred together in different articles. Thus, through the keywords presented, Figures 1a and 1b generated. Based on the results of bibliometric mapping and during the development of writing, the main application clusters and interconnections described and discussed.

RESULTS AND DISCUSSIONS

The theme of agroforestry systems has gained strength in the scientific community in recent years. Based on the research, 2.479 articles were found in the WoS, which integrate most of the journals such as Agroforestry Systems (691 articles), Agriculture Ecosystems Environmental (124), Forest Ecology and Management (76), Plant and Soil (43), Range Management and Agroforestry (28), Forests (26), Biodiversity and Conservation (25) and less than 25 publications.

In the present study, the interconnections and interdisciplinarity of agroforestry systems observed (Figures 1a and 1b). Four clusters (Figure 1a) were formed and have more frequent fields (DING; YANG, 2020) for agroforestry, systems, biodiversity, growth, productivity, biomass and carbon sequestration; and these have strong interconnections with other fields of science that appear less frequently. The co-occurrence network formed from these fields leads to studies of “plant growth and productivity in agroforestry systems”, “biodiversity, management and ecosystem services”, “carbon dynamics, biomass and nitrogen in the soil”, and “potential agroforestry for food security, climate change, land use and sustainability”.

In Figure 1a, Cluster 1 is about “plant growth and productivity in agroforestry systems”, has 73 forming items. Cluster 2, involving “biodiversity, management and ecosystem services”, has 63 items. Cluster 3 is about “carbon dynamics, biomass and nitrogen in the soil”, has 63 items. Cluster 4, involves the “potential of agroforestry for food security, climate change, land use and sustainability”, has 47 items.



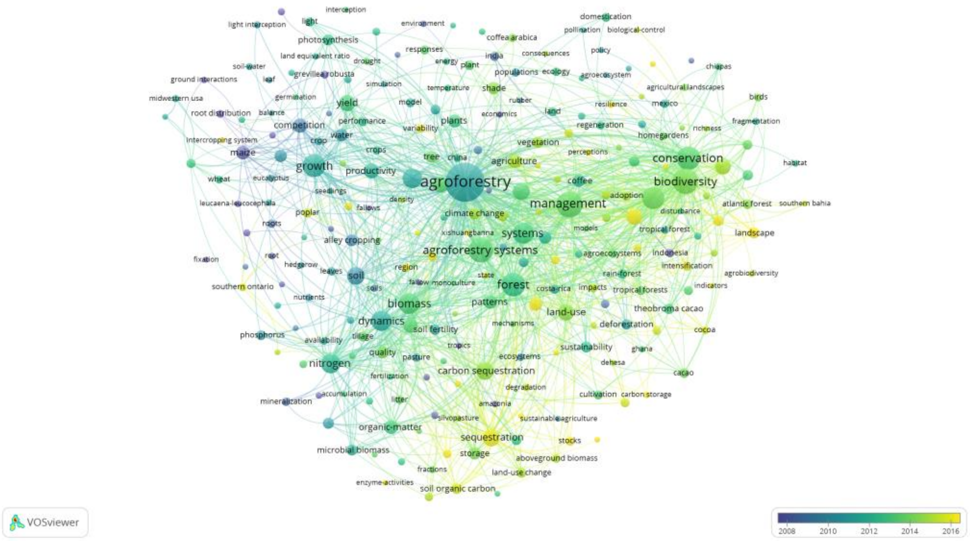


Figure 1. Combined mapping of the most frequently cited author's keywords (a) and overlap, related to co-occurrence and average publication scores per year (b) that emerged in the area of agroforestry systems using the WoS database. Source: Prepared from the bibliographic survey at WoS.

The fields of science for agroforestry seem to have a dynamic of overlap that varies over time (Figure 1b). In almost all subdomains of the agroforestry theme, as of 2014, there were frequent keywords for climate change and carbon sequestration. However, before 2014 a different context was observed. This co-occurrence allows us to visualize possibilities in serving different fields of science, especially for the challenges imposed on sustainable production, which may include the existing premises for One Planetary.

There is a search for balance and sustainable exploitation of natural resources; so that the demand for food can be met, human, animal well-being; without harming nature. Agroforestry systems can bring different positive effects, mainly due to the combination of production values and biodiversity compared to other conventional agricultural and livestock systems (SAGASTUY; KRAUSE, 2019). The adoption of agroforestry systems will depend on the region's economic and geographical characteristics, access to information, education, attitudes and relational capital (ZEWELD et al., 2018). To achieve them, appropriate technologies, specialization in the activity, institutional arrangements and support policies are necessary (BORREMANS et al., 2018).

CONCLUSIONS

Agroforestry systems play important roles in different areas and environments. The articles of agroforestry systems have fields of greater frequency for agroforestry, systems, biodiversity, growth, productivity, biomass and carbon sequestration.

Four major clusters formed through interconnections: "plant growth and productivity in agroforestry systems", "biodiversity, management and ecosystem services", "carbon dynamics, biomass and nitrogen in the soil" and "agroforestry potential for food security, changes in land use and sustainability”.

Studies have advanced in recent years to the potential of agroforestry systems as a means of intensification, carbon sequestration; land use changes; climate change and others; and it showed the capacity of these systems to meet several global objectives.

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THE EFFLUENT OF PINEAPPLE CROP WASTE SILAGE CAN BE COMPONENT OF FERTIRRIGATION SYSTEMS

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ABSTRACT

Aimed characterize the effluent of pineapple crop waste (PCW) silage. Experimental silos were made to collect the generated effluent, harvested totally at zero (D0), one (D1), 30 (D30), 60 (D60) 90 (D90) and 120 (D120) days after ensiling. Were analyzed pH, potential of ox reduction (PO), electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), salinity (SAL) and effluent production. Macronutrients values was obtained by sample pooling throughout the period. EC at D0 was lower than D1, D30 and D120, while the lowest DO occurred at D0. There was no difference in TDS and SAL in relation to the days, with averages of 5.70 g L^{-1} and 5.07‰, respectively. The pH presented quadratic behavior (R^2=0.685). PO decreased as a function of days (R^2=0.7087), while production increased (R^2=0.998). TDS and SAL were a high correlation between these and the other variables evaluated, besides a high correlation between pH and EC and between EC and TDS, pH, DO and SAL. Total N, P_2O_5 and K_2O were 0.2, 1.4 and 0.4%, respectively. We concluded that effluent of PCW can be considered a wastewater with pollutant power and potential for fertirrigation use in agricultural systems.

Key words: *Ananas comosus*; integrated systems; leaching

INTRODUCTION

The challenge of increasing food production, reducing the environmental impacts inherent to the processes, necessarily demands sustainability strategies, based on the recovery or reuse of natural resources, through synergistic actions between agriculture and livestock and waste from production processes. As a consequence of the rational use of such resources, decrease market demands on sustainable initiatives in the productive environment (BINI et al., 2018), in addition to the possibility in several cases, to allow the creation of a new product, with financial, environmental and social viability.

Brazilian pineapple production (*Ananas comosus*) reached, in 2018, 1.7 billion fruits in more than 71 thousand hectares in planted (IBGE, 2019). The pineapple crop waste (PCW) is made up of plants that remain in the field after harvest fruits and seedlings, producing approximately 15.4 tons of green matter per hectare. In several producing regions, the dry period of the year coincides with the improvement of the harvest, proving to be a very viable alternative for dairy production, since administered with due care together with supplementation (FAGUNDES; FAGUNDES, 2010).

However, the PCW storage processes lead to the formation of effluents, being greater in ensiled material, due to the fermentation process. Such effluent, as well as that of all ensiled materials, high power of pollution of the soil and water due to the excess of leached organic material. As a result, research has already been carried out that suggest alternatives for capturing and using these effluents in integrated systems, by fertirrigation (SOUZA, 2015).

The scarcity of studies on PCW silage in animal nutrition and its effluent are factors that justify the performance of this work, in order to obtain more information about these nutritional elements, mainly of its effluent. Thus, the objective of this work was to characterize the effluent generated by the waste silage from the pineapple crop.

MATERIAL AND METHODS

The PCW ensiling was carried out three days after the pineapple cv. pérola harvest in a conventional production property in the Frutal (Minas Gerais, Brazil, 20º01'97"S, 48º56'26"W). The PCW was composed of pineapple leaves, containing fruits with crowns in approximately 12% of the feet, cut about 10 cm from the soil, with an average particle size of 15 mm^2, with 17.7% of dry matter. Samples of the material were immediately obtained, which was compacted at a density of 520 $kg.m^{-3}$ in experimental silos made with PVC tubes with volumetric capacity of 47.12 dm^3, containing a drain for the total collection of effluent.

The characterization of PCW silage effluent occurred in D0, D1, D30, D60, D90 and D120, using a U-50 multiparameter meter (Horiba™) that determined the pH, PO, EC, DO, TDS and SAL. Effluent in D0 was obtained by manual pressing of the fresh PCW while on the other days the complete collection of the effluent was carried out. The volume of effluent production was carried out through total collection by draining the silos. For nitrogen (N), phosphorus (P) and potassium (K) analysis, according to EMBRAPA (2009).

The analyzes of pH, PO, EC, DC, TDS, SAL and effluent production occurred with six days of collection (0, 1, 30, 60, 90, 120) and four replications (experimental silos). In the determination of N, P and K the analyzes were carried out with three repetitions. Statistical analyzes were made in GraphPad Prism™ statistical program 5.0, by obtaining a regression curve for pH, PO and effluent production and analysis of variance using Tukey test with 95% significance level ($p < 0.05$) for the variables CE, DO, TDS and SAL.

RESULTS AND DISCUSSIONS

The EC means was 10.11 $mS.cm^{-1}$ (Table 1), being lower in D0 compared to D1, D30 and D120 ($p < 0.05$). Determination of EC in a solution considers the passage of electrical current between the electrodes subjected to a solution with ions, being a low-cost measure that can determine the amount of organic matter present in a solution or, in the case of substrates, the amount of fertilizers applied to the material (MOTA et al., 2017).

Higher DO values ($p < 0.05$) were observed from D1, when compared to D0. DO characterizes the volume of O_2 contained in aqueous media and determines the ability of aquatic organisms to survive and the polluting potential of effluents. Because they have low DO values and a high load of microrganisms, including aerobic, silage effluents, a small amount of this material (1L) has capacity to deplete the DO of up to 10m^3 of water (GEBREHANNA et al., 2014).

In search of wastewater treatment strategies for processing coffee, Matos; Eustáquio Junior; Matos (2015) did not observe DO in the evaluated material (DO = 0). According to the mass oxygen consumption, initiated in the ensiling process, by aerobic microorganisms from the forage, a decrease in the DO was expected. Two hypotheses can justify the unexpected result mentioned above: the exposure of the effluent to oxygen may have favored the increase in DO concentrations from D1, since the collection lasted for the entire period of the effluent leaving. The second results from the method of obtaining the sample in D0, since it occurred through pressing, instead of collecting the leachate, from D1.

The average DO value of the PCW effluent during the ensiling period was 7.07 mg L^{-1}. In a compilation of studies of aquatic environments in the Amazon Basin, Silva (2012) reports values between 0.17 and 9.21 mg L^{-1}, highlighting the high variation of data and that the DO values have a negative correlation (R^2 = -0.7518) in relation to the biological oxygen demand, showing that the amount of organic matter in an effluent has control inversely proportional to the DO concentrations.

There was no variation in the TDS values, with an average of 5.70 g L^{-1} throughout the evaluated period. The values found are lower than those obtained by Bernardino et al. (2005), who observed between 21.71 and 27.21 g L^{-1} of TDS in elephant grass silage effluents (*Pennisetum purpureum* Schum.), with dry matter of 12.4%. The variation between the experiments can be justified mainly by the fact that the authors mentioned performed collections only between the first and seventh days of ensiling, a period when maximum solids leaching of mass occurs (BORREANI et al., 2018). Thus, a lower TDS was expected with the increase of the ensiling period, which was not observed.

Berger et al. (2013) evaluated the material from the biodigestion of the starch effluents, observing a correlation (above 0.6) between the total solids values and the EC. These values indicate that the presence of solids is related to the increase in EC, due to the electrical charges contained, mainly in the dissolved salts. Corroborating with the absence of TDS variations ($p \geq 0.05$) during the ensiling period, no variation was observed in the salinity of the PCW silage effluent, with an average of 5.05‰.

The pH of the PCW silage effluent proved to be acid, even before the compaction of the material (3.49). Regardless of the material, the pH of the effluent produced by the ensiling process keeps it close to pH 4 or below that, in some conditions. This fact occurs due to the specific fermentation profile of a silo, which seeks precisely the acidification of the medium for the conservation of the material (VILELA; VEIGA, 2003).

Considering the use of PCW silage effluent, Xu et al. (2010) quote that the inclusion of acidic wastewater in crop irrigation may be of agricultural interest, due to the absorption of existing nutrients by plants, enabling increased productivity. However, it also highlights that, gradually, this process leads to acidification of the soil, suggesting that its use must be accompanied by techniques to correct the acidity of the soil, such as liming.

Table 1. Means, coefficient of variation (CV%), regression equations and determination coefficient (R^2) of electrical condutivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), salinity (SAL), pH and production of pineapple crop waste silage effluent in days 0, one, 30, 60, 90 and 120 after ensiling.

Variable	**D0**	**D1**	**D30**	**D60**	**D90**	**D120**	**Means**	**CV%**
EC (mS cm^{-1})	7.53^{B}	10.85^{A}	11.55^{A}	10.15^{AB}	9.64^{AB}	11.10^{A}	10.11	14.14
DO (mg L^{-1})	2.71^{B}	7.99^{A}	8.02^{A}	7.96^{A}	7.91^{A}	7.85^{A}	7.07	24.30
TDS (g L^{-1})	4.75^{A}	5.97^{A}	6.05^{A}	5.31^{A}	6.03^{A}	5.91^{A}	5.70	22.95
SAL (‰)	4.10^{A}	4.97^{A}	5.73^{A}	4.73^{A}	5.33^{A}	5.33^{A}	5.07	21.39

	Regression equation	**R^2**
pH	$y = 4.046 + 0.08239x - 0.001537x^2 + 0.000007359x^3$	0.685
DO	$y = -0.6250 + 162.7x$	0.7087
Effluent production	$y = 0.0838x + 5.999$	0.998

Means with different letters on the line differ statistically by the Tukey test ($p<0.05$).

Ribeiro (2014) applied treated solid sewage in the fertirrigation of corn, cotton and beans crops in succession, with the objective of supplying potassium (K) between 50% and 200% of the recommendation for these crops. It was observed that in the layer up to 0.2 m of soil depth, there was a reduction in pH, exchangeable calcium, base sum and saturation and potential cation exchange capacity, in addition to an increase in potential acidity. Despite this, there was no risk of toxicity to the plants, with savings of 50% of the water required for the crops, in addition to reducing 65, 69 and 49.5% of nitrogen (N) and 42, 83 and 41% of P_2O_5, respectively, in corn, cotton and beans.

Depending on the days after silage, there was a decrease with a linear trend ($R^2 = 0.7087$) of the PO of the PCW silage effluent. In contrast, the production of effluent occurred in a linear manner ($R^2 = 0.998$) throughout the experimental period. Such production has relation with factors such as the ensiled plant material, size of the particle cut and the stage of the fermentation process. However, the most determining factor in relation to the volume of effluent production is the moisture content of the forage at the time of cutting (VILELA; VEIGA, 2003).

In this way, each process has a pattern of effluent production during ensiling that can be estimated using specific equations. In this work, it is possible to observe the production with a linear trend, as opposed to what was stated by Vilela and Veiga (2003), which mentions that most effluent production occurs up to four days after ensiling. report linear effect of effluent production occurred up to 120 days, probably justified by the vertical shape of the experimental silos, and the equation $y = 0.0838x + 5.999$, it was estimated, in the experimental period, a production of 160.55 L t^{-1} of effluent per ton of dry matter, or 28.06 L t^{-1} of green matter.

Due to the variations in the values of EC, DO, pH and PO, the correlation matrix between each of the parameters was determined. Although there was no variation ($p < 0.05$) in TDS and SAL depending on the days after ensiling, there was a high correlation between these and the other variables evaluated (Table 2).

Table 2. Correlation matrix between the physical-chemical parameters evaluated as a function of the days after silage of the wastewater silage from the pineapple crop in experimental silos[1].

Variable	**TDS**	**pH**	**PO**	**DO**	**SAL**
EC	0.836	0.823	-0.017	0.886	0.848
TDS	-	0.708	0.034	0.852	0.922
pH	-	-	0.174	0.785	0.866
PO	-	-	-	-0.220	0.047
DO	-	-	-	-	0.800

[1]EC: electrical conductivity; TDS: total dissolved solids; pH: hydrogen potential; PO: redox potential; DO: dissolved oxygen; SAL: salinity. The correlation coefficients are significant ($p<0.05$).

In a livestock production scenario, that increasingly finds environmental issues as a questioning factor about the sustainability of processes, the alternative and efficient use of effluent from silages, both as a fertilizer in crops, pastures or forestry. The values of total N, P_2O_5 and K_2O determined in the PCW silage effluent sample pool obtained during the silage period were, respectively, 0.2, 1.4 and 0.4%. Bernardino et al. (2005) found values between 0.08 and 0.12% of total N in effluents from elephant grass silage effluents between one and seven days, respectively. In comparison with the data presented above, there is a high percentage of N in the PCW silage effluent in relation to elephant grass silage.

In silages of materials with low dry matter content, such as PCW effluent (17.69%) and fresh tropical grasses, there is a significant loss of nutrients that are carried through their leaching (TOMICH et al., 2003) or through the proliferation of bacteria of the *Clostridium* genre (FERREIRA et al., 2013), usually resulting from compaction and/or inadequate sealing.

As alternatives to the losses resulting from leaching in silage processes, mainly due to the excess humidity of some silage forages, Negrão et al. (2016) added between 10 and 40 g kg^{-1} of rice bran in the silage of *Brachiaria decumbens* cv. Basilisk and concluded that, even in the lowest concentrations (10 g kg^{-1}), it was possible to reduce losses by effluents, increasing the dry matter and favoring the chemical composition of the silage.

When we verify high volumes of effluent production from the PCW silage (160 L t^{-1} dry matter of silage) in period, associated with the leaching of macronutrients such as N, P and K, it is possible to suggest viability - economic and environmental - in the creation of a system to capture such waste. The objective of this technics is to obtain and using through fertirrigation, given the gradual need for models of agricultural and livestock production, as integrated models.

Jesus et al. (2020) highlight the need for initiatives that determine alternatives for the use of wastewater for irrigation, based on their physical, chemical and biological parameters. Through a bibliographic review, the authors state that the residues of different cultures can be used in the irrigation of production systems, as long as their compositions are known.

Thus, strategies for capturing and distributing PCW silage effluent, as well as other types of silage, minimize the environmental risks inherent in the elimination of effluents in silage processes, with emphasis on the leaching of nutrients to surface, underground water bodies or to the soil itself.

Meantime, the development of methods for collecting silage effluents, as well as agronomic tests that determine dosage and feasibility of using the material in fertirrigation, must be carried out.

In view of the risks inherent to the product ensiling process, especially those of high humidity, there is a clear need for studies, surveys and public measures that elucidate and stimulate producers to seekin the construction of silos that minimize the leaching of organic matter into soils and water courses, in addition to fostering strategies for capturing and using silage effluents appropriately.

CONCLUSIONS

The PCW silage effluent is produced in high volumes during the ensiling, in addition to having aspects that characterize it as wastewater with polluting capacity. This characteristic allows its use in integrated systems by means of fertirrigation. Research is needed to better characterize application dosages and storage strategies for this effluent.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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PHYSICAL QUALITY OF A REGOSOL UNDER INTEGRATED CROP-LIVESTOCK SYSTEMS

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ABSTRACT

The effect of systems of integrated agricultural production on the physical quality of sandy soils is still poorly understood. Therefore, the aim of this study was to evaluate the physical quality of a Regosol managed with different crop-livestock integration systems, after seven years of implantation. A randomizedblock with 11 treatments and 5 replications was used. The elements studied were: *Urochloa* Grass (T1); *Brachiaria decumbens* + Corn (T2); *Brachiaria brizantha* + Single corn (T3); Single corn (T4); Peanut (T5); *Urochloa* Grass + Corn (T6); Corn + Pigeonpea (T7); *Brachiaria decumbens* (T8); Forest (T9); Fodder Sorghum (T10) and Massai Grass (T11). The soil attributes such as, porosity of total soil, macroporosity, microporosity, soil aeration capacity, saturated hydraulic conductivity, water dispersible clay, clay flocculation degree and grain-size distribution of the sand fraction were evaluated in layers, at a depth of 0-10 and 10-20 cm. The data were analyzed using the analysis of principal component. It was concluded that the treatments composed by the consortia, between the cover plant (*Brachiaria brizantha*; *Urochloa* Grass and Pigeonpea) and corn showed to be promising management alternatives for the improvement of the physical quality of the Regosol.

Key words: soil conservation; sustainable agriculture; Soil porosity

INTRODUCTION

In the tropics, livestock production has been widely questioned due to the type of the system adopted. It involves the establishment of grasses monoculture, with low animal stocking rates after cutting them, and burn of native vegetation (POLANÍA-HINCAPIÉ et al., 2021). In the most part of Brazil, livestock farming is an activity with low technological employment, causing erosive processes by the lack of soil management, high compaction, acidification, and loss of soil organic matter (SCHEFFLER et al., 2011). Changes in soil management strongly impact its structural quality, impacting in a negative way the development of plants. Thus, the knowledge of the soil physical quality (SPQ), becomes an indispensable tool to evaluate the impacts caused by the production systems and management of soil. The indicators of soil physical quality are important tools, supporting assessments of economic and environmental sustainability of agricultural practices, which are responsible for improving or impoverishing the physical, chemical, and biological properties of the soil (CASTELLINI et al., 2018). Indicators related to the storage and movement of water in the soil are the most widely used (REYNOLDS et al., 2002). Moreover, other important indicators are bulk density (BD), porosity of total soil, soil aeration capacity, field capacity, plant-available water capacity (REYNOLDS et al., 2007), water release curve and S-value (DEXTER, 2004) and pore size distribution (RIBEIRO et al., 2007).

In Brazil, the use of indicators assessing physical quality of sandy soils, under integrated agricultural production systems, is still moderate. Perhaps, it may be linked to the fragility that its soil offers to crop production. This kind of soil, which make up around 8% of Brazilian territory, are known to have low natural fertility and high susceptibility to erosion and water deficit (DONAGEMMA et al., 2016). However, in recent years these soils have been incorporated into some crop production, resulting in a very significant potential to physical and chemical degradation (SALVIANO et al., 2016). A possible alternative to make these Brazilian Northeast soils productive is the adoption of integrated agricultural production systems, such as crop-livestock and crop-livestock-forest integration. The crop-livestock integration system is a promising strategy for improving soil quality (VALANI et al., 2021), being it characterized as a sustainable production system. It comprises the association between agricultural crops, animals, and florest species, in the same area, in succession or rotation, aiming the synergy between the components of the agroecosystem (BALBINO et al., 2011). Among the benefits of these production systems there are the formation and stabilization of soil aggregates, improvement of the permeability and development of the root system (COSTA et al., 2012). Moreover, it promotes the supply and maintenance of organic matter, the cycling of nutrients (FACCIN et al., 2016), besides benefiting the physical attributes of the soil by promoting increased porosity of total soil and plant-available water capacity (SEAFIM et al., 2013).

Therefore, this work evaluated the hypothesis that the implementation of crop-livestock integration systems with different arrangements, promotes improvements in soil physical quality, considering medium and long term. The main objective was to evaluate the physical quality of a Regosol managed with different crop-livestock integration systems after seven years of implantation.

MATERIAL AND METHODS

Characterization of the experimental area and delineation

The experiment was implemented in 2014 in an experimental area of the Paraiba Company of Research, Rural Extension and Land Regularization (EMPAER), Lagoa Seca city, Paraíba harsh climate (7°10’15’’ S e 35°51’13’’ W; 640 a.s.l.). According to Köppeng-Geiger classification, the predominant climate is the As' type, warm and humid weather, with an annual average temperature of 24 ° C, a relative humidity of 79% and an average rainfall of 990 mm (SANTOS et a., 2014). The largest rainfall volumes occur between April and June (MEDEIROS et al., 2015). The topography is strongly rolling, and the soil is classified as a Regosol (SANTOS et al., 2018). The experimental design that was adopted is completely randomized with 11 treatments and 5 repetitions (11x5). The following elements were analayzed: *Urochloa* Grass (T1); *Brachiaria decumbens* + Corn (T2); *Brachiaria brizantha* + Single corn (T3); Single corn (T4); Peanut (T5); *Urochloa* Grass + Corn (T6); Corn + Pigeonpea (T7); *Brachiari adecumbens* (T8); Forest (T9); Fodder Sorghum (T10) and Massai Grass (T11).

The soil samples with undisturbed structure were collected in the layers of 0-10 and 10-20 cm depth, with Uhland cylinders (volume of 100 cm^3). The disturbed soil samples were collected with a cut shovel, in the same layers. Bulk density (BD; g cm^{-3}) of the samples were determined through the relationship between the oven-dry soil mass and corresponding bulk (undisturbed) soil volume (BLAKE; HARTGE, 1986). The total porosity of the soil (POR_t; m^3 m^{-3}) was determined by the saturated soil’s mass. Microporosity (Mi; m^3 m^{-3}) was defined as the volumetric water content at the matrix potential of -60 hPa using the tension table displayed at (TEIXEIRA et al., 2017). By the difference between total porosity (PORt) and microporosity (Mi), the macroporosity (Mac; m^3 m^{-3}) was also obtained. According to Reynolds et al. (2002), the soil aeration capacity (SAC; m^3 m^{-3}) was determined. Saturated hydraulic conductivity (K_θ; cm h^{-1}) was determined with a permeameter of constant load, according to the methodology described by Teixeira et al. (2017). The moisture at field capacity, permanent wilting point was obtained by a Richards’ extractor with porous plates, using a matrix potential of -33 and -15000 hPa, respectively (KLUTE, 1986). The plant-available water capacity (θ_{AD}; m^3 m^{-3}) was calculated by difference between the volumetric water content in field capacity and permanent wilting point (θ_{CC} - θ_{PMP}) (TEIXEIRA et al., 2017).

After being air-dry and sieve at 2 mm mesh, the disturbed soil's samples were evaluated with respect to the grain-size distribution of sand, silt and clay (g kg^{-1}), using sodium hydroxide as a chemical dispersant (TEIXEIRA et al., 2017), clay flocculation degree (%) and water dispersible clay (g kg^{-1}). Furthermore, the sand was divided into size classes, considering it Very coarse sand (2-0.84 mm); Coarse sand (0.84-0.5 mm); Medium sand (0.5-0.21 mm); Fine sand (0.21-0.105 mm); Very fine sand (0.105-0.053 mm).

Statistical Analysis

The mean values of the attributes of each treatment were evaluated using multivariate statistics: Principal component analysis (PCA), through the statistical software R (R Core Team, 2013).

RESULTS AND DISCUSSIONS

Table 1 shows the eigenvectors of principal component analysis (PCA), for the Regosol's physical attributes under a crop-livestock integration system. For porosity of total soil (POR_t), macroporosity (Ma), microporosity (Mi), bulk density (BD), saturated hydraulic conductivity (K_θ) and soil aeration capacity, 67.96% of the accumulated variance was explained by main component 1 (CP1), while 19.80% was explained by main component 2 (CP2).

For grain-size distribution, dispersible water clay (DWC), clay flocculation degree (CFD) and fractionated sand parameters, 34.59% of the variance was explained by CP1 and 19.59% by CP2. By Table 1, the most representative correlation values were -0.453 for BD in CP1 and -0.815 for Ma in CP2. For indicators related to soil's grain-size distribution, the significant correlation values were 0.478 for sand in CP1 and 0.598 for very coarse sand in CP2. Regarding the sorting diagram, Figure 1A shows the formation of four main groups: G1 (UG; BRA + C; SC; PEA); G2 (C + PIG; UG + C; BD; FL; SORGHUM); G3 (BD + C) and G4 (Massai).

G1 was the most representative in comparison to the other groups, probably due to its influence on the attributes Mi, POR_t, Ma, SAC and K_θ. On the other hand, it may be suggested that BD was the attribute responsible for discriminating G2 in relation to the other groups formed (Figure 1A). Regarding the mean values of BD, for G1 there was an average of 1.51 g cm^{-3}, while for G2 the average was 1.57 g cm^{-3}, with a difference of approximately 4% between them. For Assis et al. (2019), the highest BD in the treatments that make G2 reach higher values may be related to compaction promoted by animal trampling or lack of soil's mobilization. Considering BD attribute, in G1 the physical conditions are less restrictive for plants development. Additionally, the negative correlation between BD and the other soil attributes were evaluated (Ma, Mi, POR_t, SAC, K_θ).The literature reports that the increasement in BD tends to reduce soil pore spaces, especially the Ma, as they are sensitive to changes in soil use, in agreement with Silva et al. (2018) and Assis et al. (2019).As highlighted by Andreola et al. (2000), when the soil is maintained in its natural state (under native vegetation) some characteristics, such as bulk density and porosity are suitable, which changes when it is submitted to some crop process. Therefore, the treatments performed in G1 suggests bulk density are maintaining adequate. If the BD values are above the critical limit there may be a decrease in soil's biological activity, limiting the root system development and decreasing the absorption of water and nutrients by plants, which is possible a problematic situation (WENDLING et al., 2012).

G2 (SC; UG + C; UG; SC; PEA) and G3 (SORGHUM; BB + C; FL; C + PIG) presented better values of indicators related to grain-size distribution (Figure 2B). For group two (G2), most treatments were different at a depth of 0-10 cm, while for group three (G3) it occurs using a depth of 10-20 cm. The clay flocculation degree was lower in G3 in comparison to the other groups evaluated, likely related to the clay content in soil deeper layers, as demonstrated in Figure 1B.

Table 1. Analysis of main components for Regosol's physical attributes and grain-size distribution under the Crop-Livestock integration system, in Lagoa Seca, PB.

Variance		**Main componentes**	
Components	**CP1**	**CP2**	**CP3**
Variance	4.078	1.188	0.432
Proportion %	67.964	19.808	7.194
Accumulated %	67.964	87.772	99.171
		(Physical attibutes) Eigenvectors	
POR_t	0.4717	0.0789	-0.4228
Ma	0.2198	-0.8159	-0.0536
Mi	0.4096	0.4419	-0.4362
BD	-0.4537	0.3162	0.1343
K_θ	0.4133	0.1526	0.6228
Aeration	0.4296	0.0965	0.4376
		Grain-size distribution	
Variance	3.805	2.156	1.617
Proportion %	34.590	19.597	14.702
Accumulated %	34.590	54.187	68.889
		Eigenvectors	
Sand	0.4784	0.0397	0.2689
Silt	-0.2991	-0.1404	-0.0335
Clay	-0.4319	0.0225	-0.2916
VCS	0.0421	0.5983	-0.1401
CS	0.3591	0.4415	-0.0472
MS	0.3993	-0.2457	0.2326
FS	0.2494	-0.0923	-0.0778
VFS	-0.1252	-0.3769	0.4928
DWC	-0.2807	0.2965	0.5006
CFD	0.2192	-0.3552	-0.5156

POR_t – Porosity of total soil, Ma – Macroporosity, Mi – Microporosity, BD – Bulk density, K_θ– Saturated hydraulic conductivity, VCS – Very coarse sand, CS – Coarse sand, MS – Medium sand, FS – Fine sand, VFS – Very fine sand, DWC – Dispersible water clay, CFD – Clay flocculation degree.

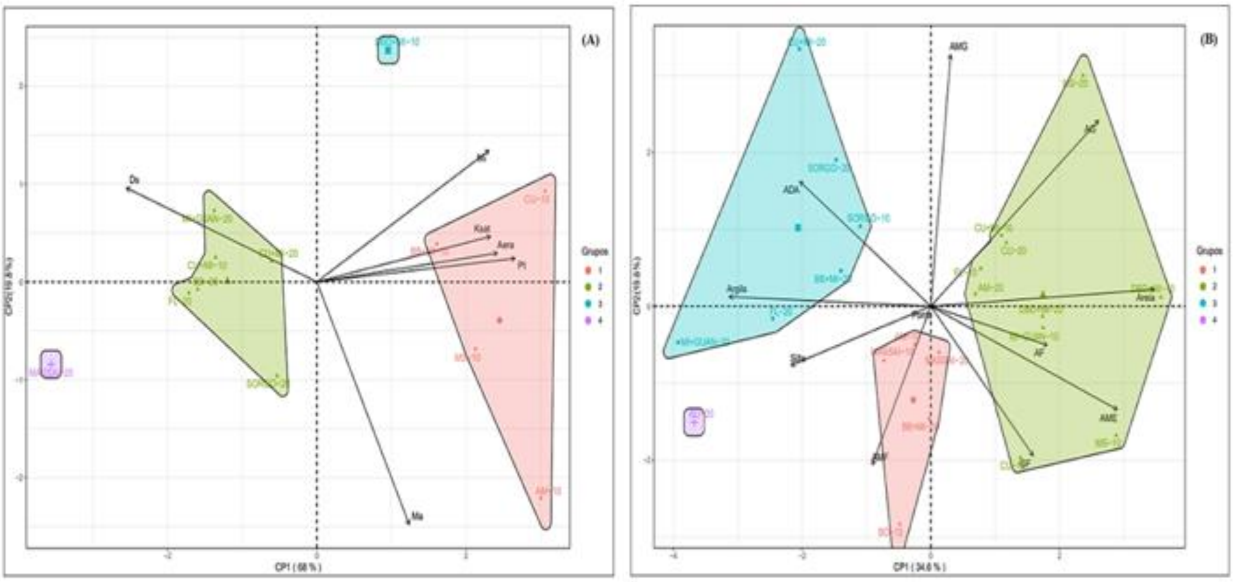

Figure 1. Ordering diagram of the principal component analysis for Regosol's physical attributes (A) and grain-size distribution (B) under the Crop-Livestock integration system, in Lagoa Seca, PB.

For layer of 0-10 cm of depth, there was an average of 80 g kg^{-1} for WDC, with emphasis on BDE treatment with 200 g kg^{-1}. For those of 10-20 cm depth, the average value of WDC was of 216.36 g kg^{-1}, especially considering FLO treatment an average of 340 g kg^{-1} was observed. Figueiredo et al. (2021) have shown the soil electrochemical imbalance, promoted by the potential acidity, is positively correlated with increasing clay dispersion degree. The high rate of clay dispersion in the deeper layers of the soil, including FLO treatment, used as a reference, may be attributed to the electrically neutral property of sand particles, which is different in comparison to clay, that has a high specific surface. According to Pavan and Roth (1992), higher WDC results may be linked to the reduction of exchangeable H^+ and neutralization of Al^{3+}, which are positive species related to the soil structure stabilization, that fosters clay dispersion in crop systems. For instance, the increase in the clay particles' surface net load, increases the thickness of the diffuse double layer, raising the repulsion force among the particles (ALBUQUERQUE et al., 2000). Furthermore, the clay and WDC showed a negative correlation with the fractions of sand (VCS, CS, MS, and FS). In soils where sand predominates, the soil's mineral fraction in its coarser fraction, the formation of empty spaces of larger diameter, usually macropores, increases, favor the eluviation of clay.

CONCLUSIONS

Despite a considerable effect of the coarse sand fraction on the soil mineralogy, the treatments composed by *Urochloa* grass, *Brachiaria brizantha* + Corn, Single corn and Peanut promoted physical improvements to the soil quality, with particular higher values for total porosity, aeration capacity and saturated hydraulic conductivity. For the flocculation degree, considerable improvements were observed in the treatments Single corn at depths of 0-10 and 10-20 cm, *Urochloa* grass + Corn, Forest, and Corn + Pigeonpea. The treatments composed by the consortia between cover plant (*Brachiaria brizantha*; *Urochloa* grass and Pigeonpea) with corn showed to be promising management alternatives for improving soil physical quality in a Regosol.

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CHARACTERIZATION OF FORAGE MASS IN INTERCROPPING PIATÃ PALISADEGRASS WITH DIFFERENT PLANTS AT SECOND CROP IN THE AMAZON BIOME

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ABSTRACT

The use of grasses intercropped with different forage plants in succession to soybean is an alternative to produce forage in crop-livestock integration system, and biomass for soil cover in no-tillage system. Thus, the goal was to characterize the forage production in intercrops of grass with forage plants at second crop in the Amazon biome. The trial was carried out at the Pontal farm, in Nova Guarita-MT, and the laboratory analyzes were carried out at the Forage Science Laboratory of the Federal University of Mato Grosso, Sinop campus, and at Embrapa Agrossilvipastoril. A completely randomized design was used, with five replications, which were collected as pseudo-repetitions. The treatments corresponded to six modalities of intercropping with Piatã palisadegrass (grass with buckwheat; grass with forage turnip; grass with red hemp; grass with cowpea; sixfold - grass with cowpea, niger, buckwheat, red hemp and turnip forage; and monoculture Piatã palisadegrass), which were established on a commercial scale, with 50 to 90 ha. Piatã palisadegrass in monoculture promoted higher forage productivity at second crop compared to use in intercropping, 50 days after sowing, in the Amazon biome. Intercrop with different forage plants promoted assistance in the control of weeds.

Key words: *Brachiaria brizantha*; cover plants; crop-livestock

INTRODUCTION

The crop-livestock integration system promotes the diversification, rotation, intercropping and succession of crop and livestock activities within the farm in a planned manner, in such a way that there are benefits for both activities, with synergism between the crop and the pasture (ALVARENGA et al., 2007). Thus, an alternative feed supply for ruminants during the dry period is the cultivation of forage plants in agricultural areas in the off-season, in integrated system, which allows a greater livestock production. The use of forage plants in succession to the soybeans cultivation is not restricted to animal feed only, being an alternative to increase biomass and soil cover for the main agricultural crops under no-tillage systems. Among the most used options, grasses of the genus *Brachiaria* (syn. *Urochloa*) stand out. Legumes can be used in animal diet as a source of protein, such as the pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*), among others. As in the dry season, grasses present low protein levels, the supply of legumes for ruminant animals is an alternative to increase efficiency on forage-based systems. The use of legumes of the genus *Crotalaria*, such as *C. ochroleuca* (red hemp), has increased in the state of Mato Grosso, due to its ability to control nematodes that attack soybeans (HUANG et al., 1980). The intercrop between grass and legume for animal supplementation in the off-season is a viable alternative due to the complementation that one provides to the other. Grasses, with slower decomposition, provide a more stable residual soil cover, while legumes contribute to a greater nitrogen supply and faster decomposition (KOGEL-KNABNER, 2002). In addition to legumes, there are other plants that can be used to produce straw for the no-till system, which can serve as feed in the production of ruminants, such as forage turnip and buckwheat. Forage turnip (*Raphanus sativus*; Crusciferae family) is a forage with fast initial growth and high capacity to recycle nutrients, mainly nitrogen and phosphorus, in addition to growing well in weak soils, with acidity problems, and producing good amount of dry mass, being an excellent option for crop rotation and for the practice of no-till cultivation (SLUSZZ; MACHADO, 2006). On the other hand, buckwheat (*Fagopyrum esculentum*) is a Polygonaceae with good mass production capacity in acidic soils, which can be used in animal feed, has little use in mid-northern region of Brazil. Despite the numerous studies on the grass use in succession to soybeans, both for feeding ruminants in integrated system and for producing straw for the no-tillage system, there are few studies on the cultivation of grasses intercropped with other plants for these purposes. Thus, the goal was to characterize the forage production in the intercrop of grass with forage plants at second crop in the Amazon biome.

MATERIAL AND METHODS

The trial was carried out at the Pontal farm, located in Nova Guarita-MT. Laboratory analyzes were carried out at the Forage Science Laboratory of the Federal University of Mato Grosso, Sinop campus, and at Embrapa Agrossilvipastoril. A completely randomized design was used, with five replications. The five repetitions were collected as pseudo-repetitions, since they were collected within the same area. The treatments corresponded to six modalities of intercrop with Piatã palisadegrass (1: grass with buckwheat; 2: grass with forage turnip; 3: grass with red hemp; 4: grass with cowpea; 5: sixfold - grass with cowpea, niger (*Guizotia abyssinica*), buckwheat, red hemp and turnip; 6: monoculture Piatã palisadegrass), which were established on a commercial scale, with pastures from 50 to 90 ha. The intercrops were established after the soybean harvest in February 2019. After sowing, 110 kg/ha of the formulated NPK 04-30-16 was applied, as top-dressing. During the experiment, four applications of insecticides were performed (two applications of lambda-cyhalothrin, and two applications of thiamethoxam + lambda cyhalothrin). The Piatã palisadegrass and forage turnip was hand sown, with a sowing rate of 6.0 and 5.0 kg of pure and viable seeds/ha, respectively, with subsequent incorporation with a closed light harrow. The cowpea and red hemp were sown with a seeder, with a spacing between rows of 0.50 m and sowing rates of 6 and 200 seeds/m, respectively. The buckwheat was hand sown at a sowing rate of 20 kg/ha, with subsequent incorporation with a closed light harrow. In the sixfold intercrop, 12 kg/ha of the mixture was used, with a volume ratio of: 1 part of Piatã palisadegrass, 1 part of red hemp, 1 part of pigeon peas, 1 part of forage turnip, 1 parts of buckwheat and 0,5 part of niger. The forage collection was carried out in April 2019, 50 days after implantation. First, the canopy height was measured using a measuring tape. Subsequently, the forage was cut, close to the soil surface, using a quadrat with measures of 1.0 m x 0.5 m. After cutting, the samples were weighed and taken to UFMT, for the botanical separation of the plants (grass, other plants, weeds), with subsequent weighing of the components. Then, the samples were transported to Embrapa Agrossilvipastoril, where they were pre-dried in a forced ventilation oven, with a temperature of 55° C for 72 h, to determine de dry matter content, with what the forage mass of grass, other plants and total (grass + weeds + other plants components) was calculated. The data obtained were subjected to analysis of variance and the means compared by the Scott- Knott cluster test, adopting the probability level of 5%, through the Sisvar statistical application.

RESULTS AND DISCUSSIONS

For the variables of height and forage mass of grass, other plants and total mass, a treatment effect was observed (Table 1). The intercrop of grass with buckwheat, forage turnip and the sixfold had a lower canopy height. Regarding the forage mass, in the monoculture Piatã palisadegrass treatment, the highest values were observed for the forage mass of grass and for total mass (grass + weeds), while for the production of the other plants, different from the grass, the sixfold intercropping presented the highest value.The higher values of forage mass in the treatment of monoculture Piatã palisadegrass may be due to the high biomass production that tropical grasses have in comparison to forage plants of other species, mainly in tropical conditions, as in the biome Amazonia, for presenting C4 type metabolism, which may be affected by the competition with the other plants in the intercropping treatments. In the sixfold intercropping, the greater forage mass of plants of other species, different from the grass, is due to the treatment consisting of a poly cropping, with different species.

Table 1. Canopy height and forage dry matter production from different intercrops with Piatã palisadegrass, implanted in February 2019. Nova Guarita-MT.

Treatment	**Height (cm)**	**Dry mass (kg/ha)**		
		Grass	**Other plants**	**Total**
Grass with buckwheat	57.10^{b}	$1,238^{b}$	143^{c}	$2,226^{c}$
Grass with red hemp	63.70^{a}	257^{c}	105^{c}	$2,253^{c}$
Grass with cowpea	65.80^{a}	$1,082^{b}$	901^{b}	$2,114^{c}$
Sixfold	51.60^{b}	$1,005^{b}$	$1,111^{a}$	$2,208^{c}$
Grass with forage turnip	59.80^{b}	490^{c}	140^{c}	$2,837^{b}$
Single piatã palisadegrass	68.70^{a}	$2,139^{a}$	0^{c}	$3,704^{a}$
CV (%)	10.95	34.18	29.54	13.33

CV: Coefficient of variation. Means followed by the same letter in the column do not differ by the Scott-Knott cluster test (P <0.05).

For the plant proportion, a treatment effect was observed (Table 2). The intercropping of Piatã palisadegrass with red hemp and with forage turnip presented the lowest proportion of grass and the highest for weed, while in the sixfold intercropping and grass with cowpea, the highest proportions of other plants were observed. In the sixfold intercropping, a proportion of 45.2; 3.7; 5.6; 5.6; 29.7 and 4.2% was observed for Piatã palisadegrass, cowpea, forage turnip, red hemp, niger and buckwheat, respectively.

Table 2. Proportions of plants in different intercrops with piata palisadegrass, implanted in the 2nd half of February 2019. Nova Guarita-MT.

Treatments	**Proportion (%)**		
	Grass	**Weed**	**Other**
Grass with buckwheat	55.81^{a}	37.77^{b}	6.42^{b}
Grass with red hemp	11.16^{b}	84.13^{a}	4.72^{b}
Grass with cowpea	50.12^{a}	6.01^{c}	43.87^{a}
Sixfold	45.22^{a}	4.23^{c}	50.55^{a}
Grass with forage turnip	17.74^{b}	77.37^{a}	4.89^{b}
Single piatã palisadegrass	57.61^{a}	42.39^{b}	0.00^{b}
CV (%)	32.07	29.65	33.47

CV: Coefficient of variation. Means followed by the same letter in the column do not differ by the Scott-Knott cluster test (P <0.05).

The highest proportion of weeds and the lowest amount of grass for the piata palisadegrass intercroped with red hemp and forage turnip, possibly was due to the condition of the weeds in the stands, with emphasis on the presence of itchgrass (*Rottboellia cochinchinensis*). The smaller proportions of weeds in the intercrop of Piatã palisadegrass with cowpea and in the sixfold intercropping are due to the greater proportion of the other plants, the legume in the case of treatment with cowpea, and of the other forage plants in the poly cropping. The sowing of many plants in the sixfold intercropping seems to have contributed to the control of weeds. It is important to emphasize that the proportion of the grass must be kept greater than 50% of the pasture botanical composition, when intercropped with plants from other families, both to avoid metabolic problems of grazing animals (RIET-CORREA, 2007), as well as to promote the production of sufficient straw for the no-till system. Thus, it is necessary to adjust the seeding rate in the sixfold poly cropping, in order to increase the proportion of grass in the system.

CONCLUSIONS

The use of Piatã palisadegrass in monoculture promoted higher forage mass at second crop compared to intercropping, 50 days after sowing, in the Amazon biome. The poly cropping with different forage plants promoted a higher proportion of forage plants other than grass in the intercropping, with assistance in the control of weeds.

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EUCALYPTUS DEVELOPMENT AND CARBON SEQUESTRATION IN AN INTEGRATED PRODUCTION SYSTEM IN SÃO DOMINGOS DO ARAGUAIA, PA

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ABSTRACT

Among the benefits of the Integrated Production System - ICLF is the reduction of CO_2 emission into the atmosphere and the consequent mitigation of climate change. This study aimed to evaluate the eucalyptus growth and estimate its carbon sequestration in a crop-livestock-forest integration system located in the southeastern region of Pará. The data were collected at *Fazenda Cristalina*, in the municipality of São Domingos do Araguaia, PA. In order to assess the growth and carbon stock of the forest species, annual measurements were taken up to 60 months of age in 10 plots measuring 524 m^2, the first of which was at six months old. The volume of 74.52 m^3 ha^{-1} was observed with an estimated carbon stock of 15.98 Mg of C ha^{-1} and 58.58 Mg of CO_2 eq ha^{-1} being sequestered from the atmosphere, thus providing a potential to neutralize methane emission of 6.23 AU ha^{-1} $year^{-1}$.

Key words: Sustainable production; Integrated production systems; Carbon stock

INTRODUCTION

The integrated crop-livestock-forest system (ICLF) consists of the joint management of crops, cattle breeding and forest cultivation based on the integration, succession or rotation of its components. The system tends to oppose the current monoculture models, thus providing the diversification of activities (VILELA et al., 2011; BALBINO et al., 2011). It can also increase the environmental and economic benefits in the properties that adopt it (BALBINO et al., 2011) in order to reconcile productivity with sustainability.

ICLF enables the achievement of satisfactory productivity and compensates for greenhouse gas emissions from livestock activities (OLIVEIRA et al., 2017), providing a positive carbon balance thanks to the reduction of CO_2 emissions into the atmosphere as compared to traditional systems, as well as the consequent mitigation of global climate change (MÜLLER et al., 2009). Trees in this system provide a valuable environmental service because they sequester carbon and provide thermal comfort to animals, in addition to wood and non-wood products, generating greater income opportunities for producers. This study aimed to assess eucalyptus growth and estimate its carbon sequestration in a crop-livestock-forest integration system located in the region of São Domingos do Araguaia, PA.

MATERIAL AND METHODS

The study was conducted at *Fazenda Cristalina*, in the municipality of São Domingos do Araguaia, PA, from 2013 to 2018. The area is located at latitude 5°36’63” S, longitude 48°29’26” W and an altitude of 120 meters. According to Köppen (1936), the climate is tropical semi-humid (Aw/As), with average monthly temperatures between 22.9 and 32.0 °C and an annual average of 26.0 °C. The soil has been classified as Moderate A Espesarenic Red-Yellow Dystrophic Latosol with medium texture on flatlands (RAMOS et al., 2016).

In September 2013, 1.5 t ha^{-1} of dolomitic limestone was applied to the study area by broadcasting. In December of the same year, the ICLF system was implemented using eucalyptus (*Eucalyptus* *urocam* cv VM 01) in a simple arrangement, with 25-m spacing between rows and 3-m spacing between plants, resulting in 133 trees ha^{-1}. In the planting pit, 400g/plant of thermophosphate (Yoorin) and 50g plant^{-1} of NPK 10-28-20 were used. For cover fertilization, 200g plant^{-1} of the NPK 10-28-20 formulation was used, divided into two applications, as well as 50g plant^{-1} of FTE BR12 (micronutrients). In the first two years, maize intercropped with brachiaria was cultivated for ground cover and biomass production. In the second cycle, maize was again cultivated and the definitive pasture was introduced by sowing *Panicum maximum* cv Mombaça. Basic maize fertilization consisted of 200 kg ha^{-1} of NPK 10-30-10 formulation, and 200 kg ha^{-1} of NPK 20-00-20 formulation was used in the cover. The maize/grass/eucalyptus intercrop was adopted only in the first two years, after which only Mombaça grass was kept between the eucalyptus lines for animal grazing.

In order to assess the growth and carbon stock of the eucalyptus trees, measurements were taken at 6 months after planting and every year after implantation. Data collection from the eucalyptus was carried out in 25 x 21-m plots, totaling 524 m² in each plot, in which height (H) was measured from the vertex, and the diameter at breast height (DBH) by a tape measure. The volumes per plant and per hectare (m³ ha^{-1}) were calculated using the adjusted equation of the model by Schumacher and Hall (1933), according to Campanha et al. (2017).

According to Oliveira et al. (2018), in order to estimate the carbon stock (C) in the eucalyptus trunk, an average carbon content of 49% and an average wood density of 0.35 Mg m^{-3} were considered, estimating 0.17 Mg of C m^{-3}. According to IPCC (2006), it can be considered that 1 t of C is equivalent to 3.6667 t of CO_2 eq, thus estimating a fixation of 0.62 Mg of CO_2 eq per m³ of wood. The trunk biomass was estimated by multiplying the volume by the respective density of the adopted wood, multiplied by the carbon content.

RESULTS AND DISCUSSIONS

The trees implanted according to the ICLF system in the studied region showed good development, with a mean height of 4.6 and 6.8 m at 6 and 12 months, and a mean DBH of 3.73 and 8.01 cm, respectively (Table 1), with an estimated mean volume per hectare of 0.31 m³ ha^{-1} at 6 months and of 2.10 m³ ha^{-1} at 12 months with a capacity of 133 trees ha^{-1}. At 24 months, eucalyptus showed a gain of 66.17% and 107.36% in height and mean DBH, respectively. At 60 months, the mean height was 18.7 m, and mean DBH was 28.70 cm, with a mean volume of 74.52 m³ ha^{-1}. These results are lower than those reported by Campanha et al. (2017), who found eucalyptus (*Eucalyptus grandis* (Hill) ex Maiden x *Eucalyptus urophylla* S.T Blake strains GG100), with a mean height of 32 m, a mean DBH of 17.9 cm and a volume of 82.8 m³/ha at 60 months in an ICLF system intercropped with agricultural crops (333 trees ha^{-1}, 15 x 2 m) in Sete Lagoas, MG. In Macedo et al. (2006), the results were similar to those found in the first years.

Table 1. Mean height, DBH and volume of eucalyptus by month and by hectare in an integrated crop-livestock-forest system (ICLF). São Domingos do Araguaia, PA.

Age in months	**Mean Height (m)**	**Mean DBH (cm)**	**Mean Volume (m³ ha^{-1})**
6	4.6	3.73	0.31
12	6.8	8.01	2.10
24	11.3	16.61	15.05
36	16.5	22.19	39.25
48	18.5	25.90	60.04
60	18.7	28.70	74.52

Eucalyptus in the ICLF system showed a linear behavior over the months in relation to carbon sequestration from the atmosphere. At 12, 24, 36 and 48 months, eucalyptus was responsible for sequestering 0.45; 3.23; 8.41; 12.57 Mg of C ha^{-1}, respectively, reaching 60 months with a carbon stock of 15.98 Mg of C ha^{-1} (Table 2).

It is estimated that 11.83 Mg ha^{-1} of CO_2 eq are sequestered at 24 months, and 58.58 Mg ha^{-1}of CO_2 eq at 60 months of age. According to IPCC (2006) an AU (Animal Unit) that is equal to 450 kg (live weight) on average emits 1.88 Mg ha^{-1} of CO_2 eq year^{-1}. Thus, after 60 months of age, the ICLF system with 133 trees ha^{-1} and a 15 x 2-m arrangement has the potential to neutralize the methane emission of 6.23 AU ha year^{-1}, that is, a total of 31 adult bovines per hectare (31 AU) in five years. Such results are similar to those found by Campanha et al. (2017), which, in an ICLF system with 333 trees ha^{-1} in the 15 x 2-m arrangement, defined such neutralization in 5.81 AU ha^{-1} year^{-1}, with a total of 29 adult bovines per hectare (29 AU) in five years.

Table 2. Estimated carbon and CO_2 eq stock per hectare in the trunk of eucalyptus trees and the potentially neutralized stocking rate for an Integrated Crop-Livestock-Forest System with 133 eucalyptus trees per hectare. São Domingos do Araguaia, PA.

Age in months	**Carbon stock (Mg of C ha^{-1})**	**CO_2 eq stock (Mg ha^{-1} of CO_2 eq)**	**Neutralized stocking rate (AU ha^{-1} year^{-1})**
6	0.07	0.24	0.26
12	0.45	1.65	0.88
24	3.23	11.83	3.15
36	8.41	30.85	5.47
48	12.87	47.19	6.28
60	15.98	58.58	6.23

Thus, it is observed that the trees in the ICLF system have great capacity to mitigate GHG emissions from animal production, since according to Alves et al. (2015), the average stocking rate of Brazilian pastures comes close to 1.0 AU ha^{-1} year^{-1}.

CONCLUSIONS

Eucalyptus in the ICLF system and under the observed conditions showed a volume of 74.52 m³ ha^{-1} at 60 months of age with an estimated carbon stock of 15.98 Mg C ha^{-1} and 58.58 Mg ha^{-1} of sequestered CO_2 eq from the atmosphere, thus providing a potential to neutralize methane emission of 6.23 AU ha^{-1} year^{-1}.

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EUCALYPTUS CARBON INCREMENT AND SEQUESTRATION IN AN INTEGRATED LIVESTOCK-FOREST SYSTEM IN BOM JESUS DO TOCANTINS, PA

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ABSTRACT

Among the benefits of the Integrated Production System - ILF is the enhancement of the forestry component of carbon immobilization in biomass, reducing CO_2 emission into the atmosphere and, consequently, reducing climate change. This study aimed to evaluate eucalyptus growth and estimate its carbon sequestration in an integrated livestock-forest system (ILF) located in the southeastern region of Pará. Data were collected at *Fazenda Riacho Grande*, in the municipality of Bom Jesus do Tocantins, PA. In order to assess the growth and carbon stock of the forest species, annual measurements were taken, one at 12 months and another at 27 months of age, in 3 plots measuring 1,271 m². The volume of 9.97 m³ ha^{-1} and a mean annual increment (MAI) of 4.43 m³ ha^{-1} $year^{-1}$ were observed, with an estimated carbon stock of 2.14 Mg of C ha^{-1} and 7.83 Mg ha^{-1} of CO_2 eq being sequestered from the atmosphere, thus providing a potential to neutralize methane emission of 2.08 AU ha^{-1} $year^{-1}$ at 27 months of age.

Key words: Sustainability; Crop-forest integration; Carbon stock

INTRODUCTION

The Integrated Livestock-Forest System (ILF) is a set of technologies that consists in diversifying and combining different productive systems in the same area, in intercropped cultivation, so that there is a synergistic effect among the components (BALBINO et al., 2011). The possibilities to combine components in the system are many and adjustments are necessary, depending on producers' interests as well as on edaphoclimatic and market aspects.

The forest component is perennial, and for that reason, when present in the systems, it enhances carbon immobilization in biomass for long periods (JOSE, 2009), thus silvopastoral systems can fix significant amounts of carbon in the soil and in biomass, providing an important contribution to climate change reduction (MÜLLER et al., 2009; LOSS et al., 2012), in addition to resulting in several benefits for the other components in the system, such as improvement in climate, soil, microorganisms, forage plants and animals, representing an important development strategy, both for diversification and income increase for rural producers and for environmental conservation.

Milk production in the southeastern region of Pará state is characterized by being developed in low-productivity processes, with a low degree of adequate land use and low productive efficiency. Most undertakings take place in pasture areas with very limited productivity, a low stocking rate (1 AU hectare $year^{-1}$) and an average production of 4-5 liters per animal/day, in an approximate period of seven months per year (VEIGA et al., 2006; GONÇALVES et al., 2006). Considering the importance of integrated production processes for environmental adaptation of regional systems in small properties for cow milk production, the use of the forestry component also improves the thermal comfort of animals, thus allowing for better production conditions.

Given the above, this study aimed to evaluate eucalyptus growth and estimate its carbon sequestration in a livestock-forest integration system located in the region of Bom Jesus do Tocantins, PA.

MATERIAL AND METHODS

The study was conducted at *Fazenda Riacho Grande*, in the municipality of Bom Jesus do Tocantins, PA, from 2018 to 2021. The area is located at latitude 5°06'22.16" S, longitude 48°34'01.83" W and an altitude of 175 meters. According to Köppen (1936) the climate is tropical semi-humid (Aw/As) with average monthly temperatures between 22.7 and 32.1°C, and an annual average of 26.3°C. The soil has been classified as (Oxisols) Dystrophic yellow Latosol (SANTOS et al., 2013).

In September 2019, 2 t ha^{-1} of dolomitic limestone was applied to the study area by broadcasting. In December of the same year, an ILF system (silvopastoral) was implemented, using eucalyptus (*Eucalyptus brassiana x Eucalyptus grandys* VD469) in a triple arrangement, with 25-m spacing between rows, 3-m spacing between lines and 3-m spacing between plants, resulting in 244 trees ha^{-1}, and occupying 19.5% of the area with a forest species, where pasture, which had already been formed with *Urochloa brizantha* cv. Marandu, had been used in the productive process with cows. The pits were opened manually, and 200g of single super phosphate was placed in the planting pits. Also, 200g plant^{-1} of NPK 10-28-20 was applied twice in a circle shape at a distance of 20 cm from the plants The first application took place 15 days after planting and the second at 40 days. For cover fertilization, 200g plant^{-1} of the NPK 10-28-20 formulation was used, divided into two applications, as well as 50g plant^{-1} of FTE BR12 (micronutrients). Two controls were performed using an agrochemical (glyphosate) for crowning the eucalyptus in the wet season (rainy), during the whole first year. In the first year, the trees were protected by electric fences in order to prevent them from being damaged by the animals.

In order to assess the growth and carbon stock of the eucalyptus trees, measurements were taken at 12 and 27 months after planting. Data collection from the eucalyptus was carried out in three 315 x 45-m plots, totaling 1,271 m² in each plot, in which height (H) was measured from the vertex, and the diameter at breast height (DBH) by a tape measure. The volumes per plant and per hectare (m³ ha^{-1}) were calculated using the adjusted equation of the model by Schumacher and Hall (1933), according to Campanha et al. (2017).

According to Oliveira et al. (2018), in order to estimate the carbon stock (C) in the eucalyptus trunk, an average carbon content of 49% and an average wood density of 0.35 Mg m^{-3} were considered, estimating 0.17 Mg of C m^{-3}. According to IPCC (2006), it can be considered that 1 t of C is equivalent to 3.6667 t of CO_2 eq, thus estimating a fixation of 0.62 Mg of CO_2 eq per m³ of wood. The trunk biomass was estimated by multiplying the volume by the respective density of the adopted wood, multiplied by the carbon content.

RESULTS AND DISCUSSIONS

The trees implanted according to the ILF system in the studied region showed good development, with a mean height of 4.0 m and a mean DBH of 3.63 (Table 1) at 12 months and an estimated mean volume of 0.48 m³ ha^{-1} and MAI of 0,48 m³ ha^{-1} year^{-1}, with a capacity of 244 trees ha^{-1}. At 27 months, eucalyptus showed a gain of 155% and 186% in height and mean DBH, respectively, with a mean height of 10.2 m, a mean DBH of 10.50 cm, a mean volume of 9.97 m³ ha^{-1} and MAI of 4.43 m³ ha^{-1} year^{-1}. These results are similar to those by Campanha et al. (2017), who found eucalyptus (*Eucalyptus grandis* (Hill) ex Maiden x *Eucalyptus urophylla* ST Blake strains GG (100) in an ICLF system intercropped with agricultural crops (333 trees ha^{-1}, 15 x 2 m) in Sete Lagoas, MG, with a mean height of 10.3 m, mean DBH of 10.5 cm, volume of 15.8 m³ ha^{-1} and MAI of 7.88 m³ ha^{-1} year^{-1} at 24 months. Such higher figures for volume and MAI were due to the larger number of trees, that is to say, a system with higher tree density in relation to that in this study. In an investigation conducted by Macedo et al. (2006), the results were greater than those in this study, as they found a mean height of 11.82 m, a mean DBH of 14.19 cm and volume of 19.94 m³ ha^{-1} in an ICLF system using eucalyptus species at an age of 28 months, in a 10 x 4-m arrangement forming a stand of 247 trees ha^{-1}.

Table 1. Mean height, DBH, volume and MAI of eucalyptus by months and by hectare in a Livestock-Forest Integration System (ILF). Bom Jesus do Tocantins, PA.

Height months	**Mean height (m)**	**Mean DBH (cm)**	**Mean volume (m³ ha^{-1})**	**MAI[1] (m³ ha^{-1} year^{-1})**
12	4.0	3.67	0.48	0.48
27	10.2	10.50	9.97	4.43

[1]MAI = Mean Annual Increment.

Regarding carbon sequestration from the atmosphere, eucalyptus in the ILF system was responsible for sequestering 0.10 Mg of C ha^{-1} at 12 months of age, reaching 27 months with a carbon stock of 2.14 Mg of C ha^{-1} (Table 2).

It is estimated that 0.37 Mg ha^{-1} of CO_2 eq is sequestered at 12 months, and 7.84 Mg ha^{-1} of CO_2 eq at 27 months of age. According to IPCC et al. (2006) an AU (Animal Unit) that is equal to 450 kg (live weight), on average, emits 1.88 Mg ha^{-1} of CO_2 eq year^{-1}. Thus, after 27 months of age, the ILF system with 244 trees ha^{-1}, in a 25 x 3 x 3-m arrangement, has the potential to neutralize methane emission to the extent of 2.08 AU ha^{-1} year^{-1}, that is, in two years, a total of 4 adult bovines per hectare (4 AU). Such results corroborate those found by Campanha et al. (2017), who reported a neutralization potential of 2.77 AU ha^{-1} year^{-1} at 24 months, with a total of 5.5 adult bovines per hectare (5.5 AU) in two years in an ICLF system in the 15 x 2-m arrangement with 333 tress ha^{-1}.

Table 2. Estimated carbon and CO_2 eq stock per hectare in the trunk of eucalyptus trees and the potentially neutralized stocking rate for an Integrated Livestock-Forest System with 244 eucalyptus trees per hectare. Bom Jesus do Tocantins, PA.

Age months	**Carbon stock (Mg de C ha^{-1})**	**CO_2 eq stock (Mg ha^{-1}of CO_2 eq)**	**Neutralized stocking rate (AU ha^{-1} year^{-1})**
12	0.10	0.37	0.20
27	2.14	7.84	2.08

Thus, it is observed that the tree component in the ILF system has a great capacity to mitigate GHG emissions from animal production, since, according to Alves et al. (2015), the mean stocking rate of Brazilian pastures comes close to 1.0 AU ha^{-1} year^{-1}.

CONCLUSIONS

Eucalyptus in the ILF system, under the observed conditions, showed a volume of 9.97 m³ ha^{-1} and MAI of 4.43 m³ ha^{-1} year^{-1} at 27 months of age, with an estimated carbon stock of 2.14 Mg C ha^{-1} and 7.83 Mg ha^{-1} of CO_2 eq being sequestered from the atmosphere, thus providing a potential to neutralize methane emission of 2.08 AU ha^{-1} year^{-1} at 27 months of age.

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PRODUCING QUALITY MEAT IS POSSIBLE USING RESOURCES FROM INTEGRATED CROP-LIVESTOCK SYSTEM

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ABSTRACT

The objective of this work was to evaluate the fatty acid (FA) profile of *Longissimus thoracis* (LT) muscle from cattle finished in feedlot, fed with grains and silage produced in an integrated crop-livestock system (ICL). Nellore (IBW = 344.4 ± 30 kg, n = 25) and Angus x Nellore (IBW = 426.5 ± 27 kg, n = 25) crossbred young bulls were used, and the diet had a concentrate: roughage ratio of 65:35. The crossbred animals had higher levels of saturated FA (SFA) ($P = 0.05$) and lower levels of unsaturated FA (UFA) ($P = 0.02$) and monounsaturated FA (MUFA) ($P = 0.04$). There was no significant difference for the concentrations of PUFA, Ω-6, Ω-3, and PUFA/SFA and Ω-6/Ω-3 ratio between the breed compositions ($P > 0.05$). Nellore produced meat with a better fatty acid profile due to the physiological maturity stage at which this group was slaughtered. The production of quality meat through ICL resources is an interesting strategy for adding value to the system.

Key words: Agricultural system; Beef cattle; Fatty acid profile

INTRODUCTION

Many producers have adopted beef cattle production in a crop-livestock integration system (ICL) to produce grains and animal products with high efficiency. This production system makes it possible to provide a quality diet to the animals throughout the year, as it allows the production of annual crops and grass for livestock exploitation. The system becomes more technified and intensive with beef cattle finished in feedlots, using forages and grains resources from ICL's.

The feedlot is a strategy that can be used in ICL systems through the use of forage resources and grains produced at ICL (SOARES et al., 2018). There are several benefits obtained from this strategy: removal of heavier animals from pastures during the dry season of the year, an increase of the weight gain of animals during the period of lower food supply, reduction in age at slaughter, greater payment to the producers, in addition to carcass and meat quality benefits.

The crossbreed between *B. Taurus* and *B. indicus* animals have frequently been used in beef cattle production systems in Brazil to reduce the age at slaughter, increase carcass weight, and improve body fat deposition and meat quality (LOPES et al., 2012).

There is a growing concern on the part of consumers regarding the excessive consumption of fats, especially saturated fats (LOCKE et al., 2018). However, beef is a source of MUFA such as oleic acid (C18:1, *cis*-9) and polyunsaturated fatty acids (PUFA) such as linoleic (C18:2, Ω-6) and linolenic acid (C18:3, Ω-3) that act to protect the cardiovascular system, as they help to reduce LDL and total cholesterol (BRESSAN et al., 2016; BRIGGS et al., 2017).

The objective of this work was to evaluate the fatty acid (FA) profile of *Longissimus thoracis* (LT) muscle from beef cattle finished in feedlot, fed with grains and silage produced in an integrated crop-livestock system.

MATERIAL AND METHODS

All experimental procedures were approved by the Ethics Committee for Animal Use of the Federal University of Minas Gerais.

The experiment was conducted in the ICL System demonstration unit installed in the experimental field at Embrapa Maize and Sorghum, Sete Lagoas/MG, Brazil. The crops were established in an integrated agricultural and livestock production system in 22 hectares (ha). The crop-livestock system included the rotation of corn and soybeans for grains and corn for silage with a pasture of *Megathyrsus maximum*. The corn used for silage was sown under a no-tillage system in a consortium with the grasses *Urochloa brizantha* and *Megathyrsus maximum*.

The feedlot began between May and June (2017), ending in October (2017). For the feedlot, 50 animals (25 Nellore and 25 Angus x Nellore) with approximately 20 months of age were used, with an initial body weight (IBW) of 344.4 ± 30 kg and 426.5 ± 27 kg to Nellore and crossbred, respectively. The diet contained corn silage (35%), ground corn (54%), soybean grain (5%) and mineral mix (6%), with a concentrate: roughage ratio of 65:35. The animals were fed over 107 (Crossbred) and 128 days (Nellore).

The corn silage, corn grains and soybean used in the diets were produced in the ICL System demonstration unit area. The animals belonged to the same herd and came from the same breeding season. Before the feedlot, the animals were kept on a pasture of *Megathyrsus maximum* with protein and energy supplement intake of 0.2% of body weight. All animals were drenched with an anthelmintic agent before the feedlot start.

In the feedlot, the animals were divided into groups according to the breed composition. They were allocated into collective pens measuring 20 x 12 m, equipped with feed lanes and drinkers. The animals were adapted to the experimental diets for 21 days. They were fed three times per day – at 07, 11, and 16 h. The diet was adjusted daily to maintain 5 to 10% refusals and was formulated to allow for 1.5 kg of average daily weight gain (VALADARES FILHO et al., 2010).

A day before slaughter, animals were weighed after 16 hours fasting period and sent to the commercial slaughterhouse, where they were kept fasting for 24 hours with only *ad libitum* water access. The slaughter was conducted according to humanitarian procedures required by Brazilian legislation, following the official rules of RIISPOA (BRASIL, 1997).

A sample of *Longissimus thoracis* muscle from each animal (n=50) was taken between the 12th and 13th ribs to analyze the FA profile of intramuscular fat. The samples were homogenized in a multiprocessor, and the FA extraction was performed according to the methodology described by Folch et al. (1957). The FA profile determination followed the procedures established by Hartman and Lago (1973).

The analyzes were performed using the statistical analysis software R (R Core Team, 2020). The assumptions of normal distribution of standardized residues were assessed by the Shapiro-Wilk test and by visual analysis of the distribution of residues with a Q-Q graph. The premises of homoscedasticity were evaluated by Bartlett's test and visual analysis of standardized residues. When the assumptions of homoscedasticity were not met, a different variance structure was selected based on the visualization of the residuals as a function of the predictor variables and values predicted by the model. The means were compared by Fisher's test.

RESULTS AND DISCUSSIONS

There were differences between the two breed compositions for the percentage of SFA, UFA, and MUFA (Table 1). The NEL animals had a lower concentration of SFA (P = 0.05) and a higher concentration of both UFA (P = 0.02) and MUFA (P = 0.04) compared to AN animals. However, there was no significant difference for the concentrations of PUFA, Ω-6, and Ω-3 and polyunsaturated/saturated and Ω-6/Ω-3 ratio between the breed compositions (*P* > 0.05).

Ruminal microorganisms strongly influence the FA profile of ruminant meat. Several studies have already reported that the content of FA in beef can be modified, mainly by feeding management and by the diet provided (VAHMANI et al., 2020). Also, distinct genetic groups may present different fat deposition patterns and FA profiles in meat, as some of these groups start fat deposition earlier than others.

Table 1. Means and standard errors of the means of the sum and ratios of fatty acids in the *Longissimus thoracis* muscle from Nellore and Angus x Nellore crossbred young bulls finished in feedlot.

Item	**Breed composition**		***P*-value**
	NEL	**AN**	
Σ Saturated[1] (%)	41.3 (1.85)	48.4 (3.65)	0.05
Σ Unsaturated[2] (%)	58.7 (2.08)	51.6 (3.88)	0.02
Σ Monounsaturated[3] (%)	51.6 (1.74)	45.4 (3.85)	0.04
Σ Polyunsaturated[4] (%)	7.1 (1.21)	6.2 (1.21)	0.59
Ω-6[5] (%)	5.67 (0.79)	5.35 (0.79)	0.84
Ω-3[6] (%)	0.61 (0.07)	0.50 (0.07)	0.81
Polyunsaturated/saturated	0.17 (0.03)	0.13 (0.03)	0.16
Ω-6/Ω-3	9.3 (0.21)	10.7 (0.21)	0.89

SFA[1] = (C8:0 + C10:0 + C11:0 + C12:0 + C13:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0);

UFA[2] = (C10:1 + C12:1 + C14:1 *cis*-9 + C16:1 *cis*-9 + C17:1 *cis*-9 + C18:1 *trans*-11 + C18:1 *cis*-9 + C18:1 *cis*-11 + C18:1 *cis*-12 + C 18:1 *cis*-13 + C 18:1 *cis*-15 + C18:1 *trans*-16 + C18:2 n-6 + C18:2 *cis*-9, *trans-11*+ C18:3 n-3 + C20:1 + C20:2 n-6 + C20:3 n-6 + C20:4 n-6 + C24:1 + C22:5 n-3);

MUFA[3] = (C10:1 + C12:1 + C14:1 *cis*-9 + C16:1 *cis*-9 + C17:1 *cis*-9 + C18:1 *trans*-11 + C18:1 *cis*-9 + C18:1 *cis*-11 + C18:1 *cis*-12 + C 18:1 *cis*-13 + C 18:1 *cis*-15 + C18:1 *trans*-16 + C20:1 + C24:1);

PUFA[4] = (C18:2 n-6 + C18:2 *cis*-9, *trans-11* + C18:3 n-3 + C20:2 n-6 + C20:3 n-6 + C20:4 n-6 + C22:5 n-3);

Ω-6[5] = (C18:3 n-3 + C22:5 n-3);

Ω-3[6] = (C18:2 n-6 + C20:2 n-6 + C20:3 n-6 + C20:4 n-6).

Generally, animals with higher zebu breed percentages have higher concentrations of PUFA in intramuscular fat due to their fibre composition characteristics and the increase in muscle membranes (ITO et al., 2012). According to Gruffat et al. (2013), discrepancies in PUFA concentrations can be explained by genetic differences in the expression of genes that influences the activity of enzymes involved in FA biosynthesis.

The current recommendations to reduce SFA intake in humans are based on the findings of studies from the mid-20th century, which eluded that dietary SFA causes an increase in total serum and LDL cholesterol and, therefore, increases the risk of CVD (STEINBERG, 2005). More recently, some studies have questioned the current dietary recommendations against consuming SFA and have revealed that SFA intake is not associated with an increased CVD risk (LAWRENCE et al., 2013; PUASCHITZ et al., 2015).

The Ω-3 FA helps prevent various diseases like arthritis, depression, cancer, and even Alzheimer's disease. The Ω-6 FA has some essential functions in blood pressure regulation and circulation to prevent inflammation (KIM et al., 2016). The Ω -6 FA that has been widely studied in the last years is the conjugated linoleic acid (CLA).

Several studies have demonstrated the benefits of CLA in human health. It is a potent anticarcinogenic agent, has anti-diabetic effects, and improves the immune system and bone mineralization. Besides, CLA is found only in animal products, and, therefore, ruminant fat is the richest natural source of these essential AGs (GEBAUER et al., 2015; VAHMANI et al., 2020).

The PUFA/SFA and the Ω-6/Ω-3 ratios are essential indexes to assess the nutritional value of fats for human consumption. PUFA/SFA ratio should be as large as possible since PUFA is the most beneficial to human health. Nevertheless, it must be considered that the meat from ruminants has a lower PUFA/SFA ratio due to the hydrogenating action of ruminal microorganisms.

According to FAO and WHO (2010), the consumption of PUFA should stay between 6 and 11%, with a total intake of Ω-3 varying between 0.5 to 2%, and the input of Ω-6 ranging between 2.5 to 9%. There are no recommendations for the Ω-6/ Ω-3 ratio intake, as long as Ω-6 and Ω-3 are within the recommended.

CONCLUSIONS

The production of quality meat through ICL is an interesting strategy for adding value, increasing income, and intensifying production in rural properties that adopt the integrated crop-livestock system.

Nellore produced meat with a better fatty acid profile due to the physiological maturity stage at which this group was slaughtered.

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PREVIOUS AGRICULTURAL MANAGEMENT AFFECTS YIELD OF TRIPLE INTERCROPPING OF CORN, PALISADEGRASS AND PIGEONPEA

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ABSTRACT

Intercropping different plant species is very important to improve soil properties, especially biological traits, increasing crop yield. At the same time, adjusting seeding rate and agricultural management in order to obtain the maximum benefits of the intercropping is a challenge. Moreover, intercropping results can change according to soil fertility and agricultural management of the field. Therefore, we evaluated the effects of previous crop and pigeonpea cultivation on the forage and corn yield in a triple intercropping of corn, palisadegrass and pigeonpea. The experimental area had a degraded pasture in 2014. The area was separated in two systems: crop-livestock integrated system (CLIS) and pasture recovering (P). Each system had areas with and without previous cultivation of pigeonpea. In the season of 2016/2017, the intercropping of corn, palisadegrass and pigeonpea was equally sowing in the whole field. Pigeonpea forage production was not affect by previous agricultural management. Palisadegrass proportion in forage was higher in the area of previous pasture recovering. The results indicated higher corn and forage yield in fields in third year of crop-livestock integrated system.

Key words: grains; forage; sustainability

INTRODUCTION

Corn is nowadays one of the main commodities in Brazilian market (ARTUZO et al., 2019), with growing demand for cattle feeding (MANFRON et al., 2021), fuel (DA SILVA et al., 2020) and human feeding (MARTINS et al., 2012). Between 2018/2019 and 2028/2029, the corn cultivated land is expected to expand by 7.2% due increase in cultivation of corn in the second crop season (BRASIL, 2019). The crop-livestock integrated system (CLIS) is the use of different crops in rotation and/or succession with an animal grazing period. CLIS has been characterized as important option to increase yield and sustainability of the system. The CLIS can be used for pasture recovering, higher biomass production for direct seeding management, increase soil carbon stock and decrease soil erosion (HACKER et al., 2009; CARVALHO et al., 2011a).

Actually, corn and palisadegrass intercropping is considered a good agricultural practice to sustainability of agricultural systems (BORGHI et al., 2013; KICHEL et al., 2009). Use of intercropping proportionate better soil covering, water conservation (FISHER; TOZER, 2012) and improvement of chemical, physics and biological properties of the soil (CALONEGO et al., 2011). In general, with good management, the corn yield is not compromised by palisadegrass intercropping (CHIODEROLI et al., 2010). However, the correct management of the intercropping can change according to soil fertility and previous agricultural management on the field. Therefore, the present study aims to evaluate the effect of previous crop and pigeonpea cultivation in the area on the forage and corn yield in a triple intercropping of corn, palisadegrass and pigeonpea.

MATERIAL AND METHODS

The experiment was conducted in the Experimental Farm (16º25’29’’S and 51º09’04’’W, mean altitude of 602 meters) of Federal Institute Goiano Campus Iporá during the crop season of 2016 and 2017. The experimental area in 2014 had a pasture in degradation with predominance of *Urochloa decumbens*. In the seasons of 2014/2015 and 2015/2016, the field (9 ha) was divided in 18 paddocks. Half of the paddocks was cultivated in a crop-livestock integrated system (CLIS – high input system) with corn cultivation in the first season and soybean in the second. CLIS had beef cattle grazing during the off-season (dry period of the year). The chemical and physical soil limitations were correct with gipsy (1,000 kg ha^{-1}) application and 0.4 m deep ploughing. Other half of the paddocks went to a pasture recovering system (PASTURE - low input system) with beef cattle grazing management and low levels of fertilization. In each system, we had part of the paddocks with pigeonpea cultivation intercropped with corn and palisadegrass (CLIS) and intercropped with previous palisadegrass (PASTURE).

The triple intercropping of corn (*Zea mays*), palisadegrass (*Brachiaria brizantha* cv. Xaraes) and pigeonpea (*Cajanus cajan* cv. Super N) was equally sowed in the whole area on November 23th of 2016 using a multi-seed drill. Corn (Biomatrix hybrid – BM840®) was sown in 0.8 m spaced rows at 60,000 seeds ha^{-1} and corn rows were intercalated with pigeonpea rows also 0.8 m spaced at 180,000 seeds ha^{-1} (13.3 kg of seeds ha^{-1}). The palisadegrass was superficially sown using the fine seeds distribution system at 360,000 seeds ha^{-1} (4.2 kg of viable seeds ha^{-1}) using a multi-seed drill.

The fertilization was performed with 310 kg ha^{-1} of simple superphosphate (18% of P_2O_5) in seeding rows with the seed drill. At V4 corn stage, 250 kg of urea ha^{-1} (112.5 kg of N ha^{-1}) were spread superficially. It was not necessary to use herbicide or insecticides after sowing.

At 94 days after sowing (February 25th, 2017), forage was sampled in fifty-four random points in experimental area. Harvesting point was determined by the optimum point for corn ensilage, 30 to 35% of dry matter content. Forage was cut at 0.1 m from soil surface.

At each sampling point, we collected 1 m^2 of corn-exclusive sample and other 1 m^2 of total forage sample with the three species intercropped for estimation of dry matter content and chemical composition analyses. One sample was evaluated for total forage availability (three species intercropped) and the other sample was stratified on each forage species.

Ten corn plants in a row were harvested and plant population was measured. The corn production estimation was adjusted for corn population. It was realized four measurements in each paddock. The grain weight was adjusted for 13% of moisture.

The data was evaluated by mixed model considering the fixed effect of crop cultivation year (1º or 3º of crop cultivation) and previous pigeonpea cultivation (yes or no). The paddocks were considered as random effect. If a significant fixed effect was identified, least square means was compared by Tukey test ($p<0.05$). Principal component analysis was performed to identified the relationship of yield with the other evaluated traits. Statistical analyses were carried out in R software (R CORE TEAM, 2020) using lmer (FOX; WEISBERG, 2020) and emmenas packages (LENTH et al., 2020).

RESULTS AND DISCUSSIONS

The third crop cultivation year had twice corn yield compared to the fields in the first crop cultivation year (Table 1). The previous pigeonpea cultivation did not affect the corn production, even the values are higher in the areas with pigeonpea than areas without.

Nitrogen fertilization is extremely important to corn production (JIN et al., 2012), as the nutrient are essential in photosynthetic activity and plant growth (TAFTEH; SEPASKHAH, 2012). Therefore, it is possible that the previous soybean cultivation in the fields of third year in CLIS proportionate better conditions for corn production. However, the previous pigeonpea cultivation (also a legume species) did not affect corn yield.

Pacheco et al. (2009) showed higher soybean yield using *B. ruziziensis* as cover crop compared to control without cover crops. Therefore, CLIS promotes higher sustainability, with intense nutrients cycling and increase yield.

Table 1. Mean grain production per hectare (kg ha^{-1}) (± standard error) in fields in first and third year of crop cultivation with or not previous pigeonpea cultivation.

Pigeon pea	**Years of previous crop cultivation**		
	1º	**3º**	
Yes	1594 (± 335) b	3075 (± 237) a	2335 (± 205)
No	1289 (± 237) b	2851 (± 335) a	2070 (± 205)
	1442 (± 205) b	2963 (± 205) a	

a,b: means followed by different letters in the row means statistical difference between years of previous crop cultivation.

In relation to forage production for silage harvesting, the corn and palisadegrass proportion (in dry matter basis) had a significant effect of the years of previous crop cultivation (Figure 1). In the first year, palisadegrass represented a higher proportion of the forage produced with corn contribution to forage production with an opposite result. Thus, there is a higher palisadegrass participation in the fields of first year of crop cultivation compared to third year. Pigeonpea proportion in forage dry mass did not change between years of previous crop cultivation.

Pigeonpea and corn population did not have difference between years of previous crop cultivation. However, palisadegrass had lower population in the third year. These results showed that corn growth is favored in better soil condition (third year). In this condition, corn had higher dominance over palisadegrass, impairing their establishment and growth. Balbinot Junior and Fleck (2005) described corn as a plant with higher competitive capacity.

Guimarães et al. (2017) evaluated the same triple intercropping system and suggested that palisadegrass did not affect corn growth and dry matter forage production. These same authors suggest that pigeonpea can affect corn yield depending on the population. Guimarães et al. (2017) concluded that up to 200,000 plants of pigeonpea per hectare did not affect corn yield. Carvalho et al. (2011b) also observed higher pigeonpea effect on corn growth with higher pigeonpea seeding rate. Here, the pigeonpea population was close to 60,000 plants per hectare, therefore, it is unlikely that pigeonpea impaired corn growth and yield.

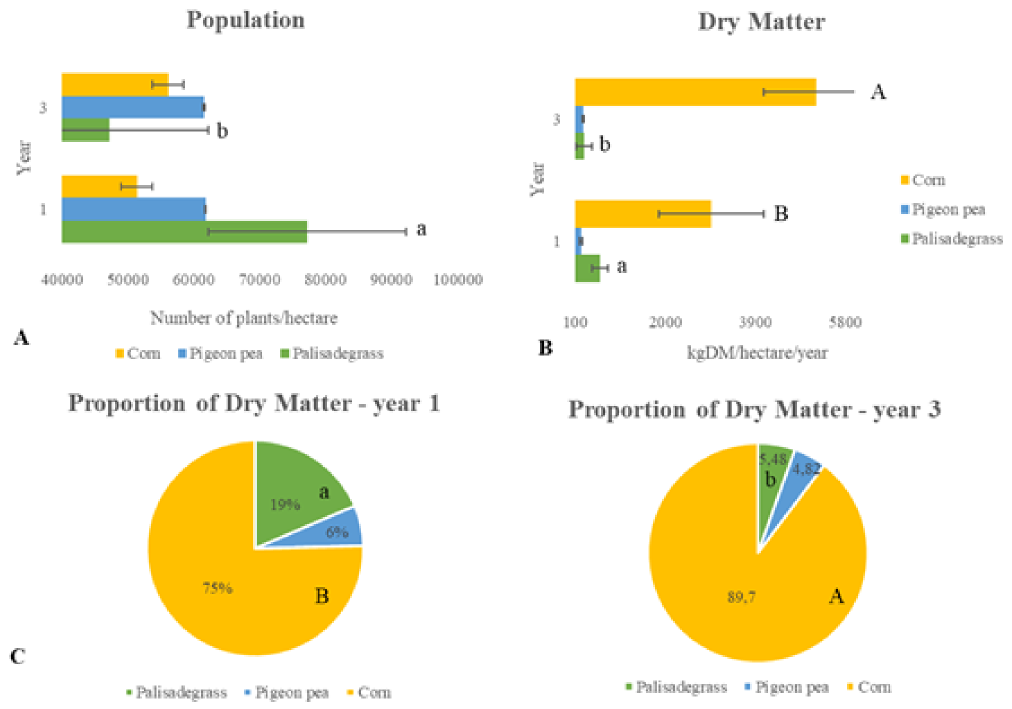

Figure 1. Means of population, forage dry matter production and botanical composition of the forage produced with the intercropping of corn, palisadegrass and pigeonpea in fields of first and third year of crop cultivation A: plant populations. B: forage dry matter production. C: proportion in forage dry matter produced at stage of silage harvesting. Means followed by different letters means statistical difference between years of previous crop cultivation.

CONCLUSIONS

Crop-livestock systems can increase grain yield through the years of cultivation. Previous pigeonpea cultivation did not affect grain and forage yield in succession crop. When evaluating intercropping results, it is very important to comprehend the previous agricultural management of the field. As seen here, the interspecies competition and forage production can be very different according to the previous crop cultivation and land management.

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SOIL RESISTANCE TO PENETRATION IN AN OXISOL UNDER INTEGRATED AND NON-INTEGRATED GRAZING SYSTEMS IN SOUTHEAST BRAZIL

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ABSTRACT

In order to learn more about soil physical quality in integrated systems, this study proposed comparing soil penetration resistance in two different depths, 0 - 5 cm and 12.5 - 17.5 cm, in areas under different managements. The systems evaluated were continuous grazing (CONT), rotational grazing (ROT), integrated livestock-forest system (ICL), integrated crop-livestock system (ILF), integrated crop-livestock-forest system (ICLF), and native vegetation (NV). The study site was in an experimental unit in the Brazilian Agricultural Research Corporation located in São Carlos, Brazil, where the climate is humid subtropical, and the soil is classified as an Oxisol. Undisturbed soil samples were collected with four replicates in each system. Soil resistance to penetration (SRP) was assessed with a benchtop electronic penetrometer in which the water content was previously standardized to be equivalent to a tension of -6 kPa. Data were statistically analyzed with a two-way analysis of variance (ANOVA) followed by Tukey tests (significance level: α=0.05). Significant differences were found among the studied systems. NV presented the lowest SRP. All the agricultural systems had SRP means higher than the limit of 2 MPa.

Key words: soil mechanical resistance; integrated crop-livestock-forest systems; soil physical quality

INTRODUCTION

In recent times, the search for highly sustainable and productive agriculture systems has risen due to the challenge of feeding seven billion people and the pressure for environmental conservation (CARDOSO et al., 2013). Integrated crop-livestock-forest systems are considered prospects for sustainable agricultural intensification, combining crops, livestock, and forestry, which could be integrated into space using intercropping cultivation or in time by rotating systems (BALBINO et al., 2011). Several agronomic, environmental, and socio-economic benefits are expected from integrated systems, such as yield increase, mitigation of greenhouse gases, and a better physical, chemical, and biological soil quality (KICHEL et al., 2014).

Soil quality is a comprehensive concept related to physical, chemical, and biological soil properties or processes (CHERUBIN et al., 2015). It is generally inferred by assessing soil properties sensitive to land use and management changes (CARDOSO et al., 2013). Among soil properties, soil resistance to penetration (SRP) is an important physical indicator of soil quality, as it directly influences plant growth and crop production (LETEY, 1985).

Despite several benefits of integrated systems, there is a lack of studies investigating soil physical quality under these systems. A literature review (VALANI et al., 2021) showed that: i) only 9% of the published studies evaluated two integrated systems, and none of them compared three or more integrated systems, and ii) less than 20% of all the reviewed papers assessed integrated systems with the forest component. Therefore, there is a need to evaluate more diverse integrated systems, especially under experimental designs. This study may fill the gap in the literature about physical soil quality in integrated systems, especially in the systems with trees.

This study aimed to compare SRP in two soil layers of an Oxisol in three different integrated systems, as well as in two non-integrated grazing systems and a native vegetation area.

MATERIAL AND METHODS

The soil was sampled from an experimental unit in the Brazilian Agricultural Research Corporation located in São Carlos, Brazil. The region's climate is humid subtropical (ALVARES et al., 2013), with a mean annual temperature of 21 ºC and mean annual rainfall of 1420 mm. The soil in the area is an Oxisol (STAFF, 2014), with a clay content of about 300 g kg^{-1}, as previously described by Calderano Filho et al. (1998).

Six soil management systems were studied: continuous grazing (CONT), rotational grazing (ROT), integrated livestock-forest system (ICL), integrated crop-livestock system (ILF), integrated crop-livestock-forest system (ICLF), and native vegetation (NV). A summary of the study sites can be found in Table 1. The five agricultural systems were arranged in randomized blocks of 3 ha each, with two replicates covering a 30 ha area. Although the native vegetation was not part of the experimental design, it is essential to note that the soil type is the same as the experimental area (CALDERANO FILHO et al., 1998), and thus the native vegetation was studied as a reference for the agricultural sites.

Table 1. Summarized information about the studied sites.

ID	Establishment	Species grown	System description
CONT	< 1980	*Brachiaria decumbens*	No farm inputs, not degraded due to controlled animal stocking
ROT	2011	*Brachiaria brizantha* 'Piatã'	Liming and fertilizers are applied regularly. Rotational grazing.
ILF	2011	*Brachiaria brizantha* 'Piatã' *Eucaliptys urograndis* cl. GG100	Grass management as ROT. Trees with a spacing of 15 m x 4 m.
ICL	2011	*Brachiaria brizantha* 'Piatã' *Zea mays* 'DKR390PRO2'	Grass management as ROT. Corn was sown every three years under no-tillage with a spacing of de 0.25 m x 0.8 m, harvested for silage.
ICLF	2011	*Brachiaria brizantha* 'Piatã' *Zea mays* 'DKR390PRO2'	Grass management as ROT. Trees management as ILF and corn management as ICL.
NV	<1975	Semideciduous forest with 146 cataloged species (Silva and Soares, 2003)	Shannon-Wiener diversity index of 3.45 (Silva and Soares, 2003)

CONT: continuous grazing, ROT: rotational grazing, ILF: integrated livestock-forest system, ICL: integrated crop-livestock system, ICLF: integrated crop-livestock-forest system.

Undisturbed soil samples were taken with soil cores (5 cm of height, 97 cm^3 of volume) at two soil depths: 0 – 5 cm (topsoil) and 12.5 – 17.5 cm (subsoil) which were sampled with four replicates in each studied site. Soil resistance to penetration was assessed with a benchtop electronic penetrometer (CT3 Texture Analyzer, Brookfield, Middlebore, MA, EUA) in which the water content was previously standardized to be equivalent to a tension of -6 kPa. The equipment had a metallic rod with a cone at its end, set to penetrate the soil at a speed of 20 mm sec^{-1} down to 480 mm, with a data acquisition rate of 40 points per second, totaling 960 values for resistance to penetration in each sample. The data were filtered to include only the 600 values from the central portion of each sample.

The resulting dataset, average means and standard deviations were calculated for each system and soil depth was assessed. As the data were normally distributed as determined by the Shapiro-Wilk test ($p > 0.05$), a two-way analysis of variance (ANOVA) was performed, considering studied systems and soil depth as the two factors. The means were therefore compared by the Tukey test ($p < 0.05$). The data was analyzed by Statistica for Windows (Statsoft, Tulsa, USA).

RESULTS AND DISCUSSIONS

Considering the two-way ANOVA, significant differences ($p < 0.01$) were found between the studied systems. No differences were found between soil depths ($p = 0.92$) or interaction between studied systems and soil depths ($p = 0.29$). The lowest means for SRP was found in the topsoil of NV (0.77 MPa), while the highest mean was found in the subsoil of ICL.

Table 2. Average means and standard errors for soil resistance to penetration in two soil layers and subsoil of studied systems.

System	**Soil resistance to penetration (MPa)**		**Homogeneous subsets**
	Topsoil (0 – 5 cm)	**Subsoil (12.5 – 17.5 cm)**	
CONT	2.87 ± 0.79	2.18 ± 0.71	b
ROT	3.16 ± 1.55	2.87 ± 1.11	b
ILF	3.52 ± 1.04	3.00 ± 0.72	b
ICL	3.10 ± 0.68	4.36 ± 1.04	b
ICLF	3.47 ± 1.14	3.01 ± 0.72	b
NV	0.77 ± 0.50	1.07 ± 0.18	a

CONT: continuous grazing, ROT: rotational grazing, ILF: integrated livestock-forest system, ICL: integrated crop-livestock system, ICLF: integrated crop-livestock-forest system. The same letter in the last column does not differ by the Tukey test ($p < 0.05$).

No difference was found between the topsoil and subsoil in any of the studied systems concerning both soil depths studied. This result may be related to the soil type, an Oxisol, a soil order known as deep soils due to weathering (BIRKELAND, 1984), and therefore assessments in deeper soil layers may be needed to investigate SPR in these systems. Nevertheless, considering only absolute values, SRP was lower in the topsoil compared to the subsoil for all systems, except the integrated crop-livestock system.

No differences were found within agricultural systems (Table 2). Considering the critical limit for SPR widely suggested of 2 MPa (TORMENA et al., 1998; SILVA et al., 2008; DE LIMA et al., 2012), all systems should need amelioration to limited plant growth and development. However, considering the studied systems under no-tillage (ICL and ICLF) and the suggested critical limit for SPR in no-tillage systems of 3.5 MPa (MORAES et al., 2014), SRP in the ICLF may be considered as not limitingfor plant growth and development. The higher critical value for SRP in no-tillage systems is related to the presence of continuous and biological pores, which favor root growth even in areas with low SPR (TORMENA et al., 2007; BETIOLI JÚNIOR et al., 2012).

CONCLUSIONS

Soil resistance to penetration did not differ between the topsoil (0 – 5 cm) and the subsoil (12.5 – 17.5 cm) in the studied systems. SRP in the native vegetation was lower than all other systems. No differences were found between agricultural systems, in which SRP was always higher than the suggested critical limit of 2 MPa. Considering the critical limit of 3.5 MPa for no-tillage systems, the integrated crop-livestock-forest system may be suggested as the only agricultural system in which SRP is not limiting for plant growth and development in both assessed soil depths.

Further studies should assess different physical indicators of soil quality to contribute to the understanding of soil functioning in integrated and non-integrated grazing systems, including assessments in greater depths.

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PEDOTRANSFER FUNCTIONS TO ESTIMATE FIELD CAPACITY AND PERMANENT WILT POINT IN A PLANOSOL UNDER INTEGRATION CROP-LIVESTOCK-FOREST SYSTEM IN THE AGRESTE OF PARAÍBA

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ABSTRACT

Pedotransfer functions are methods proposed with the objective of obtaining indirect information, with greater speed and ease to estimate various soil attributes. Thus, the objective of this work was to generate and obtain pedotransfer functions (PTFs) to predict the moisture retained at specific potentials in a Planosol under integration crop-livestock-forest system in the Agreste of Paraíba, three years after implementing the system. The research was conducted in an area located at the Experimental Station of the Paraíba Company of Research, Rural Extension and Land Regularization - EMPAER, in the district of Alagoinha, PB. The experimental design utilized was that of randomized blocks with 5 integration systems and 4 repetitions. The treatments were structured as 1) Gliricídia + *Brachiaria decumbens* (GS+BD); 2) Mimosa *caesalpiniaefolia*+ *Brachiaria decumbens* (MC+BD); *Tabebuia alba* + *Brachiaria decumbens* (TA+BD); 4) Zea mays + *Brachiaria decumbens* (ZM+BD); 5) *Brachiaria decumbens* (BD). Soil samples with undisturbed structure were collected in three layers (0.00-0.10; 0.10-0.20 and 0.20-0.30 m). Soil water retention was determined in the following matrix potentials: Ψm = -33 e -1,500 kPa. According to the results, it was possible to observe an increase in the available water content in all treatments, as a function of depth, and the soil granulometry was shown to be related to the increase of clay particles in the subsurface.

Key words: soil water; pedofuctions; agrosilvopastoril systems

INTRODUCTION

The soil water retention curve can be obtained directly, through the tension table and Richards chamber, the psychrometer, the centrifuge, or indirectly through mathematical models.These models, also called Pedotransfer Functions (PTFs), are intended to make the obtaining of difficult determination data easier (OLIVEIRA et al., 2002; MICHELON et al., 2010; COSTA et al., 2013), based on atributes which are constantly measured with great ease and low cost (SANTRA; DAS, 2008; SILVA et al., 2008), transforming the available information into necessary data (BOUMA, 1989).

Knowing the behavior of water in the soil is important for decisions in aspects involving the environment at all scales, since the use of pedotransfer models for soils in regions, management and conditions different from the conditions that originated the calibration data must be avoided., since it increases the risk of making a wrong prediction (SILVA; ARMINDO, 2016).

It can be said that, in order to estimate water retention in the soil, using Pedotransfer Functions (PTFs), deep and textural resources, are good predictors when present in mathematical models. Andrade et al. (2020), developed models for estimating field capacity and permanent wilting point, in Argissolos Amarelos in the coastal tableland region of the state of Pernambuco, the models generated were composed of the content of clay, sand, mesoporosity and soil density.

In Agreste Paraibano, Pequeno et al. (2020), developed PTFs where the variables that most contributed to the generation of functions were coarse sand content, microporosity and soil density. The authors concluded that the generated PTFs generated good accuracy and can be used to estimate the water content retained in Dystrophic Yellow Latosol and Eutrophic Red Argisol, for the region's edaphoclimatic conditions.

In this sense, this work aimed to generate and obtain pedotransfer functions (PTFs) to predict the retained moisture to special potentials in a Planosol under integration crop-livestock-forest system in the Agreste of Paraiba.

MATERIAL AND METHODS

Location and characterization of the study área

The experimental area is located in the experimental station of the Paraiba Company for Research, Rural Extension and Land Regularization - EMPAER, located in the municipality of Alagoinha, in the Agreste mesoregion of the State of Paraíba, under the coordinates 06º57'00” S and 35º32'42” W and 317 m altitude. The region's climate is characterized as As', hot and humid, with autumn-winter rains according to the classification proposed by Koppen-Geiger. The average annual precipitation is 995 mm, with the rainy season covering the months of March to August. The annual average temperature varies between 22 and 26 ºC.

Experiment implementation

The soil of the experimental area was classified as Eutric Planosol with moderate A horizon and sandy loam texture according to SiBCS (SANTOS et al., 2018).

An experiment was installed in July 2015 and the evaluation was carried out in March 2018. The experimental design adopted was in randomized blocks (RBD) with five treatments and four replications (5 x 4). The experimental plots were 38 x 20 m, making a total area of 760 m2. The treatments consisted of: 1) *Gliricidia sepium* (Jacq.) Steud + *Brachiaria decumbens* (GS+BD); 2) *Mimosa caesalpiniaefolia* (Benth)+ *Brachiaria decumbens* (MC+BD); 3) *Tabebuia alba* + *Brachiaria decumbens* (TA+BD); 4) *Zea mays* L. + *Brachiaria decumbens* (ZM+BD); 5) *Brachiaria decumbens* (BD). The forest species were planted in triple rows, with 3 x 2 m spacing at the edges of each plot, adding up to six rows per plot, while the corn was planted under no-tillage system.

The undisturbed soil samples were collected in three layers: 0.00-0.10 m, 0.10-0.20 m and 0.20-0.30 m, in each experimental plot.

Generation and obtaining of pedotransfer functions (PTFs)

Data was submitted to statistical analysis using the statistical software SigmaPlot, where, first, a simple correlation analysis was performed between all variables. Subsequently, multiple regression analysis was performed using the “stepwise” option to obtain the PTFs. In the definition of multiple linear regression equations, to predict the model's attributes, it was established that the behavior of a characteristic in the equation must affect the parameter to be predicted (dependent variable) being consistent with the empirical and theoretical knowledge of the process.

From the existing data in the database, PTFs were generated to estimate each of the points (-33and -1500 kPa) of the water retention curve in the soil. These PTFs were generated through independent variables included in the model, at 5% error probability. The independent variables used in this study were: sand and clay content, flocculation degree, soil density, particle density, macroporosity, microporosity, total porosity and pH in water. The dependent variables were the matrix potential water contents of -33 and -1500 kPa.

RESULTS AND DISCUSSIONS

The pedotransfer functions (PTFs) generated and their respective determination coefficients in the matrix potentials of Ψ-0.3 and Ψ-1.5 (kPa) are shown in Table 1. The composition of the PTFs took into account, mainly, structural and textural variables, in addition to pH. The R^2 values obtained by each model, represent the importance of the structure and texture of the soil in water retention.

Table 1. Pedotransfer functions generated and validated to estimate field capacity (FC) and permanent wilt point (PWP) and their respective statistical indicators (R^2, ME and RSME) in a Planosol under the Integratedcrop-livestock-forest system in the Agreste of Paraíba.

PTFs	**R^2**	**ME**	**RSME**
$\Psi_{-0.033}$= 0.263 + (0.000621 * Clay) - (0.0372 * pH)	0.91	0.00053	0.00207
$\Psi_{-1.5}$ = -1.047 + (0.0000522 * total sand) - (0.630 * PT) - (0.0000408 * GF) + (0.367 * DP) + (0.0782 * DS) + (0.0613 * pH)	0.86	0.00060	0.00233

D_P = particle density; D_S = bulk density; PT = total porosity; R^2 = determination coefficient; ME = average error; RSME = square root of the mean error.

For the matrix potential Ψ-0.033, the ME value (0.0005 cm^3 cm^{-3}) indicated a slight overestimation of the data calculated through the PTFs. The observance of the 1: 1 straight line with RSME value (0.0021 cm^3 cm^{-3}) demonstrated a good fit between the estimated and observed data, with moderate dispersion. The coefficient of determination (R^2) was around 0.90. Thus, 90% of the variation in the water content retained is explained by the model.

In the matrix potential Ψ-1.5, referring to the permanent wilting point of the soil, the statistical indicators showed a slight underestimation in the retained water content estimated by the PTFs (ME = -0,0006 cm^3 cm^{-3}), in addition to a low data dispersion in relation to the 1: 1 line (RSME = 0.0023 cm^3 cm^{-3}). The coefficient of determination (R^2) with a value of 0.86 indicates a good adjustment of data by the model, where 86% of the variations in the water content can be explained by the same.

Both functions presented high R^2 values and low ME and RSME values, denoting the good accuracy of these PTFs in the prediction of water retention values in the soil in all potential matrix tested in the study, referring to a Planosol.

CONCLUSIONS

Points of the water retention curve in the soil can be estimated with reasonable precision, based on the functions of the generated pedotransferences, using the contents of sand and clay, density of the soil and particles, macroporosity, microporosity and total porosity, degree of flocculation and pH.

The generated and validated pedotransfer functions can be applied in simulations to obtain points on the retention curve, considering the adjustments obtained, for the studied Planosol, considering the geographic region, the climate, the hydrology and the use of the soil.

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HARVESTING POINT AND FORAGE PRODUCTION IN INTERCROPPING PALISADEGRASS AND PIGEONPEA

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ABSTRACT

Pigeonpea have a great potential to be explored for forage production in intercropping with grass species. The intercropping of leguminosae (Fabaceae) and grass (Poaceae) for forage production is especially challenging due the difference in growth physiology between the families. Therefore, it is very important to determine the optimum time for harvesting the forage for conservation purpose. This study aimed to determine the best time for harvesting the palisadegrass (*Urochloa brizantha* (Syn. *Brachiaria brizantha*) cv. Xaraés) and pigeonpea (*Cajanus cajan* cv. SuperN) intercropping for production of hay, looking for the best balance between quantity and quality. The experimental trial had 16 plots with 4 m² each. The forage was harvested at: 55, 68, 82 and 95 days after pigeonpea sowing. Each time had four repetitions. At harvest, it was measured the pigeonpea population and forage production by each species. At 123 days after sowing, all plots were harvested again to evaluate pigeonpea regrowth and the change in pigeonpea population. Chemical composition was determined in all forages collected. The days for harvesting did not impair the regrowth and survival of pigeonpea plants. The best time to harvest palisadegrass and pigeonpea intercropping was close to 80 days after sowing.

Key words: *Brachiaria brizantha*; *Cajanus cajan*; existem

INTRODUCTION

The forage conservation process maintain forage with good nutritional value with minimal loses. Hay production is a very good option for forage conservation, allowing to equilibrate the animal demand and forage growth throughout the year (CÂNDIDO et al., 2020). Almost all kind of forages can be conserved, however it is always very important to understand the plant growth to find the best harvest point, balancing quantity and quality (nutritional value) of the forage (ANDRIGUETTO et al., 2002). Legumes and grass intercropping is a good option for production of high quality forage with high yield per land unit. Moreover, leguminosae plants in symbiotic association with bacteria promotes nitrogen fixation, decreasing the demand for chemical fertilizer and, in general, these plants produce a high-protein forage (AGUIRRE et al., 2014).

Xaraes grass (*Urochloa brizantha* (Syn. *Brachiaria brizantha*) cv. Xaraés) have one of the highest forage yield between cultivars of its gender, which is the main forage gender cultivated in Brazil (FLORES et al., 2008). Pigeonpea is a bi-annual shrub leguminosae, being an important crop in some Asian and African countries (AZEVEDO et al., 2007). This plant has a great potential to be used in tropics to produce a high-quality forage and for intercropping with grasses (PALUDO et al., 2012). Moreover, palisadegrass and pigeonpea intercropping is an option as cover crop with high biomass production for crop-livestock integrated systems, promoting crop rotation/succession with higher biodiversity increasing soil organic matter (SIX et al., 2004) and improving soil structure and fertility (GARLAND et al., 2016).

In general, the forage accumulation in pastures had three defined phases: first - slow forage accumulation with root growth; second – fast growth; and third – net forage accumulation tends to zero due death of old leaves, when the pasture hits the maximum forage accumulation per land (HODGSON, 1990). The forage nutritional value normally tends to decrease during the growth of the pasture and more intensely on the third phase. Therefore, the correct definition of the forage harvesting time is essential to have a good amount of forage with good nutritional value (NETO, 2020).

Thus, the present study aimed to determine the best forage harvesting time of the palisadegrass and pigeonpea intercropping.

MATERIAL AND METHODS

The experimental field (16º25’29’’S,51º09’04’’W, 602 m de altitude) had pasture of *Urochloa brizantha* (Syn. *Brachiaria brizantha*) cv. Xaraés. The pasture was mowed, followed by Pigeonpea (*Cajanus cajan* cv. Super N) sowing with direct seeding drill without soil loosing and herbicide at 23 of January of 2020.

The experimental area was divided in 16 plots with 4 m² each. The forage had their first harvest at four times: 55, 68, 82 and 95 days after sowing. Each harvest time had four repetitions. At 28 days after the last harvest (123 days after sowing), the forage of all plots were sampled again (second harvest) to evaluate the pigeonpea regrowth and survival from the first cut, as normally the mechanical cutting is very damaging to pigeonpea. Pigeonpea population was determined in each forage sampling. The forage was cut at 10 cm from the ground and fresh material was weighed. Forage samples were placed in paper bags at the forced air oven (65ºC) during 72 hours and them weighed again, determining the dry matter proportion. The samples were grounded and proceed to chemical composition analyses. It was measured: crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, ether extract (EE), ash, phosphorus (P) and calcium (Ca) (DETMANN et al., 2012). Nitrogen in NDF and ADF were also measured.

It was evaluated regression models evaluating the linear and quadratic effect of days from sowing to harvest and linear effect of pigeonpea population. The reduction of pigeonpea population between the second and first cut was also evaluated as independent variable considering days (linear and quadratic) and pigeonpea population at first cut as dependent variables. We also performed a principal component analysis (PCA) to comprehend the relationship between the variables, mainly the relationship between the forage chemical composition data. The data was analyzed using R software (R Core Team, 2020), using *car* package (FOX; WEISBERG, 2019) for regression analyses and *FactoMineR* (Le et al. 2008) and *factoextra* (KASSAMBARA; MUNDT 2020) packages for PCA.

RESULTS AND DISCUSSIONS

Pigeonpea population did not have a significant effect on forage quantity and chemical composition at the first harvest. It was observed the maximum point of forage accumulation (kg of dry matter per hectare) close to 80 days after sowing ($DM\_ha = -6231.09 + 207.09*days – 1.28*days^2$; $R^2 = 0.18$). According to Bonamigo (1999), in a grazing trial, 65 to 80 days after sowing was the best time for the first grazing, which is similar to our results. The other variable with significant regression with days after sowing was neutral detergent fiber ($NDF = 38.72 + 0.71*days – 0.004*days^2$; $R^2 = 0.39$).

The regrowth data had more significant regressions for days after sowing to first harvest and pigeonpea population (Table 1). Ash, Total digestible nutrients (TDN), DM_ha, neutral detergent fiber (NDF) and Mean forage accumulation rate (RATE - kg of DM per hectare per day) yield a significant regression with days and pigeonpea population. Crude protein (CP) and phosphorus (P) content had significant regression with days after sowing to first harvest.

Principal component analyses with first harvest data (Figura 1A) showed, at first component, grouping of crude fiber, acid detergent fiber and ether extract in opposition to TDN, calcium and RATE. Increasing the days after sowing to harvest led to low RATE and lower forage TDN. At second component, CP and P had an inverse relationship with NDF, DM_ha and protein in acid detergent. Therefore, higher forage production was associated with lower CP content.

Principal component analyses with second harvest data (Figura 1B) grouped the dry matter proportion, ash and days in opposition to pigeonpea population, RATE and DM_ha. Thus, more days to first harvest led to lower RATE and lower pigeonpea population. These results highlights that a late harvest is more damaging to pigeonpea plant, impairing their final population.

Table 1. Results of regression models of regrowth data (after first harvest) of palisadegrass and pigeonpea intercropping considering the days after sowing to harvest (linear and quadratic) and pigeonpea population as independent variables.

Variables	**p-value**			**Regression model**	**R^2**
	Days	**Days^2**	**PPpop**		
Ash	0.092	0.039	0.016	Ash = 9.566 – 0.08534*days + 6.989*days^2 - 0.00001834*PPpop	0.79
TDN	ns	ns	0.008	TDN = 0.6278 + 0.00003244*PPpop	0.69
DM_ha	0.032	0.023	0.009	DM_ha= - 7629 +239.8*days -1.667 *days^2 + 0.0431*PPpop	0.60
NDF	0.032	0.029	0.027	NDF= 53.78+ 0.3693*days – 0.002433* days^2 - 0.00005398 * PPpop	0.40
RATE	0.05	0.049	0.016	RATE = - 142.8 + 4.200*days – 0.02729* days^2 + 0.0007514* PPpop	0.40
PPloss	ns	ns	0.046	PPloss = - 0.0004226 + 0.883* PPpop	0.23
P	0.06	0.07	ns	P = - 0.06836 + 0.006553*days – 0.00004161* days^2	0.32
CP	0.009	0.008	ns	CP = 18.19 – 0.3098*days + 2.031 * days^2	0.35

ns: not significant (p>0.05); TDN: total digestible nutrientes; DM_ha: forage amount per hectare (kg of dry matter ha^{-1}); NDF: Nitrogen detergent fiber (%); RATE: Mean accumulation rate (kg of DM ha^{-1} day^{-1}); PPloss: Loss in pigeonpea population between the first and second harvest (plants ha^{-1}); P: Phosphorus (%); CF: Crude fiber (%); MM: Ash (%).

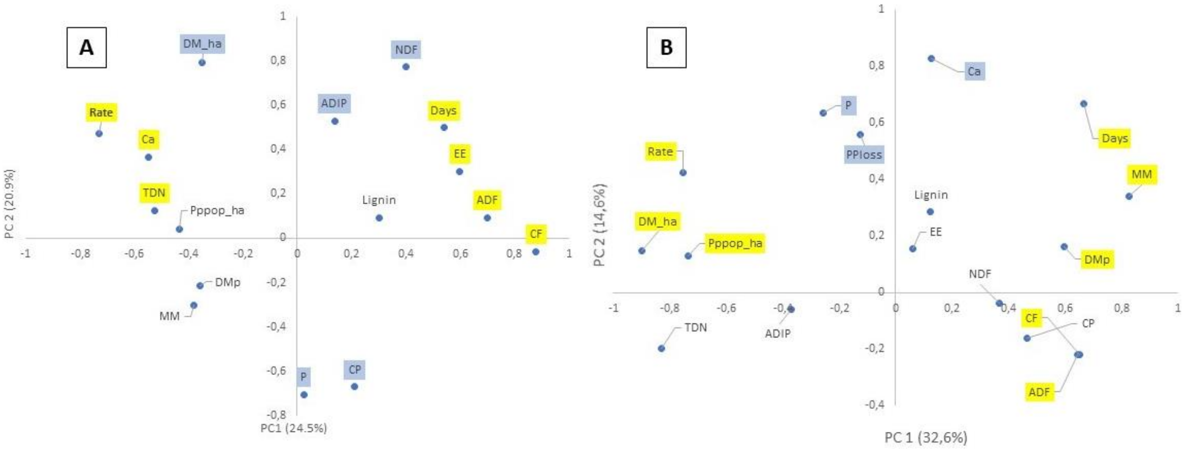

Figure 1. Principal component analyses with forage data of the first harvest (A) and the second harvest (B). Yellow-highlighted variables had significant correlation with first dimension and blue-highlighted variables had significant correlation with the second dimension. DM_ha: forage amount per hectare (kg of dry matter ha^{-1}); PPpop_ha: Pigeonpea population (plants ha^{-1}); P: Phosphorus (%); Ca: Calcium (%); MM: Ash (%); TDN: Total digestible nutrients (%); ADIP: Acid detergent insoluble protein (%); ADF: Acid detergent fiber (%); NDF: Nitrogen detergent fiber (%); CF: Crude fiber (%); PPloss: Loss in pigeonpea population between the first and second harvest (plants.ha^{-1}); EE: Ether extract (%); DMp: Dry matter proportion in fresh material (%); RATE: Mean accumulation rate (kg of DM.ha^{-1} day^{-1}); Days: days from sowing to first harvest. CP: Crude protein (%); Lignin (%).

CONCLUSIONS

Pigeonpea and palisadegrass intercropping had the best harvesting time close to 80 days after sowing. Increasing the days between sowing and first harvest decrease the total digestible nutrients of the forage and the mean forage accumulation rate per land unit. Thus, it highlights the importance of knowing the best harvesting point of the forage

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DAMAGE AND IMPACTS BY DAIRY CALVES IN FRUIT TREES OF SILVOPASTORAL SYSTEMS

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ABSTRACT

Compatibility between fruit trees and animals is fundamental to the success of silvopastoral systems. The aim was evaluating the compatibility between fruit trees and dairy calves in silvopastoral systems. The experiment was carried out on the experimental basis of milk production in integrated systems, at Embrapa Agrossilvipastoril, located in Sinop, Mato Grosso state, Brazil, during 2018, when the fruit species already were 48 months old after planting. Five silvopastoral systems with fruit tree species were evaluated, being: caja fruit, red guava, cashew tree var. Embrapa 51 and cashew tree var. CCP76 and acerola fruit with Tifton-85 grass, under a complete block design, with two repetitions, under continuous stocking. All fruit trees had some damage to their structure by consuming the animal. The *acerola* fruit was the most damaged, reaching levels of unfeasibility, the *caja* fruit had slight damages and no impact on its architecture and the cashew trees had substantial damages, however, the impacts of these damages were null on the architecture of the treetops. The guava had some damages but had positive impacts on the architecture of the treetops. We recommend red guava and cashews like the best species to intercrop with dairy calves in silvopastoral systems.

Key words: intercropped; architecture; browse

INTRODUCTION

Population growth has been accompanied by several environmental and social impacts, among which the biggest impacts have been climate change and increased deforestation, however what has been required are agricultural systems that aim at sustainability, food security and bring economic power to the rural producer (BALBINO et al., 2011).

Brazil is one of the largest food producers in the world, so several technologies have been developed to obtain greater productivity per hectare, such as silvopastoral systems, where it is possible to integrate trees with the livestock, which promote animal welfare with the use of natural shading provided by trees, increases the income of the producer with the production of goods that can be traded, intensifies productivity and guarantees the production of food while respecting environmental sustainability (FEY et al., 2015).

Following, silvopastoral systems with tree species has been valued, by addition extra income to the producer, have kept the tree upright, without the need to cut it down to obtain income, like is the case of fruit tree species (GIUSTINA et al., 2017). However, these species have structures that can be attractive to the animal's consumption, which would make it unfeasible. In this way, studies that confirm the animal's preferences and compatibility between the coexistence of the species is urgent in the productive environment.

In the experiment, five silvopastoral systems were tested, composed of five fruit trees intercropped with Tifton 85 (*Cynodon* spp), as follows: *caja*, red guava var. *Paluma*, cashew var. *Embrapa* 51 and var. CCP 76, and *acerola* var. *Sertaneja*, focusing on the compatibility between fruit species and animals and their respective damages and impacts, indicating which species would be better adapted to the integrated system.

MATERIAL AND METHODS

The experiment was carried out on the experimental basis of milk production in integrated systems, at *Embrapa Agrossilvipastoril*, located in Sinop, Mato Grosso state, Brazil (11º51'43" S, 55º35'27" W, 384 m asl). The climate of the region is classified as a tropical humid or sub-humid Am type (Köppen) (ALVARES et al., 2013), with an average annual temperature of 25ºC, relative air humidity of 76%, and precipitation of 2,020 mm (INMET).

The experimental area measured 3.75 ha, where the five silvopastoral systems were distributed. These systems were composed of eight fruit trees intercropped with Tifton-85 (*Cynodon spp*), as follows: *caja* (*Spondias mombin*); red guava (*Psidium guajava*) cv. *Paluma*; cashew (*Anacardium occidentale*) var. *Embrapa 51* (*EMB51*) and var. *CCP76* and *acerola* (*Malpighia glabra*) var. *Sertaneja*.

A completely randomized block design was adopted, with two replications of area per treatment. Each 1,650 m^2 experimental unit received different numbers of fruit tree seedlings, according to the canopy architecture and the spacing recommended for single cultivation. The plots with *caja*, and guava trees and the two cashew varieties received 27 plants spaced 4 × 10 m. The plots with *acerola* received 36 plants distributed in a double center row with 4 × 4 × 10 m spacing. Only the central plants in the inter-rows were evaluated in each plot disregarding the borders.

The forage was planted using seedlings after allocation, correction, furrowing, fertilization, and planting of the fruit species. Both the forage plant and the fruit tree were fertilized following basic recommendations for the species.

In this study, we evaluated the damage and impacts of these damages on the canopy tree architecture caused by dairy calves in silvipastoral systems.

The fruit trees were monitored to assess the degree of damage caused by the presence and actions of the animals. The initial method used was Porfírio-da-Silva et al. (2012) and had to be adapted to assist in the assessments caused by the animals' browse. They were described as: breakage of the main stem or trunk (Tq); lesion of the trunk reaching the wood through the removal of the foreign exchange tissue(T1); breaking of branches / secondary branches (Gq); skin lesion, without reaching the exchange rate (C1); breaking of thin branches and consumption of leaves or branching (Rq) and lesion greater than 5 cm in diameter (D1).

For each damage, a system of weights and grades was established, being: Tq = 10.0; T1 = 4.0; Gq = 2.0; Cl = 1.5; Rq = 1.0; and Dl = 1.0 (Figure 1). The final score for everyone was calculated as the sum of the respective incident damages.

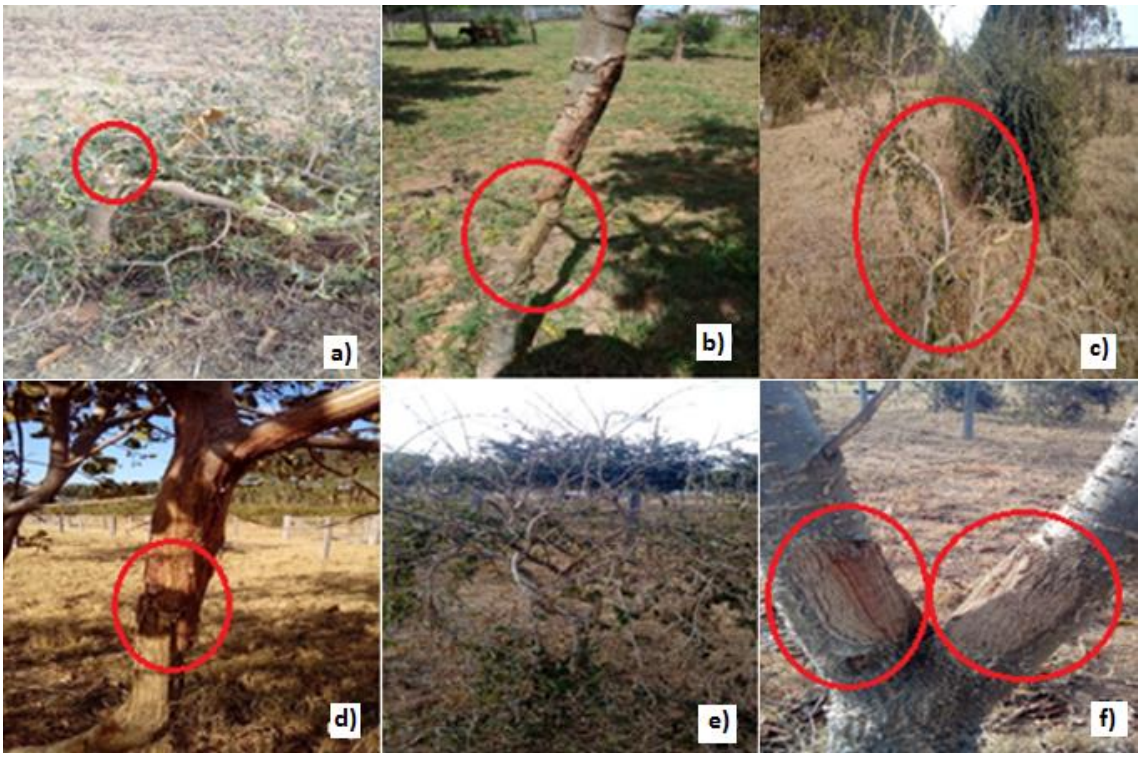

Figure 1. Types of damage to fruit trees caused by dairy calves in silvopastoral systems. a) Tq (break of the main stem or trunk), b) Tl (injury of the trunk reaching the wood through the removal of the exchange tissue), c) Gq (breaking of branches / secondary branches), d) Cl (bark injury, without reach the exchange rate), e), Rq (breaking of thin branches and leaf consumption, or browse) and f) Dl (lesion greater than 5 cm in diameter).

During the experiment, it was noted that the method adopted at the beginning did not show the reality obtained during the study observed in the field, with the need to create a new methodology that would be able to meet the analyzed damages. The new evaluation methodology was created after intense training of the evaluator, through visual and tactile observation of the fruit trees for an average period of six months. The impacts caused by the damage to the architecture of the trees were considered on a scale that varied from "-3 to +3", where the damage evaluated with "-3" would be where the action of the animals had a negative impact on the fruit tree canopy (Figure 2a); the value "0" was considered when the animals' branching did not change significantly in the canopy shape (Figure 2b), and "+3" would be evaluated when the presence of the animals brought benefits to the development of the fruit tree canopy (Figure 2c) , increasing the "skirt height" and eliminating undesirable shoots (GUIMARÃES FILHO and SOARES 2003).

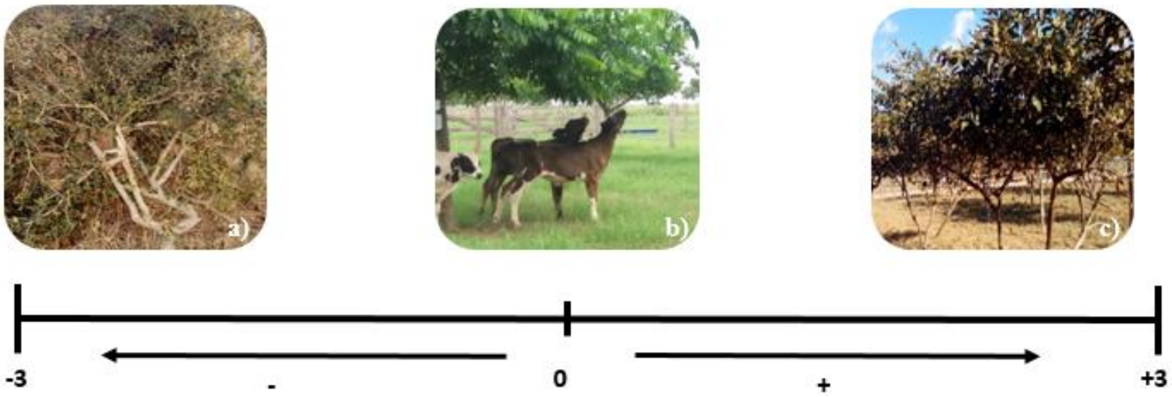

Figure 2. Impact degree of animal damage on architecture of fruit trees canopy. a) Unviable fruit tree, b) fruit tree with zero impact and c) fruit tree benefited by the branching process.

The data were subjected to Kolmogoroff-Smirnoff-based normality tests to evaluate data distribution via a normal PROC univariate procedure. The analysis of variance was performed using the PROC Mixed procedure. Means were compared using PDIFF at 5% probability. The software utilized for statistical analysis was SAS 9.2 (SAS Institute, 2008).

RESULTS AND DISCUSSIONS

The coexistence of calves with fruit trees promoted damage that was dependent only on the silvopastoral system (P = 0.0013). Cashew trees were the fruit trees that suffered the most damage (cashew *CCP76* with 3.7 and cashew EMB51 with 4.3), followed by acerola fruit (3.0), while for cashew and guava the least damage was observed (1.3 and 1.7, respectively).

In both cashew varieties (*CCP76* and *EMB51*), the damage “damage to the trunk reaching the wood by removing the foreign exchange tissue”, “skin damage, without reaching the exchange” and “injury greater than 5 cm in diameter” were identified, caused mainly by chewing, but the impacts to canopy architecture were close to zero. Although chewing the bark of trees by cattle is considered an unusual damage, according to Porfírio-Da-Silva et al. (2012), this was observed in these fruit trees during the experimental period.

The damage degree caused after the adoption of a new “fruit tree damage impact” methodology, there was an effect only from the silvopastoral system (P <0.0001). The *acerola* fruit was the tree species most negatively impacted (-2.4) to its architecture, while the cashew trees and the cashew tree were not affected by the damage caused by the animals (-0.1; on average), and the guava tree was positively impacted (0.9).

CONCLUSIONS

The use of *caja* fruit intercropped with Tifton-85 grass grazed by dairy herd calves did not suffer negative by animal action in the coexistence. Despite to the damage by animals, the impacts to architecture of the cashew trees (var. *CCP76* and *EMB51*) were null and can used to intercropped. Red guava var. *Paluma*, can be indicated for silvopastoral systems in the north of Mato Grosso, with positive action of the browse in the architecture of the tree canopy.

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ESTABLISHMENT AND PRODUCTION OF FORAGE GRASSES UNDER DIFFERENT LEVELS OF SHADING IN AN INTEGRATED SYSTEM

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ABSTRACT

The aim of this research was asses the establishment, yield and nutritive value of forage cultivars of *Brachiaria* and *Panicum* genus under different level of shading in integrated crop-livestock-forestry system (ICLF). The experiment was carried out in Embrapa Beef Cattle, Campo Grande-MS, Brazil, between April 2018 and June 2019. The randomized blocks design was used with split-plot scheme for establishment and production stage, with three repetitions. In order to assess the forages establishment, the treatments of the plots were the forages (*Brachiaria brizantha* cv. Marandu, cv. BRS Piatã, *Brachiaria* spp. cv. BRS Ipyporã, *Panicum maximum* cv. Massai and *Panicum* spp. cv. BRS Tamani) and split-plots the levels of shading between *Eucalyptus* rows [sampling points A (North), B (Center) and C (South)]. To assess the forage yield and nutritive value, the forage harvest took place at 60-day intervals (split-split-plots: cut 1, 2 and 3). The forage cultivars Piatã, Marandu and Massai showed higher leaf blade yield under shading environment, on the other hand Piatã was outstanding in relation to biomass yield and nutritive value.

Key words: *Brachiaria*; *Panicum*; shade

INTRODUCTION

The integrated systems have been developing in Brazil since 1970 decade and adopted with higher intensity from 2010, results of the improvement of Low Carbon Emission in Agriculture (ABC Plan). These integrated systems of production are promoted as worth options of sustainable intensification way for diversification and efficient use of the agriculture land. Besides, this integrated system decreases the environmental impact, especially with the carbon sequestration and mitigation of greenhouse gas emission. But, the implementation of trees into the production system can affect the biomass production of the forages species cultivars due to modification of the environment with shading. In ICLF, with the increment of trees growth there is decreasing in photosynthetically active radiation (PACIULLO et al., 2011), which affect the photosynthesis and biomass production associated with decreasing in nutritive value. Definition of forage species is crucial for the success of the system, because the species must have features quite specific as resistant to shading, besides the adaptation of the soil and environment in the region. Among the tropical forage grasses species used in Brazil, the *Brachiaria* and *Panicum* genders shows the features that is possible to implement into the integrated system, but the researches surround the shading tolerant must be improved in order to improve the biomass yield and nutritive value.

MATERIAL AND METHODS

The evaluation for this research in integrated crop-livestock-forest systems were carried out in April 2018 to June 2019 at the Embrapa Beef Cattle Research Center in Campo Grande, Mato Grosso do Sul State, the soil class of the area is a distroferric red latosol (LVdf), as described by Santos et al.

(2013). The area is located between the geographical coordinates: 20°27’04” S and 54º42’57” W, altitude of 530 m. The climatic pattern in the region is described, in accordance with Kottek et al. (2006), as transition zone between Cfa and Aw wet tropical. The mean annual rainfall is 1560 mm, with a wet summer and a dry winter, in Cerrado biome.

The randomized block design was used with split-plot scheme for establishment stage, with three repetitions. In order to assess the forages establishment, the treatments of the plots were the forages (*Brachiaria brizantha* cv. Marandu, cv. BRS Piatã, *Brachiaria* spp. cv. BRS Ipyporã, *Panicum maximum* cv. Massai and *Panicum* spp. cv. BRS Tamani) and split-plots the levels of shading between *Eucalyptus* rows [sampling points A (North), B (Center) and C (South)]. To assess the forage yield and nutritive value, after establishment stage, forage harvest occured at 60-day intervals (split-split-plots: cut 1, 2 and 3).

The integrated crop-livestock-forest systems were installed in January 2012. Soybean (*Glycine max* cv. BRS 285) was seeded in November 2011 in a conventional tillage system, and rows were marked out in advance for the later preparation of trenches in which *Eucalyptus* would be planted with the different spatial arrangements described subsequently. The planting of *Eucalyptus* clones was carried out after soybean was established. Preparation and planting took place in January 2012, with the planting trenches prepared using below-ground fertilizer, applying 200 g of the formula NPK 06-30-06 with 0.5% of zinc and 0.5% of boron per meter of trench. Cover fertilization of the *Eucalyptus* plants was carried out in two plots (3 and 9 months after planting), applying formula NPK 20-00-20 with 0.5% of boron and 0.5% of zinc, at a rate of 120 g plant^{-1} in each dressing.

For the planting, the tube surrounding each seedling was used to open a hole with the same dimensions as the root system of the seedling. The *Eucalyptus* seedlings measured on average 30 cm in height and were irrigated on the day of planting with 2 L of water per seedling. The spacing between the stands of Eucalyptus was 14 m, the gap was the space occupied by soybean crop (*Glycine max* cv. BRS 285) at the first year. After the harvested soybean, millet was sown as soil mulch for later planting in no-till system. In November 2012, the spaces between the *Eucalyptus* stands were again used for the cultivation of soybean in the summer, under no-till planting. After the soybean had been harvested, the forage grass, *Brachiaria brizantha* cv. Marandu, was sown in March 2013. Animals were put out to pasture, after the forage grass had been established, in June 2013. The first grazing in the area took place when the Eucalyptus trees showed diameter at breast height (DBH) bigger than 6 cm, which allowed for lower branches to be removed to obtain better quality timber and so that the animals could then move into the area.

Three Eucalyptus clones were used: Urocam VM1 (*Eucalyptus urophyla* × *E. camaldulensis*), Grancam 1277 (*E. grandis* × *E. camaldulensis*) and Urograndis I144 (*E. urophyla* × *E. grandis*) and two spatial arrangements (single and double row).

In the single row arrangement, the spacing was 14 m between stands and 2 m between trees in the row (14 m × 2 m), totaling 357 trees ha^{-1}. In the double row arrangements, spacing of 14 m between stands of trees were used, 3 m between rows within the stand and 2 m between trees in the row (3 m × 2 m) + 14 m, totaling 588 trees ha^{-1}.

The present experiment was carried out in March 2018 with the desiccation of weeds and seeding of the forage cultivars in April 2018 under plots of 12 m x 2.5 m and 0.5 m spaced between plots. The seeding rate was adjusted in 300 and 70 viable pure seeds per square meters for cultivars of gender *Panicum* and *Brachiaria*, respectively. In December 2018 after 230 days of sowed was made the uniformed cut at 15 cm height, which was followed by cuts into 60 days after regrowth. The cut for forage yield were in February (cut 1), April (cut 2) and June (cut 3) 2019 yr, which was considered for evaluation the height of 10 cm above the canopy of each cultivar. Right after the cut for forage harvest all experimental plots was uniformed at 15 cm of canopy height. For evaluation of forage yield were considered three points following the gradient of shading with point A (North) corresponding 3 meters of trees simple row, B (Center) into the center point between trees rows and point C (South) to 3 meters of double trees rows. By portable spectrometer were defined the photosynthetically active radiation (PAR) in each sampling point in the morning and in the afternoon. In order to evaluate the forage components were considered the sampling area of 1 m x 1 m in each point. The canopy height was obtained through the graduate rule in centimeter and the soil cover by visual observation in percentage. Thus, the forage cut was conducted right after in the level of soil. The forage samples were forwarded to laboratory to weight and separation of components as leaf blade, stem + sheath and senescent material. All these components were weighted and inserted in forced air circulation oven to 65^0C temperature until constant weight being weighted after the dry to obtain the dry matter content. The components of leaf blade were milled with a 20 *mesh* sieve and analyzed through near-infrared spectroscopy (NIRS) to defined the crude protein (CP) and neutral detergent fiber (NDF) (MARTEN et al., 1985).

The data were submitted to analysis of variance and, when there were significant differences between means up to 5% significance, the means were compared by Tukey test with 5% probability, using SAS software 9.2.

RESULTS AND DISCUSSIONS

In the trial period, the *Eucalyptus* trees showed on average height of 20 m. In relation to point A (North) the shading gradient close to simple rows showed higher PAR, followed by point C (South) close to double trees rows and point B (Center) corresponding to central point between the trees rows with 440, 339 and 295 µmol m^{-2} s^{-1}, respectively. Higher PAR in central point (B) was observed due to sun inclination during the day and year stations associated with trees height that promoted higher shading in this point.

In Table 1 there are the results related to the establishment of the forage cultivars after 230 days from seeding. The implementation of the forages in the end of the rain season in 2018 associated with delay of following rainfall season resulted in higher period of forages establishment. The forage canopy height was affected by interaction between cultivar *vs.* sampling point ($p<0.05$). In point A with higher PAR there was no significant difference in forage height with average of 44.6 cm. In point B with lower PAR the Piatã showed higher height (97 cm) with Marandu under intermediary position (66.7 cm) and the other cultivars as Ipyporã, Tamani and Massai did not differ among them showing average of 46.1 cm. Piatã showed higher height in all sampling points and Ipyporã, Tamani and Massai did not differ while Marandu showed higher height in sampling point C followed by B and A (Table 1).

It was observed effects on sampling point on cover soil, dry matter content and forage yield into the stage of cultivars establishment (Table 1). Cover soil and forage yield were higher in B and C points (average of 53.5% and 1,882 kg DM day^{-1}) in relation to point A (31% and 877 kg DM day^{-1}). While the content of dry matter was higher in point A (26%) where observed higher PAR followed by point B with intermediary and C with lower value.

In Table 2 were showed the results related to period of production of forage cultivars in three forage harvests conducted in space of 60 days. It was observed significant difference in canopy height among the forage cultivars which Marandu showed higher height (58.4 cm) and Ipyporã lower height (44.9 cm) while Piatã, Massai and Tamani were on average 54.7 cm. The variables total forage biomass and leaf blade biomass showed interaction effects between forage cultivar *vs.* cut age ($p<0.05$). Total forage biomass and leaf blade were higher in second cut (April) in relation to first cut (February) and third cut (June) which did not differ among the cultivars, with exception of Tamani which showed lower leaf blade yield in third cut. As observed before, the rainfall in the beginning of rainy season in 2018 were lower than historic average which may explain lower yield in the first cut in relation to second cut when the rainfall accumulated improved the forage growth. In third cut in June which occurred in the dry season of the year showed impact on biomass production decreasing its increment. Total forage dry matter in first and third cuts did not differ among the cultivars with average of 710 and 651 kg DM ha^{-1}, respectively. In second cut Marandu and Massai showed higher yield (average of 2,646 kg DM ha^{-1}) than the other that did not differ (average of 2,039 kg DM ha^{-1}). Leaf blade biomass in first cut Tamani showed higher yield (570 kg DM ha^{-1}) and Piatã lower yield (313 kg DM ha^{-1}). Ipyporã, Marandu and Massai did not differ that showed average yield of 436 kg DM ha^{-1}. In second cut Massai showed higher yield (1,417 kg DM ha^{-1}) and Ipyporã and Tamani lowers yield (888 kg DM ha^{-1}). Marandu and Piatã showed intermediary yield (average of 1,184 kg DM ha^{-1}). In third cut there was no significant difference among the forages species which showed on average of 317 kg DM ha^{-1}. Interaction effect was observed between cultivar *vs.* sampling point for leaf blade biomass ($p<0.05$). Ipyporã and Tamani did not change leaf blade biomass between the sampling points, on the other hand Piatã and Marandu showed higher yield on point B lower in point A and intermediary in point C, while Massai showed higher yields in points B and C and lower in point A. In relation to variables, total forage biomass and leaf blade biomass showed higher variation among cultivars in conditions of higher yield as the second cut and in sampling point B and C (Table 2).

Table 1. Forage canopy height, soil cover, dry matter content, forage yield in sampling point[1] with different levels of photosynthetically active radiation (PAR) in establishment stage of forage cultivars.

Cultivar	**Sampling point**		
	A	**B**	**C**
		Height (cm)	
Piatã	51.3 Ab	97.0 Aa	93.7 Aa
Marandu	42.0 Ac	66.7 Bb	82.7 Aa
Ipyporã	47.7 Aa	46.0 Ca	48.0 Ba
Tamani	43.7 Aa	42.7 Ca	42.7 Ba
Massai	38.3 Aa	49.7 Ca	49.0 Ba
Variable	**A**	**B**	**C**
Cover soil (%)	31 b	49 a	58 a
Dry matter content (%)	26.0 a	23.8 b	21.7 c
Forage yield (kg DM ha^{-1})	877 b	1,767 a	1,997 a

[1] Sampling point: A (PAR = 440 µmol m^{-2} s^{-1}; shading = 54%), B (PAR = 295 µmol m^{-2} s^{-1}; shading = 69%) and C (PAR = 339 µmol m^{-2} s^{-1}; shading = 65%). Different uppercase letters indicate significant difference by Tukey ($p\leq0.05$) in column. Different lowercase letters indicate significant difference by Tukey ($p\leq0.05$) in line.

In relation to crude protein (CP) in leaf blade was observed interactive effects of cultivars vs cut age and the interaction between survey points *vs*. cut age (Table 2). In first cut Massai showed lower CP (11.3%) in comparison to others that did not differ among them with average of 13.9%. In second cut Piatã showed higher CP in relation to Marandu and Massai. In third cut Tamani showed higher CP (12.3%), Massai was intermediary (10.9%) and Piatã, Ipyporã and Marandu lower CP (average 9.6%). Panicum, Massai and Tamani showed higher CP in dry season which correspond to third cut in comparison to *Brachiaria*. In relation to CP in sampling points the point B (center) showed lower PAR, but higher CP through the cut age as reported in literature (ALMEIDA et al., 2019). Neutral detergent fiber (NDF) in leaf blade differed just of cultivar which Piatã showed lower content (67%), Massaai higher content (75.1%), Ipyporã (71.2%), Marandu (70.3%) and Tamani (74.2%) with no difference among then with exception of Piatã. In the evaluation of nutritive value which involves CP and NDF the Piatã showed higher values with exception to third cut.

Table 2. Forage canopy height, total forage biomass, leaf blade biomass and crude protein content according to cut age and sampling points[1] with different levels of photosynthetically active radiation (PAR) after establishment of forage cultivars.

	Cultivar				
	Piatã	**Ipyporã**	**Marandu**	**Massai**	**Tamani**
			Canopy height (cm)		
	57.8 ab	44.9 b	58.4 a	53.4 ab	52.9 ab
			Total forage biomass (kg DM ha^{-1})		
Cut 1	612 Ba	651 Ba	830 Ba	602 Ba	854 Ba
Cut 2	2,110 Ab	1,894 Ab	2,583 Aa	2,708 Aa	2,114 Ab
Cut 3	628 Ba	784 Ba	737 Ba	639 Ba	467 Ba
			Leaf blade biomass (kg DM ha^{-1})		
Cut 1	313 Bb	358 Bab	479 Bab	472 Bab	570 Ba
Cut 2	1,186 Aab	880 Ac	1,181 Ab	1,417 Aa	895 Ac
Cut 3	314 Ba	338 Ba	305 Ba	316 Ba	312 Ca
A	433 Ba	514 Aa	512 Ba	492 Ba	666 Aa
B	781 Aab	493 Ac	832 Aab	916 Aa	607 Abc
C	600 ABab	569 Aab	621 ABab	797 Aa	504 Ab
			Crude protein (%)		
Cut 1	14.0 Aa	14.6 Aa	13.7 Aa	11.3 Ab	13.4 Aa
Cut 2	10.4 Ba	10.1 Bab	8.3 Cc	8.7 Bc	9.0 Bbc
Cut 3	9.3 Bc	9.8 Bc	9.8 Bc	10.9 Ab	12.3 Aa

	Sampling point		
	A	**B**	**C**
		Crude protein (%)	
Cut 1	13.6 Aa	13.1 Aa	13.5 Aa
Cut 2	9.8 Ba	9.4 Cab	8.8 Cb
Cut 3	9.8 Bb	11.1 Ba	10.3 Bab

[1]Sampling points: A (PAR = 440 µmol m^{-2} s^{-1}; shading = 54%), B (PAR = 295 µmol m^{-2} s^{-1}; shading = 69%) and C (PAR = 339 µmol m^{-2} s^{-1}; shading = 65%). Different uppercase letters indicate significant difference by Tukey (p≤0.05) in column. Different lowercase letters indicate significant difference by Tukey (p≤0.05) in line.

CONCLUSIONS

The forage cultivars Piatã, Marandu and Massai showed higher leaf blade yield under shading environment, on the other hand Piatã was outstanding in relation to biomass yield and nutritive value.

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YES! IT'S POSSIBLE TO PRODUCE SOYBEANS AND CORN IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS AFTER THINNING

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ABSTRACT

In 2011, a large-scale (72 ha) and long-term experiment was established in Sinop, Mato Grosso, Brazil, with the objective of evaluating different grain production systems. All systems with the presence of trees were implanted in the configuration of triple groves eucalyptus with spacing of 3.5 m x 3.0 m x 30 m (270 trees/ha). After the 5th year, we made 2 types of thinning: selective thinning, removing 50% of the trees, maintaining the configuration of triple lines (135 trees/ha); systematic thinning, with removal of the two side lines (90 trees/ha remaining). After the 8th year, the systems that were with triple rank (135 trees/ha) were again thinned, now systematically, leaving 45 trees/ha. Soybeans produced at the same level as the single system in the first three years, while corn only in the first two years. After the first thinning, there was a recovery of grain yield levels for two years for soybean and for one year for corn, in the system with systematic thinning. And after the thinning in 8th year, soybean returned to the levels of the single system as well, at least for 2 years and corn in first year as well.

Key words: sustainable intensification; brazilian agriculture; research in agriculture

INTRODUCTION

The adoption of integrated crop-livestock-forestry systems (ICLF) has increased significantly in recent years, and this is a reflection of the research that has been developed in the last 30 years, in studies conducted in different regions of Brazil (CORDEIRO et al., 2015). At the same time, the demand for new management options of these complex production systems has stimulated research to act in the development and validation of cultural practices aimed at maximizing the productivity of the system as a whole.

In general, in the planning of ICLF systems it is foreseen the use of the area for grain production only in the first years (Magalhães et al., 2019), since from a certain moment, grain yield will be affected by competition for light, water and nutrients between trees and agricultural crops. This means that, depending on the time required for the final cut off the trees, the area will be 5 to 15 years without the cultivation of grains, which can discourage producers from adopting this system.

Thus, the objective of our work is to present the results of soybean and corn grain yield over 10 years of ICLF systems, showing that it is possible to produce grains after two types of thinning.

MATERIAL AND METHODS

The experiment was established in Sinop, Mato Grosso state, Brazil (11°51’ S, 55°35’ W; 384 m elevation), October 2011. The soil was a Rhodic Hapludox (Soil Survey Staff, 2014), while the climate is tropical wet and dry (Aw) according to the Köppen classification with rainfall concentrated in the summer/autumn and water deficiency in winter/spring. The mean values of annual rainfall and temperature are 1974 mm and 24.7 °C, respectively (SOUZA et al., 2013). More details are described by Magalhães et al. (2019).

The experimental design was a randomized complete block, with ten systems and four replicates. Three of the ten systems were selected to be evaluate in this study. The systems were (i) Single soybean crop system, under full sunlight (C) – soybean cultivated between October and February (first crop); corn with *Braquiaria Brizantha* cv Marandu cultivated between February and June (second crop); (ii) integrated crop-livestock-forestry (ICLFt) - comprising eucalyptus trees (Eucalyptus urograndis clone H13) planted in triple-row groves with 3.0 m intra-row spacing, 3.5 m inter-row spacing and 30 m between groves (overall density of 270 trees ha^{-1}) planted in an east-west orientation, integrated with crop as in C. Selective thinning was performed five years after the establishment of the system leaving only 50% of the trees (135 trees ha^{-1}), but maintaining the configuration of triple rows. The last system (iii) was an integrated livestock-forestry system (ICLFs) - comprising eucalyptus trees planted as in ICLFt, but after fifth year the outer lines were thinned, becoming a ICLF with single rows spaced of 37 m (90 trees ha^{-1}) grazing pasture as in PFS. After eight years, ICLFt also were thinned, converted in single rows (45 trees ha^{-1}) and ICLFs were pruned at 12 m high. Definitions of crop production varied over the years and fertilization are presented in Table 1.

Table 1. Soybean cultivars, corn hybrids, limestone and fertilizers doses used in the period.

Crop	Soybean (October-February)	Corn (February-June)
2011/12	BRS Favorita; 350 kg ha^{-1} NPK 00-20-20	DKB 175VTPRO; 300 kg ha^{-1} NPK 04-30-16 + 300 kg ha^{-1} Urea
2012/13	BRSGO 8560RR; 350 kg ha^{-1} NPK 00-20-20	AG 9010PRO; 300 kg ha^{-1} NPK 04-30-16 + 300 kg ha^{-1} Urea
2013/14	BRSGO 8560RR; Liming 1500 kg ha^{-1}; 350 kg ha^{-1} NPK 00-20-20	DKB 390VTPRO; 500 kg ha^{-1} NPK 04-30-16 + 300 kg ha^{-1} Urea
2014/15	BRSGO 8560RR; 400 kg ha^{-1} NPK 00-20-20	DKB 175VTPRO; 350 kg ha^{-1} NPK 04-30-16 + 222 kg ha^{-1} Urea
2015/16	BRSMG 850RR; Liming 1500 kg ha^{-1}; 400 kg ha^{-1} NPK 00-20-20	DKB 177VTPRO; 350 kg ha^{-1} NPK 04-30-16 + 150 kg ha^{-1} Urea
2016/17	M8210ipro; 90 kg ha^{-1} + 90 kg ha^{-1} KCl	P3431VYH; 350 kg ha^{-1} NPK 10-17-17 + 150 kg ha^{-1} Urea
2017/18	BRS7780ipro; 200 kg ha^{-1} KCl	2B810PW; 250 kg ha^{-1} NPK 08-20-20 + 200 kg ha^{-1} Urea
2018/19	BRS 7380RR; 175 kg ha^{-1} KCl	2B810PW; 500 kg ha^{-1} NPK 06-16-16 + 110 kg ha^{-1} Urea
2019/20	TMG 1180RR; Liming 1650 kg ha^{-1}; 310 kg ha^{-1} NPK 00-20-20 + 70 kg ha^{-1} KCl	2B810PW; 400 kg ha^{-1} NPK 10-20-20 + 300 kg ha^{-1} NPK 20-00-20 + 110 kg ha^{-1} Urea
2020/21	BG 4781ipro; 400 kg ha^{-1} NPK 00-20-20 + 100 kg ha^{-1} KCl	B2620PWU; 400 kg ha^{-1} NPK 04-30-16

In the first five years, the harvest was carried out manually, with mechanical threshing, to determine grain mass and moisture content in kg ha^{-1}, considering a 13% moisture content as baseline. In C system, we harvested 2 lines of 5 meters in length. In systems with trees, evaluations were carried out in transects, also in 2 lines of 5 meters, at 4, 7.5 and 15 m from the rows on the northern and southern sides. From the 6th year, the harvest was carried out mechanically. In system C we harvest 9 lines 21 meters long, while in systems with trees we harvest all lines on the south and north side, every 3 lines of 21 meters each.

The statistical analyses of grain yield data were performed after an evaluation of the normality of the data distribution by the Lilliefors test and the homogeneity of variances by the Hartley, Cochran and Bartlett tests. The means were compared by analysis of variance and Tukey's test ($p < 0.05$). In order to better represent the effect of the ICLF systems on grain yield, the data were relativized, dividing the grain yield of the ICLF systems by the grain yield of the C system, multiplying the result by 100.

RESULTS AND DISCUSSIONS

The soybean grain yield (Figure 1) did not differ in the first three years among the treatments. From the 4th year, the soybean yield was negatively influenced by the eucaliptus, with 87 and 83% of the relative yield in the 4th and 5th year, respectively, when compared to the single soybean system. After the first management of the trees (Figure 1, arrow number 1), the triple eucalyptus rows system, but with removal of 50% of the trees (ICLFt), did not recovered the yield, while the system that was converted to simple rows (ICLFs) recovered the yield at the same levels as system C, for two years. And after the second intervention in trees (Figure 1, arrow number 2) both ICLFt (now as converted to simple rows) and ICLFs had better results, like C system.

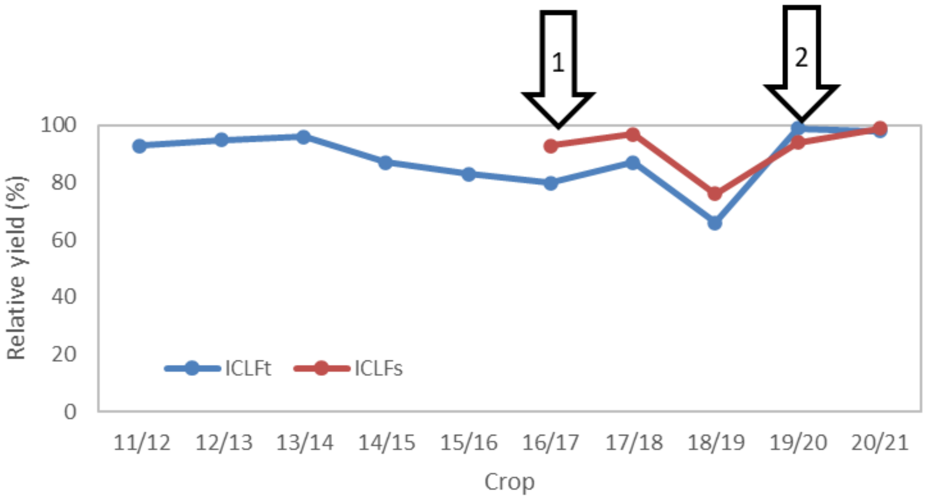

Figure 1. Relative soybean grain yield in two ICLF systems of experiment (arrows shows the moments of eucalyptus thinning).

For corn, cultivated as a second crop after soybean harvest, the yield was negatively influenced by eucalyptus rows with significant reductions (Figure 2) from the 3rd year, with yields of 83, 77 and 72% in the 3rd, 4th and 5th year, respectively relative to the C system. After the first management of the trees, the ICLFs system presented similar yield index to the C system, in the first year only. The ICLFt system, on the other hand, presented dramatic yield losses, with yield indexs of 47% in the 8th year relative to the C system. After the 2nd management on the trees, the ICLFt system switched to simple rows presented similar yield index to C system. The ICLFs, which had a pruning at 12 meters, presented lower yield levels than the C system.

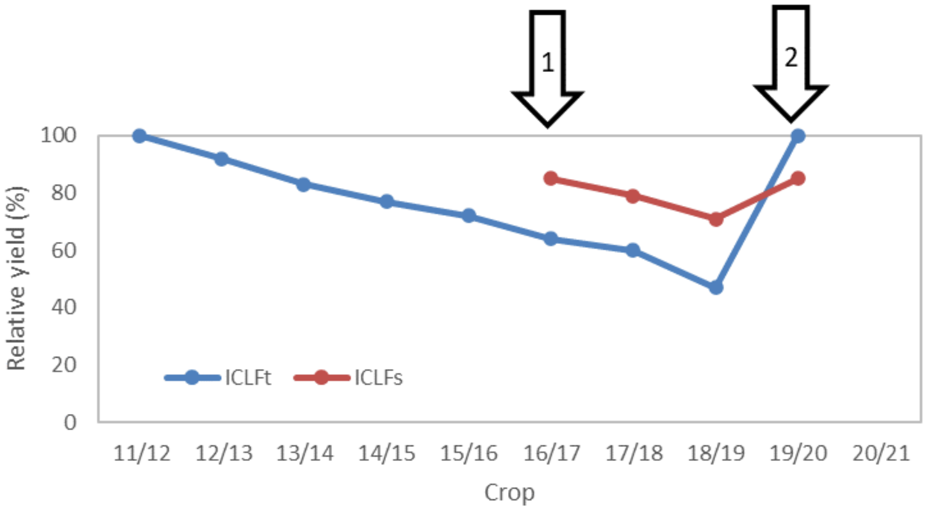

Figure 2. Relative corn grain yield in two ICLF systems of experiment (arrows shows the moments of thinning).

Along the tree's development, the projection of the shadow in the area increases throughout the years (SILVA, 2006; MAGALHÃES et al., 2020). As shown in several studies, there are really negative effects when growing grains, mainly corn, in shaded systems (CARMO et al., 2013; PAULA et al., 2013; TIBOLLA et al., 2019).

To minimize the effects of shading, soy uses morphological strategies such as the production of larger leaves to intercept a greater amount of sunlight, and physiological strategies such as stimulating the use of photosynthetic products for filling grains instead of vegetative growth (WEN et al., 2020).

The results of our study indicate with a good management of eucalypts trees densities on ICLF systems is possible to produce corn and soybeans in similar levels o single crop systems (C systems). It is noteworthy that these interventions are necessary to allow the trees with better potential to add value to the wood have optimal conditions to give maximum economic return at the end of the growth cycle (MURTA JÚNIOR et al. 2020).

CONCLUSIONS

It is possible to produce soy at the same levels as systems without trees for three years and corn for two years in ICLF systems with eucalyptus triple rows spaced 30 meters apart.

The conversion of ICLF systems with eucalyptus triple rows spaced 30 meters apart to single rows after the fifth year allows the production of soybeans for two years, and for one year for corn.

Thinning after 8th year also allows the soybean production in the same levels for the single crop at least for two years (9th and 10th year of experiment). Corn for one year at least.

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NITROGEN AND SULFUR ON PASTURE PRODUCTIVITY IN SANDY SOILS

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ABSTRACT

The quality of forage, in general, is associated with dry matter and the nutritional value of forage. In this sense, crop-livestock integration has been adopted with good results, presenting itself as an efficient way to produce pasture in quantity and quality, besides having the cost absorbed by grain production. This production system is gaining space in regions with sandy soils. The objective of the present study was to evaluate the effect of N doses with and without S on forage production, and the consequence of early application of these nutrients before soybean cultivation. The experimental design was a 5 x 2 factorial design in randomized blocks with four repetitions. The treatments consisted of five N doses (0, 150, 300, 450, and 600 kg ha^{-1}), combined with the absence and presence of sulfur (0 and 150 kg ha-1). The nitrogen source was urea (45% N) and the sulfur source was gypsum (15% S). Dry matter was evaluated. the data were submitted to regression analysis and fitted to a quadratic function. It is concluded that nitrogen fertilization combined with gypsum containing sulfur, provided an increase in the production of *Urochloa brizantha* cv. Marandu, making the soil more fertile and suitable for the entry of soybean cultivation in a crop-livestock integration system

Key words: fertilization; crop-livestock integration; dry mater

INTRODUCTION

Brazil is an important reference in the global beef cattle ranching scenario. With 214.66 million heads in 2019 (IBGE, 2020) Cultivated and native pastures are the main and cheapest source of animal feed, the basis of livestock activity occupying 22.2% of the national territory, while agriculture occupies only 8% according (EMBRAPA, 2018).

However, inadequate management and lack of nutrient replacement in pastures are causing the depletion of the production system, with a consequent reduction in animal carrying capacity (COSTA et al., 2016). Beef production would need to double in the next 30 years to meet the world demand for the protein and this growth in production can be more easily feasible in subtropical and tropical regions of the world. (COOKE et al., 2020)

Forage quality, in general, is associated with dry matter (quantity ingested) and the nutritional value of the forage (SILVA, 2001). However, nitrogen and sulfur participate together in plant metabolism through two main routes: formation of quality protein and biological fixation of N and incorporation of mineral N into amino acids. The absence/deficiency of S causes low quality protein formation in forage, deficient in cystine and methionine and its consumption can cause serious diseases in animals such as scurvy, hemophilia and night blindness (VITTI et al., 2015). Sulfur is a constituent of these two essential amino acids (cysteine and methionine) and its deficiency reduces the production of these compounds, consequently the proteins that contain them will not be formed, and N is metabolized into other forms such as amines, amides and soluble amino acids. (MARSCHNER, 2012).

N is recognized as the main nutrient for the maintenance of productivity and persistence of forage grasses (SANTOS et al., 2019), being the main constituent of proteins that act in the synthesis of plant structure compounds such as leaf size, tiller density and leaves per tiller, it is also responsible for morphogenic characteristics such as emergence rate, elongation and leaf senescence, maintaining a continuous replacement of dead tillers, a key point for the perenniality of grasses (LEMAIRE et al., 2011).

There are several works reporting increased dry matter production, improvement in the nutritive value of tropical forage grasses and the consequent increase in animal weight gain with the addition of N in the production system (DELEVATTI et al., 2019; SILVA et al, 2020; GALINDO et al., 2018).

On the other hand, the combination of N and sulphur application shows an interaction between these elements, with better results than when applied alone, considering that S plays an important role in N metabolism itself. Dry matter production is compromised even under high doses of N when combined with low supply of sulfur (OLIVEIRA et al., 2010). Therefore, fertilization with nitrogen and sulfur increases the production of leaves and tillering, and consequently the DM (HENRICHS et al., 2013), playing an important role in the nutrition and recovery of forage plants by performing catalytic, regulatory and structural functions (CAPALDI et al., 2015).

In the last few years the cattle raising and agriculture activities have started to integrate, with this occurred an increase in the adoption of the technique called crop-livestock integration (CLI). In the last decade the soybean area increased by more than 11 million hectares. The expansion of soy, also occurred in regions and areas with sandy soils. Environments with sandy soils (clay content less than 20%) have historically been considered unsuitable for soy cultivation, considering the production systems used. The restrictions on the use of sandy soils occur due to low natural fertility, low water storage capacity, susceptibility to erosion, intense mineralization of plant remains, which restricts humification and, consequently, the increase of organic matter. In this sense, CLI has been adopted with good results, presenting itself as an efficient way to produce pasture in quantity and quality, besides having the cost absorbed by grain production (CARVALHO et al., 2017).

This production system is gaining space in regions with sandy soils. The success of integrated systems is due to the physical protection of the soil due to the accumulation of straw left by the pasture, improvements in physical, chemical and biological conditions of the soil. The productive potential of sandy soils requires a differentiated management that prioritizes soil protection and aggregation, with an increase of organic matter both on the surface and in the profile (MORO; BORGHI, 2018).

The objective of the present study was to evaluate the effect of N doses with and without S on forage production, and the consequence of early application of these nutrients before soybean crop

MATERIAL AND METHODS

The experiment was developed in the Experimental Farm of Unoeste in Presidente Bernardes, located by the following geographical coordinates: Latitude: 22º17’27” and Longitude: 51º40'51, with an altitude of 385 meters. The soil is classified as Red Argissolo distroférrico (SANTOS et al., 2018) and the climate, according to the Köppen classification, is of type Aw (ALVARES et al., 2013), with an average annual temperature of 25ºC and a rainfall regime characterized by two distinct periods, one rainy from October to March and another with low rainfall from April to September.

The experimental design was a 5 x 2 factorial design in randomized blocks with four repetitions. The experimental unit had dimensions of 5.0 m long by 3.5 m wide. 17 grass lines were sown in the plot at 0.17 m spacing. The treatments consisted of five N doses (0, 150, 300, 450 and 600 kg ha^{-1}), combined with absence and presence of sulfur (0 and 150 kg ha^{-1}), according to Table 1. The N source will be urea (45% N). The source of sulfur will be agricultural gypsum (15% of S) and, was applied in early November 2020. Before the implementation of the experiment, dolomitic limestone was applied to raise the calcium and magnesium contents to the critical level to avoid interference from the calcium provided by agricultural gypsum.

Tabela 1. Description of the treatments, with the combinations of nitrogen and sulfur.

Treatment	**Sulfur**	**Nitrogen**	**Nitrogen Parcelling**		
			Dec-2020	**Jan-2021**	**Feb-2021**
	-- kg ha^{-1} ---				
1	0	0	-	-	-
2	150	0	-	-	-
3	0	150	50	50	50
4	150	150	50	50	50
5	0	300	100	100	100
6	150	300	100	100	100
7	0	450	150	150	150
8	150	450	150	150	150
9	0	600	200	200	200
10	150	600	200	200	200

* Fertilizers were applied by casting during the grazing phase.

Installation and conduction of the experiment: The implementation of the pasture was carried out after the soybean harvest of the 2019/2020 crop. *Urochloa brizantha* cv. Marandu was used. The amount of seed was calculated to obtain 22 plants m^{-2} and the spacing between rows was 0.17 m. In late September/early October 2020 (09/25 to 10/02) the aerial part of the pasture was cut and harvested at a cutting height that ranged from 30 to 50cm. Following this (10/14) a uniformization cut was made adjusted to 30cm. The final uniformization cut will be made with the beginning of the rains at a height of 20cm prior to the application of the treatments.

The Ca and Mg levels were corrected with the application of lime, raising the critical level of these nutrients so that they would not interfere with the effect of the treatments with Gypsum (source of S), a Ca based product.

The treatments were performed after the beginning of the rains the planting of soybeans is scheduled for the following spring, in November 2021.

The leveling of the pasture was performed on 12/16/2020 the other two cuts 11/01/2021 and 02/23/2021 were performed each time the pasture reached cutting height, stipulated at 35 cm cut for lowering to 15 cm. The cuts were performed to simulate grazing of the area. The cut portion was always removed from the experimental area.

Brachiaria evaluations: Quantitative evaluations (dry matter) were started after the leveling cut. Subsequent cuts were made each time the plants reached 35 cm in height. Samples of 0.5 m^2 per plot of the portion was cut and used for dry matter determination. The qualitative evaluations were started after the application of the last parceled dose of nitrogen (Table 1).

Statistical Analysis: The data were analyzed by variance analysis. The mean values were compared by the Tukey test. When the effect of the doses was significant, the data were submitted to regression analysis and adjusted to a quadratic function.

RESULTS AND DISCUSSIONS

The production of *Urochloa brizantha* cv. Marandu showed a quadratic response, in which the maximum point with the nitrogen source reached 300 kg ha^{-1} of N, occurring decrease with increasing doses of N. The quadratic response may be attributed to increased availability of N in the soil, from the mineralization of organic matter in the evaluation period (spring). Fagundes et al. (2005) evaluating nitrogen application in *Brachiaria decumbens* in the four seasons of the year, observed a quadratic effect of nitrogen on the accumulation of leaf dry matter in spring, the same period where the present study was evaluated.

Silva et al. (2009) working with the application of increasing doses of nitrogen in two species of brachiaria in pots found a quadratic effect of nitrogen on the number of leaves per tiller. According to the same authors, the total number of leaves per shoot is an important plant variable because it directly influences the production of dry matter. According to Batista and Monteiro (2006) nitrogen and sulfur exert greater production of dry mass and root dry mass.

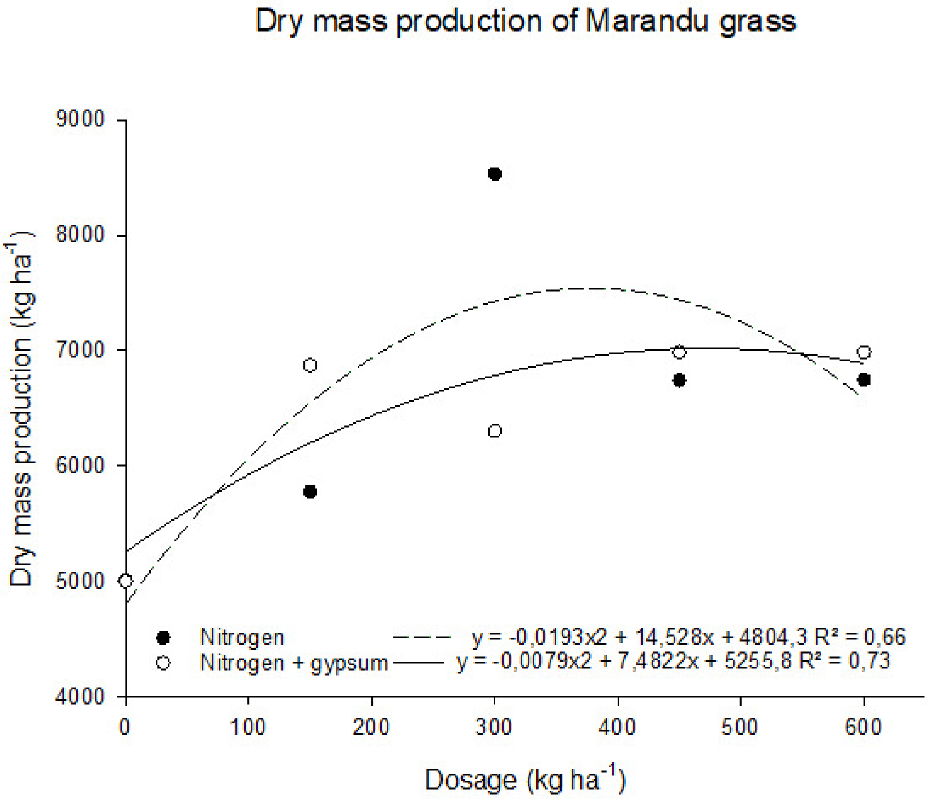

Figure 1. Production of dry mass of Marandu grass under doses and sources of nitrogen and gypsum

CONCLUSIONS

It is concluded that nitrogen fertilization combined with gypsum containing sulfur, provided an increase in the production of *Urochloa brizantha* cv. Marandu, consequently, its production adds roots and organic matter, making the soil more fertile and suitable for the entry of soybean cultivation in a crop-livestock integration system.

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CRUDE PROTEIN OF PIATÃ GRASS LEAF BLADE IN SYSTEMS IN INTEGRATION

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ABSTRACT

This study aimed to evaluate the crude protein contents of Piatã grass (*Urochloa brizantha* Piatã) leaf blade in a crop-livestock-forest integration system. The experiment was carried out in the area of Embrapa Beef Cattle, in Campo Grande – MS, Brazil, in the 2018/2019 agricultural year. The experimental design was in randomized blocks with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL) and 4 repetitions. The harvest months were January, February, March, April and May 2019, the following distances from the eucalyptus rows: ICLF28 (7m, 10m, 11m, 9m, 4m); ICLF22 (3m, 7m, 10m, 7m, 3m). The sampling locations were identified by letters A, B, C, D, E (North-South direction). The Piatã Grass was harvested at ground level, the material obtained was separated into leaf blade, stem with sheath and senescent material. The samples were taken for drying and after drying they were ground and subjected to crude protein analysis. The higher crude protein contents in the leaf blades were verified in the months of February, in the three system.

Key words: nutritional value; stem; senescence

INTRODUCTION

Brazilian pastures are in an evident degradation degree due to their exploitation without the proper nutrients replacement and without the use of conservationist practices. Currently, degraded pastures occupy an area of approximately 80 million hectares in the country (CRUSCIOL et al., 2014). Given this scenario, the search for alternatives that reverse the soil quality loss, aiming at increasing plant production in conjunction with animal production, is increasingly frequent. Among the available alternatives, we can highlight the integrated agricultural production systems (IAPs), which allow the soil fertility increase and nutrient cycling, reversing the soil degradation process. Among the IAPS modalities, the integrated crop-livestock-forest (ICLF) stands out, with significant benefits to the soil, the forage and, through the use of the tree component, to the animal performance (BALBINO et al., 2011). The integrated crop-livestock-forest system has several advantages over other systems. The trees presence in this system increases the thermal comfort for animals through the shade offered, in addition, they contribute to the soil fertility improvement through the leaves that fall on the soil, and are mineralized by environmental actions. However, several authors report that shading can cause changes in forage crude protein contents in integrated systems compared to those under full sun (Paciullo et al., 2011). Thus, in order to understand this dynamic, research is needed to assess variations in crude protein contents in integrated systems. The aim was to evaluate the crude protein content of Piatã grass leaf blades in integrated crop-livestock-forest systems.

MATERIAL AND METHODS

The experiment was carried out at the Technological Reference Unit in Agrosilvipastoral systems of Embrapa Beef Cattle in Campo Grande-MS, Brazil. The soil in the area has a flat relief, being classified as a Dystrophic Red Latosol with a clay texture. The experiment area has been used with succession cycles since 2008.The experimental design was a randomized block with 4 repetitions, with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL). In the subplots, the harvest months (January, February, March, April and May 2019) and the sample points (A, B, C, D and E) were allocated. In perpendicular transect to the tree rows in each plot, five equidistant points were defined (A, B, C, D and E), where A and E were 1 m from the tree trunks; and C corresponded to the intermediate position; totaling 5 sample points per plot. The 28 m Integrated Crop-Livestock-Forest system and the 22 m Integrated Crop-Livestock-Forest system have distances between different sampling points, due to the eucalyptus rows distance of each system. In order to evaluate the Piatã grass accumulated dry mass yield, it was harvested at ground level by means of a gasoline side harvester. The material obtained was taken to the laboratory and separated into the following fractions: leaf blade, stalk with sheath and senescent material, then they were identified, and taken to dry in a forced ventilation oven at a mean temperature of 55 to 60 ^{o}C until reaching constant mass. After drying, the leaf blade samples were weighed to determine the dry matter content and corrected by them. Subsequently, the samples were ground in a Willey mill, and packed in plastic pots, and subjected to crude protein analysis according to AOAC (1990). The data were subjected to analysis of variance and the means were compared using the Tukey test at 5% probability. The analyzes were performed using the statistical software SISVAR (FERREIRA, 2008).

RESULTS AND DISCUSSIONS

Table 1 shows crude protein values of leaf blade in the ICL, ICLF22 and ICLF28 systems, in the different sampling months. There was an effect of the interaction ($P < 0.05$) between the sampling system and month on the crude protein (CP) percentage in the Piatã grass leaves.

Table 1. Crude protein (CP) contents in the Piatã grass leaf blade in the ICL, ICLF22 and ICLF28 systems in the different sampling months.

System	January	February	March	April	May	CV	P value
ICL	13.59 Bb	21.04 Aa	16.16 Aa	14.39 Bb	16.09 Aa	8.70	0.013
ICLF22	17.84 Aa	19.05 Ab	15.94 Ba	14.66 Bb	15.98 Ba		
ICLF28	17.09 Aa	18.88 Ab	14.49 Bb	17.52 Aa	14.36 Bb		

Means followed by the same letter, lower case in the column and upper case in the row, do not differ by the Tukey test ($P > 0.05$).

For the monoculture ICL system, the months that presented the highest crude protein values were the months of February, March and May. The ICLF22 system obtained the best crude protein values in the months of January and February. The ICLF28 system obtained the best values for protein in the months of January, February and April. The highest crude protein percentages for the Piatã grass leaf blades were obtained in February, in the three systems, this probably occurs because Piatã grass presents early flowering, and from February, in which the days are longer, the grass quality reduces significantly (EUCLIDES et al., 2008), and consequently the leaf blades crude protein content of is also affected. Euclides et al. (2008) evaluating the effect of animal grazing on the forage production and on the pasture structural components of the cultivars Marandu, Xaraés and Piatã of *U. brizantha,* verified that the Piatã grass leaf blade:stalk ratio reduced, demonstrating that this cultivar loses quality during the water season. Martins et al. (2020) evaluating animal performance and Piatã Grass nutritional characteristics in two integrated systems during the summer and winter in Campo Grande – MS, Brazil, verified during the summer leaf blades crude protein contents of leaf blades of 10.5 and 7,7% in the crop-livestock-forest and crop-livestock integration system, respectively. In winter, these authors verified crude protein contents of 13.5 and 11.2% in leaf blades for the crop-livestock-forest and crop-livestock integration system, respectively. The results found by Martins et al. (2020) were lower than those found in the present study in all evaluated seasons, as shown in Table 1. The results found by Martins et al. (2020) demonstrate that in the winter season, the crude protein contents in leaf blades were higher, while those found in the present study, demonstrate that in February, in the summer, the highest were found crude protein content in leaf blades. The results found in the present study are probably justified by the effect of rainfall indicators, given that February is one of the months with the highest rainfall in relation to the rest of the year, which may have promoted an improvement in the Piatã Grass quality, and consequently leaf blades.

CONCLUSIONS

The highest crude protein percentages for Piatã grass leaf blades were obtained in February, in the three systems.

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FIBER AND DIGESTIBILITY OF PIATÃ GRASS IN SYSTEMS IN INTEGRATION

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ABSTRACT

This work aimed to evaluate the fiber contents and digestibility of Piatã grass (*Urochloa brizantha* cv. Piatã) leaf blade in a crop-livestock-forest integration system. The experiment was carried out at Embrapa Beef Cattle, agricultural year 2018/2019. The experimental design was in randomized blocks with the treatments arranged in subdivided plots, with 3 treatments (ICLF28, ICLF22 and ICL) and 4 repetitions. The evaluation months were from January to May 2019. The Piatã grass was harvested at ground level, in a 1 x 1 m sample area, the harvested material was taken to the laboratory, weighed, the Piatã grass was morphologically separated and dried in an oven with forced air circulation at 55 ºC. After removal from the oven, the leaf blade, stem + sheath and senescent material components were crushed in a mill with a 1 mm sieve, and the crude proteion contents were determined; NDF; ADF; IVOMD and IVDMD, by means of reflectance spectroscopy in the near infrared (NIRS). It was found that for the NDF contents, the ICLF28 system presented higher values, and lower IVOMD contents were observed with the ICL system.

Key words: neutral detergent fiber; acid detergent fiber; *in vitro* digestibility of organic material

INTRODUCTION

The ICLF system is an intentional combination of agricultural, livestock and forestry activities, carried out in the same area, in intercropped crop, in succession or rotation. However, there are options for cultivating crops and livestock: ICL; crop and forestry: ICF; livestock and forestry: ILF; of the three activities: ICLF. According to Balbino et al. (2011) this components combination brings several benefits to the implantation site, especially the productive capacity recovery of the pasture in degraded soils and the use intensification of the area without harm to any resource.

The grasses *Urochloa brizantha* (Marandu, Xaraés and Piatã), *U. decumbens* (*B. brizantha* cv. Basilisk), *Panicum maximum* (Aruana, Mombaça and Massai) are considered tolerant to shading and with satisfactory forage production in silvopastoral systems (ALMEIDA et al., 2011).

A pasture structure can be defined as the distribution and arrangement of components of the aerial part, such as forage accumulation, plant height, leaf density, leaf/stem ratio and senescent material proportion (Simon et al, 1987). Therefore, an evaluation of the pasture structure becomes important in shaded systems. Shaded pastures have in their structure, for example, a lower canopy height and dry forage mass, but with a higher crude protein content and *in vitro* organic matter digestibility, a reduction in the neutral detergent fiber contents (ALMEIDA et al., 2011).

In shaded systems the forage nutritive value can be affected and it becomes a basic factor to be considered, as animal production is influenced by this factor, reflecting on improvements without weight gain. Improvements in the forage composition under intense shading have been observed by several authors (PACIULLO et al., 2007; SOARES et al., 2009).

Gamarra (2015), in the 5th year of evaluation when comparing the ICL system with the ICLF, observed improvements in the forage composition in the ICLF system in relation to the ICL, with crude protein contents of 10% without ICLF and 7.3% without ICL; 70.3% NDF without ICLF versus 72.5% without ICL in the summer. This work aimed to evaluate the fiber contents and digestibility of Piatã grass (*Urochloa brizantha* cv. Piatã) leaf blade in a crop-livestock-forest integration system.

MATERIAL AND METHODS

The experiment was carried out at the Technological Reference Unit in Agrosilvipastoral systems, from Embrapa Beef Cattle, in Campo Grande-MS, Brazil. The region is located in the Cerrado biome, with an average annual rainfall of 1,560 mm, with defined seasons of rain from September to April and drought from May to August.

The experimental area used was composed of three systems: Integrated Crop-Livestock-Forest system with 28 m of eucalyptus rows (ICLF28); Integrated Crop-Livestock-Forest system with 22 m of eucalyptus rows (ICLF22); Integrated Crop-Livestock (ICL) system.

The experimental design was in randomized blocks with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL) and 4 repetitions. The harvest months were January, February, March, April and May 2019 and the sample points A, B, C, D and E made up the subplots.

In each of the samples, with a sample area of 1.0 m x 1.0 m, Piatã grass was harvested using a gasoline side harvester. The harvested material was taken to the laboratory, weighed to obtain green mass yield.

Subsequently, the separation of the Piatã grass fractions in a leaf blade, stem with sheath, senescent material was carried out in the laboratory. These fractions were packed in paper bags and placed in a forced air circulation oven at a temperature of 55 ºC for three days. After taen out from the oven, the samples were weighed to obtain dry matter values and sent for grinding.

The leaf blade, stem + sheath, senescent material components were crushed in a mill with a 1 mm sieve, packed and sent to the laboratory to determine the neutral detergent fiber (NDF) content; acid detergent fiber (ADF); *in vitro* organic matter digestibility (IVOMD) and dry matter (IVDMD). These determinations were performed by means of reflectance spectroscopy in the near infrared (NIRS), according to Marten et al. (1985).

The data were subjected to analysis of variance and the means were compared using the Tukey test at 5% probability. The analyzes were performed using the SISVAR statistical package (FERREIRA, 2008).

RESULTS AND DISCUSSIONS

There was no interaction among the systems and the sampling months for any evaluated variables (Table 1). Regarding the leaf blade ADF and IVDMD variables, no difference was observed among the systems. The highest *in vitro* organic matter digestibility of (IVOMD) of the leaf blade were observed for ICLF22 and ICLF28.

The mean ADF contents varied from 29.39 to 34.65%, and are within the mean normally registered for tropical grasses. According to Nussio et al. (1998), forage with values around 30% (ideal content for good animal intake), or at least, will be intake at high levels, while those with contents above 40%, at low levels.

Table 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and *in vitro* organic matter digestibility (IVOMD) and *in vitro* dry matter digestibility (IVDMD) contents of the Piatã grass leaf blade in ICL systems, ICLF22 and ICLF28 in the different months of sampling.

System / Month	**NDF**	**ADF**	**IVDMD**	**IVOMD**
System				
		%		
ICL	68.29 C	30.36 A	60.99 A	64.09 B
ICLF22	69.74 B	30.40 A	61.30 A	65.98 A
ICLF28	71.90 A	31.89 A	62.16 A	66.09 A
CV	2.28	2.29	3.07	1.59
P value	0.04	0.01	0.01	0.02
Month		%		
January	63.08 C	33.88 A	69.91 B	70.78 A
February	65.46 B	34.65 A	71.48 A	69.45 B
March	68.94 A	29.39 C	70.40 A	67.90 B
April	65.76 B	3210 B	68.32 B	71.30 A
May	66.78 B	32.07 B	67.19 C	70.87 A
CV	2.15	3.17	3.4	2.99
P value	<0.01	<0.01	<0.01	<0.01

Means followed by the same uppercase letter in the column do not differ by the Tukey test (P>0.05).

Regarding the NDF, the lowest contents were obtained in the ICL (68.29%) and in the month of January (63.08%). Euclides (1995), studying several forage grasses cultivars, concluded that NDF values below 55% are rare and values above 65% common in new tissues, while contents between 75% and 80% are found in physiological maturity forage.

In a shaded location, the lower pasture obtained a higher NDF, which is consistent with the idea that the growing leaf under shading tends to increase the fiber amount due to the addition of supporting tissues for leaf elongation in search of light (SOUZA et al., 2007).

According to Van Soest (1994), contents greater than 60% of NDF in dry matter limit the forage intake. The mean contents found in this research are above those established by this author, but they are in agreement with Aguiar (1999), who states that tropical forages have high NDF contents, generally above 65%, reaching 80%. This is an unfavorable characteristic for grasses, since the increase in fiber content limits the foragequality and its intake.

For the variable IVOMD, higher values were observed for the ICLF systems and for the months of April and May. High temperatures promote rapid leaf growth and development and increase in the cell wall content components and, as a consequence, also the participation of this component in the total dry matter of the plant. According to Wilson (1983), these effects are negatively correlated with IVDMD.

Gerdes et al. (2000) found, in general, that the autumn and winter seasons provided IVDMD around 6.9% and 11.2% higher than in the spring and summer, in the Marandu and Tanzania grasses, respectively.

CONCLUSIONS

The ICLF28 system showed higher NDF contents. The lowest IVOMD content was obtained with the ICL system.

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MONITORING PHYTOPATOGENS IN SOYBEAN AND MAIZE CROPS IN THE ILPF SYSTEM OF EMBRAPA AGROSILVOPASTORAL

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ABSTRACT

Since the 2011/2012 crop season, Embrapa Agrosilvopastoral in Sinop/MT has conducted na experiment of crop-livestock-forest integration, consisting of 10 treatments. The objective of this work was to monitor the incidence and severity of diseases in soybean and corn crops. The treatments studied were: LAV (soybean crop followed by corn + brachiaria), ILPF1 (crop-livestock-forest integration, crop rotation with livestock every 2 years); ILPF2 (crop-livestock-forest integration, with crop and animal entry after the corn harvest, every year); ILP (crop-livestock integration, crop and rotation with livestock every 2 years) and ILF (crop-forest integration). A randomized complete block design was used, with 4 replications. Analysis of variance and the means were compared using the Tukey test at 5% probability. In the soybean crop, in the 2011/2012 and 2012/2013 harvests, there were no diseases. In subsequent harvests, the incidence of target spot was always observed in the R5.1 phase. In the corn crop, in the years 2014, 2016 and 2019 the incidence of diseases was not observed. Bipolar spot was observed in 2017 and cercosporiosis was observed in the years 2015, 2017, 2018 and 2020. In both cultures, the incidence of diseases did not differ between treatments.

Key words: ILPF; soybean; corn

INTRODUCTION

The main difference between the Integrated Crop-Livestock-Forest System (ILPF) and conventional agricultural systems is to allow rural producers to be able to produce larger and more diversified production in an economically, socially and environmentally sustainable approach (EMBRAPA, 2021). In ten years, according to a survey carried out in 2018, the area occupied by ILPF increased by almost 10 million hectares, with 15 million hectares used with integration systems (REDE ILPF, 2021). The main advantages of using integrated production systems are related to the improvement of soil attributes, greater use of nutrients, breaking of the cycle of pests and diseases of plants, reduction of the economic risk, by the diversification of activities, and also reduction of costs with recovery of degraded pastures (SILVA et al., 2011; VILELA et al., 2011). Regarding the economical damages produced by pest and diseases, the objective of this work was to monitor the incidence and severity of diseases in soybean and maize crops.

MATERIAL AND METHODS

Since the 2011/2012 crop seasons, in the experimental area of Embrapa Agrossilvipastoral located in Sinop, Mato Grosso State, Brazil, a long-term crop-livestock-forest integration experiment has been conducted, consisting of 10 treatments. The treatments containing the crops are: LAV (soybean crop followed by corn + brachiaria), ILPF1 (crop-livestock-forest integration, crop according to LAV, but rotated with livestock every 2 years); ILPF2 (crop-livestock-forest integration, with LAV tillage and animal entry after corn harvest, every year); ILP (crop-livestock integration, farming according to LAV and rotation with livestock every 2 years) and ILF (crop-forest integration). A randomized complete block design was used, with 4 replications. All treatments are carried out in 2 ha plots, except LAV, where the plot is 1 ha. The soybean cultivars used were BRS Favorita (2011/12 harvest), BRS GO 8560 RR (2012/13, 2013/14 and 2014/15), BRSMG 850 RR (2015/16), M8210 Ipro (2016/17), BRS 7780 Intacta (2017/18), BRS 7380 RR (2018/19) and TMG 1180 (2019/20). The maize materials used were DKB 175 Pro (2011/12 harvest), AG 9010 Pro (2012/13), DKB 390 Bt (2013/14), DKB 175 Vt Pro (2014/15 and 2015/16), P3431VYH (2016/17), B2810PW (2017/18, 2018/19 and 2019/20). The forest component is the eucalyptus *Urograndis* clone H13, planted in an east-west direction, the crops were conducted according to technical recommendations, uniformly, in all treatments. In the case of soybean crops, fungicide spraying was carried out to prevent Asian soybean rust. The assessments of severity and incidence of diseases in the area of the soybean crop were carried out at the beginning of flowering (R1) and grain filling (R5.1), in the middle third portion of the plants. The evaluations of severity and incidence of diseases in the area of the corn crop were carried out in the milky grain phase, always on the ear leaf. Lastly, the data were subjected to analysis of variance and the means were compared using the Tukey test, at 5% probability.

RESULTS AND DISCUSSIONS

Related to the soybean crop, 2011/2012 and 2012/2013 crop seasons, no disease incidence was observed. In subsequent seasons, the incidence of target spot (*Corynespora cassiicola*) has always been observed in phase R5.1, in a generalized and uniform manner. The crops with the highest occurrence of the disease were 2015/16 and 2019/20 (15%), and in the 2016/17 crop (11%), however, no difference was found between treatments. The different production systems, under the same disease control management, had no influence on the occurrence and/or severity of the target spot in the soybean crop. No other diseases were observed, including Asian soybean rust. Considering corn crop, during off-season interval of 2014, 2016 and 2019, the incidence of diseases in the crop was not observed. Incidence of bipolar spot was only observed in 2017 (10%) and the severity of cercosporiosis was observed in the years 2015 (1%), 2017 (3%), 2018 (10%) and 2020 (2%), but not no difference was found between treatments. The different production systems had no influence on the occurrence and/or severity of cercosporiosis and bipolar spot in the corn crop. The genetics of the material used and/or the climatic conditions (rain/drought transition) may have influenced a lower incidence and severity of these diseases.

CONCLUSIONS

The different production systems had no influence on the occurrence and/or severity of diseases in soybean and corn crops. The genetics of the material used for both crops and/or the climatic conditions (rain/dry transition) for corn, may have influenced a lower incidence and severity of diseases.

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SEED ANALYSIS IN SOYBEAN CROP AT ILPF SYSTEMS OF EMBRAPA AGROSILVOPASTORAL – CROP SEASONS: 2014/15, 2015/16 AND 2016/17

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ABSTRACT

In the 2014/15, 2015/16 and 2016/17 crop seasons at integrated agricultural systems experimental area located Embrapa Agrosilvopastoral, an analysis of soybean seed pathology was carried out in the treatments: LAV (soybean crop followed by corn + brachiaria), ILPF1 (crop- livestock-forest, crop rotation with livestock every 2 years); ILPF2 (crop-livestock-forest integration, with crop and animal entry after the corn harvest, every year); ILP (crop-livestock integration, crop and rotation with livestock every 2 years) and ILF (crop-forest integration) .The Blotter test was used and based on the results obtained, so far, none of the studied systems had a negative impact on the quality of soybean seeds. As this is a long-term experiment, monitoring will continue to be carried out over the next few years, thus subsidizing information for the correct adoption of this system in the State of Mato Grosso, Brazil.

Key words: ILPF; soybean; seed pathology

INTRODUCTION

The crop-livestock-forest integration system (ILPF) is a sustainable production system that integrates agricultural, livestock and forestry activities, carried out in the same area, in intercropped cultivation, in succession or in rotation, and seeks synergistic effects between the components of the agro-ecosystem contemplating the environmental adequacy, the valorization of the man and the economic viability of the agricultural activity (KLUTHCOUSKI et al., 2015). This system has the advantages of improving soil attributes, greater use of nutrients, breaking the cycle of pests and plant diseases, reducing economic risk, by diversifying activities, and also reducing costs with the recovery of degraded pastures (SILVA et al., 2011). 90% of the crops used for food are propagated by seed and specifically in the soybean crop, the main pathogens that cause diseases are transmitted by the seed (HENNING, 2005), thus, the objective of this work was to evaluate the sanitary quality of soybean seeds of the 2014/15, 2015/16 and 2016/17 crop seasons.

MATERIAL AND METHODS

Soybean seeds were collected during the crop seasons of following treatments: LAV (soybean crop followed by corn + brachiaria), ILPF1 (crop-livestock-forest integration, LAV crop, but rotated with livestock every 2 years); ILPF2 (crop-livestock-forest integration, with LAV tillage and bovine animals entry after corn harvest, every year); ILP (crop-livestock integration, farming according to LAV and rotation with livestock every 2 years) and ILF (crop-forest integration). The soybean cultivars used were BRS GO 8560 RR 2014/15), BRSMG 850 RR (2015/16), M8210 Ipro (2016/17). Seed samples were collected at different distances from the trees, in the 2014/2015 and 2015/2016 crop samples were collected at a distance of 4m, 7.5m and 15m (north and south) and in the 2016/2017 crop if samples with a distance of 3.5m, 8m, 12m and 15m (north and south). For seed pathology analysis, the Blotter test was used, according to international recommendations (NEERGAARD, 1979), with some modifications. Four hundred seeds of each treatment (20 seeds per repetition) were distributed in gerboxes measuring 11x11 cm, containing three sheets of qualitative filter paper previously moistened in diluted agar (10 g of agar/1,000 mL of water) and in a solution of 2, 0.02% 4 D (sodium 2,4-dichlorophenoxyacetate - 2,4-D herbicide). The seeds were incubated for seven days at a temperature of 22ºC, under a photoperiod of 12 hours of light (fluorescent lamps type "daylight" and black "NUV") for 12 hours in the dark. After the incubation period, it was observed, with the aid of a stereoscopic microscope, the occurrence of seeds with fungi, the results being expressed as a percentage of each pathogen detected.

RESULTS AND DISCUSSIONS

Colletotrihum sp., *Phomopsis* sp., *Cercospora kikuchii*, *Fusarium* sp., and *Aspergillus* sp., were found in all harvests. For *C. kikuchii*, there was no difference between the values found in the different sampling points, nor between those with the single crop treatment, in any of the crops presented. In the 2016/2017 crop, the occurrence of *C. kikuchii* was much higher than the two previous harvests. In the 2014/2015 and 2015/2016 harvests there was no significant difference between the sampled points and even with the single crop treatment. In the 2016/2017 crop, for *Colletrotrichum* sp., With the exception of points 3.5S, 3.5N and 15N, the treatment ILPFt (triple lines) showed higher values than ILPFs (single lines) and single tillage. In relation to *Phomopsis* sp., There was no difference between the values found in the different sampling points or between those with the single crop treatment, in the 2014/2015 harvest. In the 2015/2016 harvest, the points sampled in the distances closest to the trees, on the north side, had a higher occurrence. In the 2016/2017 crop, no significant differences were found between the sampled points or between treatments. For *Corynespora cassiicola*, there was no difference between the values found in the different sampling points and neither between those with the single crop treatment in the 2014/2015 harvest. Analysis of data on the occurrence of *Fusarium* sp. in soybean seeds harvested in different positions of an ILPF system with triple rows of eucalyptus in the 2014/2015 and 2015/2016 harvests, resulted in no difference between treatments. The seeds collected in 4S in the 2016/17 crop season had a lowest incidence compared to the others and there was no difference between the values found in the other sampling points and neither between them with the single crop treatment. The transformed data of the occurrence of *Macrophomina* sp. showed that there was no difference between the values found in the different sampling points and neither between them with the single crop treatment, in any of the crops presented. In relation to seed analysis, the systems apparently did not influence the incidence of pathogens in soybean seeds, although in the 2016/2017 crop there was a higher incidence of *Colletrotrichum* sp. in some points, the same was not observed with Phomopsis sp., Pathogen whose occurrence in seeds is commonly associated with the presence of *Colletrotrichum* sp.. Probably the few differences found are related to the climatic conditions of each season, especially at harvest time

CONCLUSIONS

Based on the results obtained, so far, none of the systems studied has negatively affected the quality of soybean seeds.

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MORPHOLOGICAL COMPOSITION OF PIATÃ GRASS IN SYSTEMS IN INTEGRATION

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ABSTRACT

This study aimed to evaluate the morphological components of Piatã grass (*Urochloa brizantha* Piatã) in a crop-livestock-forest integration system. The experiment was carried out in the area of Embrapa Beef Cattle, in Campo Grande – MS, Brazil, in the 2018/2019 agricultural year. The experimental design was in randomized blocks with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL) and 4 repetitions. The harvest months were January, February, March, April and May 2019, the following distances from the eucalyptus rows: ICLF28 (7m, 10m, 11m, 9m, 4m); ICLF22 (3 m, 7 m, 10 m, 7 m, 3 m). The sampling locations were identified by letters A, B, C, D, E (North-South direction). The Piatã grass was harvested at ground level, the material obtained was separated into leaf blade, stem with sheath and senescent material. No differences were found for leaf blades, stem + sheath and senescent material percentages between the production systems. The highest leaf blades percentages were obtained in the months of January, February, March and April. The highest senescent material and stems + sheaths percentage were obtained in the months April and May, respectively.

Key words: leaf; stem; senescence

INTRODUCTION

The growing demand for food, combined with the search for sustainability in the productive sector, has promoted advances in agricultural systems, prioritizing conservation and diversified systems (FERREIRA et al., 2014). Crop intercropping can increase the sustainability of agricultural systems as a result of the production diversity (CALONEGO et al., 2011), however, it is necessary to understand the biotic factors involved in these arrangements, such as the light competition, which may affect the growth dynamics of the components of this system.

Shading increases the leaves and stems elongation rates, as well as the final leaf blades lenght. The reduction in the population density of tillers is compensated by the increase in leaves and stems elongation rates, under the conditions of more intense shading (PACIULLO et al., 2008), directly affecting the pasture morphological composition.Given the above, research evaluating the morphological composition of forages in integration systems is important to understand the dynamics of the forage component subjected to shading, allowing for the best positioning of this technology and thus guaranteeing the sustainability of this productive model. The aim was to evaluate the morphological composition of Piatã grass in crop-livestock-forest integration systems.

MATERIAL AND METHODS

The experiment was carried out at the Technological Reference Unit in Agrosilvipastoral systems of Embrapa Beef Cattle in Campo Grande – MS, Brazil. The soil in the area has a flat relief, being classified as a Dystrophic Red Latosol with a clay texture. The experiment area has been used with succession cycles since 2008.The experimental design was a randomized block with 4 repetitions, with the treatments arranged in subdivided plots, with 3 treatments in the plots (ILPF28; ILPF22; ILP). In the subplots, the harvest months of the cuts (January, February, March, April and May 2019) and the sample points (A, B, C, D and E) were allocated. In perpendicular transect to the tree rows of trees in each plot, five equidistant points were defined (A, B, C, D, E), where A and E were 1 m from the tree trunks; and C corresponded to the intermediate position; totaling 5 sample points per plot. The 28 m Crop-Livestock-Forest Integration System and the 22 m Crop-Livestock-Forest Integration System have distances between the different sample points, due to the distance of the eucalyptus rows of each system. To evaluate the morphological composition, the Piatã grass was harvested at ground level by means of a gasoline side harvester. The material obtained was taken to the laboratory and separated into the following fractions: leaf blade, stem with sheath and senescent material. The data were subjected to analysis of variance and the means were compared using the Tukey test at 5% probability. The analyzes were performed using the SISVAR statistical software (FERREIRA, 2008).

RESULTS AND DISCUSSIONS

As for the percentages of leaf blades, stem + sheath and senescent material percentages (Table 1), no differences were found between the production systems, nor between the sampling points, but differences between the sampling months were verified.

Table 1. Leaf blade (LF), stem + sheath (CB) and senescent material (SE) percentages of Piatã grass in the months of sampling.

Charactesitic	January	February	March	April	May	CV (%)	P value
LF (%)	77.85 a	74.88 a	75.60 a	72.10 a	69.20 b	14.41	<0.01
CB (%)	17.21 c	17.61 c	16.30 c	19.47 b	22.30 a	6.80	<0.01
SE (%)	5.00 d	7.50 c	8.10 b	12.44 a	8.60 b	11.70	<0.01

Means followed by the same lowercase letter on the row, do not differ by the Tukey test (P> 0.05).

The highest leaf blades percentage was obtained in the months of January, February, March and April. The highest thatch + sheath percentage was obtained in the month of May, the last month of the experiment evaluations. The highest senescent material percentage was found in the month of April. This trend is related to the fact that in the months of January, February and March the luminosity and rainfall are greater, allowing a greater use of these conditions by the forage component, which results in greater of leave proportions. The reverse occurred in May, where the conditions are not so favorable for the forage component, resulting in a greater stem fraction proportion in the canopy (EUCLIDES et al., 2008). In May, the drought begins in the region where the experiment was carried out, a season in which the precipitation falls drastically, limiting the amount of forage available to the animals, causing them to graze more intensively, leaving a higher stalks concentration in the canopy after grazing, increasing these component proportion in the next evaluations. It can be inferred that the months with the highest rainfall indexes associated with the highest light intensity, promote a higher leaf blades percentage in the canopy, which is a desirable feature, considering that in addition to representing the surface responsible for photosynthetic efficiency, it is the component higher quality in the animals' diet, which favorably influence the animal intake and performance.

CONCLUSIONS

No differences were found for leaf blades, stem + sheath and senescent material percentages between the systems being integrated. The highest leaf blades percentages, components of better quality in the animals' diet, were obtained in the months of January, February, March and April.

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MASS YIELD OF PIATÃ GRASS IN SYSTEMS IN INTEGRATION

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ABSTRACT

This study aimed to evaluate the mass yield of Piatã grass (*Urochloa brizantha* cv. Piatã) in a crop-livestock-forest integration system. The experiment was carried out in the area of Embrapa Beef Cattle, in Campo Grande – MS, Brazil, in the 2018/2019 agricultural year. The experimental design was in randomized blocks with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL) and 4 repetitions. The harvest months were January, February, March, April and May 2019, the following distances from the eucalyptus rows: ICLF28 (7m, 10m, 11m, 9m, 4m); ICLF22 (3m, 7m, 10m, 7m, 3m). The sampling locations were identified by letters A, B, C, D, E. The harvest made at ground level, the material was taken to the laboratory, weight to obtain mass yield and divided into subsamples. The ICL system showed a higher mass yield accumulated in all sampling points. In the ICLF28 system, the highest yields were at central points B, C and D. In the ICLF22 system the highest yields were at points C and D. In the ICLF systems, the end points obtained lower results than the others.

Key words: leaf; stem; senescence

INTRODUCTION

The ICLF system is an intentional combination of crop, livestock and forestry activities, carried out in the same area, in intercropped crop, in succession or rotation. However, there are options for cultivating crops and livestock: ICL; crop and forest: ICF; livestock and forestry: ILF; of the three activities: ICLF. This components combination brings several benefits to the deployment environment, especially for the productive capacity recovery in degraded soils and the intensification of the use of the area without prejudice to any resource (BALBINO et al., 2011).

The maximum yield of these systems is obtained when the animal peak production is observed without a decrease in the tree production and vice versa. Thus, to avoid reductions in forage production due to shading it is necessary that the choice of forage species that best adapt to this system, demonstrating a good tolerance level to shading, as is the Piatã Grass case (OLIVEIRA et al., 2014).

Studies carried out in several regions and ecosystems in Brazil demonstrate that this brachiaria has wide adaptation and high yield, compared to other cultivars already studied, thus representing a good option and alternative in integration systems because it has productive and favorable management characteristics, of plant, tolerance to the shading factor, quality and high leaf production (OLIVEIRA et al., 2014).

However, studies with this forage under shading conditions are scarce, and further research is needed to optimize the Piatã Grass yield in crop-livestock-forest integration systems. Thus, the aim was to evaluate the yield of Piatã grass accumulated dry mass in crop-livestock-forest integration systems.

MATERIAL AND METHODS

The experiment was carried out at the Technological Reference Unit in Agrosilvipastoral systems of Embrapa Beef Cattle in Campo Grande-MS, Brazil. The soil in the area has a flat relief, being classified as a Dystrophic Red Latosol with a clay texture. The experiment area has been used with succession cycles since 2008. The experimental design was a randomized block with 4 repetitions, with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL). In the subplots, the harvest months (January, February, March, April and May 2019) and the sample points (A, B, C, D and E) were allocated. In perpendicular transect to the tree rows in each plot, five equidistant points were defined (A, B, C, D and E), where A and E were 1 m from the tree trunks; and C corresponded to the intermediate position; totaling 5 sample points per plot. The 28 m Crop-Livestock-Forest Integration system and the 22 m Crop-Livestock-Forest Integration system have distances between different sampling points, due to the eucalyptus rows distance of each system. In order to evaluate the Piatã grass accumulated dry mass yield, it was harvested at ground level by means of a gasoline side harvester. Harvested material samples were taken to the laboratory to determine the dry mass content according to AOAC (1990). Then the dry mass yield accumulated in the season was calculated. The data were subjected to analysis of variance and the means were compared using the Tukey test at 5% probability. The analyzes were performed using the SISVAR statistical software (FERREIRA, 2008).

RESULTS AND DISCUSSIONS

For the variable accumulated dry mass yield (ADMY) (Table 1) there was interaction between systems and sampling points.

Table 1. Accumulated dry mass yield (5 harvests) (t DM ha^{-1}).

Site	ICL	ICLF28	ICLF22	CV %	P value
A	15.28 Aa	4.89 Bb	6.37 Bb		
B	14.83 Aa	7.72 Ba	5.93 Ca	15.44	<0.01
C	15.56 Aa	7.67 Ba	7.29 Ba		
D	15.03 Aa	7.00 Ba	6.02 Ba		
E	14.84 Aa	4.20 Bb	4.63 Bb		

Means followed by the same letter, lower case in the column and upper case in the row, do not differ by the Tukey test (P> 0.05).

The ICL system showed the highest ADMY results at all sample points, with no difference between the points. With regard to the ICLF28 system, it presented higher ADMY at central points B, C and D, being very similar to ICLF22 which obtained the highest values at points C and D. At ICLF, the luminous interception promoted by the treetops was greater, reducing the amount of light energy that reaches the forage component, and consequently limiting the photosynthetic process. Similarly, Souza et al. (2019) evaluating the Marandu Grass yield in crop-livestock-forest integration systems, observed that the highest yield forage yield was verified in the treatment in crop-livestock integration, justifying this fact by the lower shading level occurred in this treatment. In the ICLF systems, the end points (A and E) obtained the smallest ADMY, as they are closer to the eucalyptus rows, in line with the fact that the Piatã grass suffers competition for water, light and nutrients with the eucalyptus. Oliveira et al. (2014), working with the Livestock-Forest Integration system and Piatã grass in the second grazing cycle found a reduction in the dry mass yield of Piatã Grass forage by around 34% to 53% in relation to the Piatã grass. This effect attributed to the greater tree component growth, intercepting a greater amount of light, resulting in a reduction in the Piatã Grass yield, natural over time. According to Balbino et al. (2011), the greater the spacing between the tree rows, the greater the radiation penetration in the forage substrate, favoring the biomass accumulation. However, the spacing between rows cannot be so great as to compromise the quantity and quality of the forest product per area and the desired tree cover for the animal protection. Thus, the results demonstrate that the tree component used in the evaluated systems must be used in a way that it is not too dense, impairing the Piatã grass accumulated dry mass yield.

CONCLUSIONS

The ICL system showed the highest accumulated dry mass yield in all sampling points. In ICLF28 and ICLF22 system, the highest accumulated dry mass yields were at central points C and D.

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NUTRITIVE VALUE OF BRS PAIAGUAS GRASS LEAVES UNDER EUCALYPTUS SHADING DURING DRY AND RAINY SEASONS

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ABSTRACT

The objective was to evaluate the nutritive value of *Urochloa brizantha* cv. BRS Paiaguas fertilized via foliar, under Eucalyptus shading and full sun system during dry and rainy seasons in transition region Cerrado-Pantanal. This study was conducted in Aquidauana, MS, Brazil. The evaluations were performed at 28-day intervals (growing days) in each season. Three levels of foliar fertilization were evaluated, Quimiorgen Pasto® (3, 6 and 9 L/ha) with 2 L/ha Niphokam®, in addition to the control. The data were analyzed as a $4\times2\times2$ factorial arrangement. No effect ($P\geq0.05$) of foliar fertilizer was observed. In the dry season, higher ($P\leq0.05$) in vitro dry matter digestibility (IVDMD) was observed in full sun, while in the rainy season, IVDMD was higher ($P\leq0.05$) in the shading system. Contents of crude protein (CP) was higher ($P\leq0.05$), neutral detergent fiber (NDF) was lower ($P\leq0.05$) in the dry season. In the parameters were observed a significant effect ($P\leq0.05$) of the interaction system × growing days. Based in these results: Single foliar fertilization is not enough to alter the leaves nutritive value; the grass is adapted to the dry season conditions in the Cerrado-Pantanal transition region; and is also adapted to shading imposed by the experimental conditions.

Key words: foliar fertilization; full sun; transition region Cerrado-Pantanal

INTRODUCTION

The study of parameters related to the nutritional value of forage plants in different seasons is very important because the rainfall and temperature are climatic factors that directly interfere with the metabolism and, consequently, with the nutritional value of the plants. This is more important in regions where there are marked differences in climatic conditions between the dry and rainy seasons, as in Central region of Brazil.

In addition to the seasons, other characteristics, such as shading, can modify the nutritional value of forage plants. Positive changes in nutritional value depend on factors such as forage species, shading level and season (PACIULLO; GOMIDE, 2019). In general, the tendency is that, under shading, forage grasses have a higher content of crude protein, less cell wall content and, consequently, greater dry matter digestibility (ALMEIDA et al., 2014). Furthermore, according to these authors, grasses are more susceptible to the conditions of shading when they are in the establishment phase than in the production phase.

Age also influences the nutritional value of forage plants. Changes in plant tissues occur with growth, increasing the proportion of structural components such as cellulose, hemicellulose and lignin, and decreasing the levels of soluble carbohydrates, proteins, minerals and vitamins, the components of cellular content (REIS; RODRIGUES, 1993).

Thus, and considering the influence of seasons, shading, the use of foliar fertilization levels, and age on the nutritional value of forage plants, this work evaluates the nutritive value of *Urochloa brizantha* cv. BRS Paiaguas fertilized via foliar, under Eucalyptus shading during dry and rainy seasons in transition region Cerrado-Pantanal.

MATERIAL AND METHODS

The study was conducted in Aquidauana, MS (20º27' S and 55º40' W, 170 m average altitude). The regional climate is Aw (tropical savannah), according to Köppen (PEEL et al., 2007), and the soil is Ultisol sandy loam texture (EMBRAPA, 2013). Two simultaneous and similar experiments were conducted. The only difference was that one was performed in an area shaded by eucalyptus and the other in full sun. The evaluated forage was *Urochloa brizanth*a (Hochst. ex A. Rich.) R.D. Webster [syn. *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.] cv. BRS Paiaguas.

In 2015, soil chemical analysis indicated the following results: pH in water 5.32; 15.85 g/dm^3 organic matter; 3.96 mg/dm^3 P; 0.15 cmol/dm^3 K; 1.9 cmol/dm^3 Ca; 1.0 cmol/dm^3 Mg; 0.10 cmol/dm^3 Al; 2.68 cmol/dm^3 H + Al; 3.05 cmol/dm^3 base sum, and 53.23% base saturation. Limestone was applied followed by harrowing to incorporate the lime into the soil.

In the areas designated for the shading system, subsoiling was performed at a depth of 30 to 40 cm in the tree planting rows. Before planting at the end of 2015, the Eucalyptus seedlings were treated with mono-ammonium phosphate (1.5%) and imidacloprid based insecticide (0.5%). The tree seedlings were planted in East-West single rows, spaced 14 m between rows and 3 m between trees. The clones I-144 and 1277 of *Eucalyptus grandis* x *Eucalyptus urophylla* hybrids were planted, fertilized with 80 g NPK/plant1 (06-30-06) and irrigated with approximately 4 L water per plant. After 60 days, the Eucalyptus trees were fertilized with 80 g NPK/plant three more times, at 90 and 180 days (20-00-20), and 12 months (00-00-60). At the end of the experimental period, the eucalyptus trees had an average height of 11.98 m (ranging from 7.92 to 14.97 m) and approximately two years of age.

In November 2016, in both systems the BRS Paiaguás grass was sown. The areas were divided into three blocks, with four experimental units per block, totaling 12 experimental units (10 m x 9 m each) for each system (shaded and full sun). Twenty rows of forage were sown per experimental unit.

The evaluation period from August 2017 to March 2018 was divided into dry (82 days from August to November 2017) and rainy (88 days from December 2017 to March 2018) seasons. The average temperatures and accumulated rainfalls were 27.2ºC and 183.6 mm and 26.6ºC and 673.0 mm in the dry and rainy seasons, respectively.

Three levels of foliar fertilization were evaluated, Quimiorgen Pasto® (3, 6 and 9 L/ha) with 2 L/ha Niphokam®, and the control. The Quimiorgen pasto® nutrient percentage and concentration were 20% and 270.0 g/L P_2O_5; 0.5% and 6.75 g/L B; 3% and 40.5 g/L Mn and Zn. Whereas, Niphokam® composition was 10% and 135.0 g/L N; 8% and 108.0 g/L P_2O^5, and potassium K_2O; 1% and 13.5 g/L Ca and Zn; 0.5% and 6.75 g/L Mg, B, and Mn; and 0.2% and 2.70 g/L Cu. The foliar fertilizer was applied using a CO_2 pressurized backpack spray. In both experimental areas, fertilizer was applied at the beginning of each season, according the foliar fertilizer level.

The evaluations were performed at 28-day intervals, on 28, 56, and 84 days after foliar fertilization (considered growing days because the growth was free, without cutting or grazing), totaling three evaluations in each season (dry and rainy). In the dry season, foliar fertilization occurred in early August and the three evaluations occurred in early September, October, and November 2017, respectively. In the rainy season, foliar fertilization occurred in early December 2017 and the evaluations in early January, February, and March 2018.

The average sward height was measured using a cm-graduated ruler. Two forage samples inside a 0.0625 m^2 area defined by a metal frame, were cut close to the soil. Each sample was divided into two subsamples. One subsample was used to obtain the total dry matter. The other sub-sample was separated into leaf, stem and dead material morphological fractions, which were weighed, oven-dried at 65 °C for 72 h, and weighed again. The sampled leaves were ground in a knife mill with 2 mm mesh sieves and sent to the laboratory to estimate the nutritional value parameters: contents of crude protein (CP), neutral detergent fiber (NDF), and in vitro dry matter digestibility (IVDMD), by the Near Infrared Spectroscopy (NIRS) method.

The experimental design consisted of a randomized block with 3 blocks and 4 plots per block, for each shading system, totaling 12 experimental units per system in each season. The data were analyzed as a 4x2x2 factorial arrangement (four foliar fertilizer levels x two shading systems x two annual seasons (rainy and dry)), considering the data collected (growing days) in each plot in each season, as time-repeated measures in the same experimental unit. All interactions were evaluated, and removed from the model when not significant, or adequately unfolded.

The data were analyzed using PROC GLIMMIX of SAS University (SAS Institute Inc, Cary, CA, USA) and, where appropriate, the minimum square means of the shading systems or the seasons were compared by the pdiff of the LS means command. When the effect of the fertilization levels was identified, the average fertilization levels were compared to the control (without fertilization) using an adjustment for the Dunnett test in the pdiff option. In this case, the linear-to-quadratic effects of the used fertilizer levels were also evaluated using orthogonal contrasts. A significance level of 5% was adopted for all statistical analyses.

RESULTS AND DISCUSSIONS

In the evaluated parameters, there was no significant effect ($P \geq 0.05$) of the levels of foliar fertilizer, with average values of 8.29% of CP, 57.17% of NDF and 75.27% of IVDMD. Thus, we can infer that the foliar fertilization performed only once, at the beginning of each season, was not enough to nourish the plants and caused changes in the nutritional value of the leaves.

In the leaves IVDMD of BRS Paiaguas grass a significant effect ($P \leq 0.05$) of the system × season interaction was observed (Table 1). On the other hand, in the contents of CP and NDF, a significant effect ($P \leq 0.05$) was observed only by the seasons (Table 1).

Table 1. In vitro dry matter digestibility (IVDMD) in relation to season × system interaction, and contents of crude protein (CP) and neutral detergent fiber (NDF) in relation to seasons.

	IVDMD (%)	
	Shading system	*Full sun system*
Dry season	73.29 ± 0.99 B	77.13 ± 1.06 A
Rainy season	76.34 ± 0.24 A	74.06 ± 0.24 B
	Dry season	*Rainy season*
CP (% DM)	8.92 ± 0.15 A	7.88 ± 0.14 B
NDF (% DM)	54.73 ± 0.33 B	59.60 ± 0.31 A

Means in the same row followed by different letters differ by t-test at 5%.

The leaves CP content was higher ($P \leq 0.05$) and the NDF content was lower ($P \leq 0.05$) in the dry season (Table 1). In this way, the lower rainfall that occurred in the dry season (183.6 mm in contrast to 673 mm in the rainy season), did not compromise these nutritional parameters, indicating that the BRS Paiaguas grass can be used during the dry season, in the evaluated region. Water stress generates changes in the anatomy, physiology and biochemistry of plants, influencing their growth and the effects will depend on the degree and duration of the water deficiency, as well as the type of plant (DUARTE, 2012). According to the author, during water stress, most of the fixed carbon is used for osmotic adjustment and root growth, and may not be available for the development of the cell wall.

In the dry season, higher (P≤0.05) IVDMD was observed in full sun system, while in the rainy season, IVDMD was higher (P≤0.05) in the shading system (Table 1). The lower rainfall that occurred in the dry season associated with less light entering the sward, in the shading system, impaired the plant's metabolism. By the contents of CP and NDF obtained in the dry season, we can affirm that the shading was a decisive factor in the decrease of the leaves IVDMD. In fact, in the rainy season, when there was greater water availability, shading stimulated the improvement of IVDMD.

In the leaves contents of CP, NDF and IVDMD of the BRS Paiaguas grass were observed a significant effect (P≤0.05) of the system × growing days interaction (Table 2).

Table 2. Contents of crude protein (CP) and neutral detergent fiber (NDF), and in vitro dry matter digestibility (IVDMD) in relation to system × growing days interaction.

	Shading system	**Full sun system**
	CP (% DM)	
29 days	9.49 ± 0.24 A	8.37 ± 0.24 B
55 days	8.68 ± 0.29	8.55 ± 0.30
83 days	8.59 ± 0.20 A	6.69 ± 0.22 B
	NDF (% DM)	
29 days	57.08 ± 0.52 A	53.97 ± 0.52 B
55 days	56.58 ± 0.54	57.64 ± 0.55
83 days	56.70 ± 0.40 B	60.77 ± 0.44 A
	IVDMD (%)	
29 days	74.47 ± 0.88 B	77.74 ± 0.88 A
55 days	74.58 ± 0.97	76.31 ± 1.00
83 days	75.35 ± 0.74 A	73.03 ± 0.80 B

Means in the same row followed by different letters differ by t-test at 5%.

At 29 growing days, the contents of CP and NDF were higher (P≤0.05) in the shading system, however, the IVDMD was higher (P≤0.05) in full sun (Table 2). Thus, when the plants were younger, despite the shading positively influencing the CP levels in the leaves, it affected the IVDMD probably because the cell wall components contents were also stimulated by the shade at the beginning of the growth. We must also consider that the evaluation at 29 days of growth is the closest to foliar fertilization, which, associated with shading, resulted in higher content and cell wall contents.

At 83 growing days, the contents of CP and IVDMD were higher (P≤0.05) under shading and the NDF content higher (P≤0.05) in the full sun system (Table 2). With the increase in plant growth, shading was positive in determining adequate values of these parameters demonstrating the viability of using BRS Paiaguas grass in silvopastoral systems.

CONCLUSIONS

Single foliar fertilization is not enough to alter the nutritive value of the leaves of the BRS Paiaguas grass. Higher frequency searches are needed.

Considering the leaves CP content, the BRS Paiaguas grass is adapted to the dry season conditions in the Cerrado-Pantanal transition region.

Considering the leaves CP and NDF contents, the BRS Paiaguas grass is adapted to shading of Eucalyptus grandis x Eucalyptus urophylla hybrids, planted in East-West single rows, spaced 14 m between rows and 3 m between trees, with an average height of 11.98 m and approximately two years of age.

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PHYSICAL QUALITY OF SOYBEAN GRAINS CULTIVATED IN INTEGRATED SYSTEMS

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ABSTRACT

The integrated crop-livestock forestry system (ICLF) is a model of agricultural production that combines different activities in the same area, such as agriculture, livestock, and forestry. It aims at intensifying the use of land and enhancing the production of grains, wood, meat, milk, and other products, consciously and sustainably. The purpose of this study was to evaluate the effect of the integrated crop-livestock forestry system on the physical quality of cultivated soybeans integrated with eucalyptus. For this, we evaluated two treatments [integrated crop-livestock forestry system with single rows of trees (ICLF-S) and integrated crop-livestock forestry system with triple rows of trees (ICLF-T)] and the exclusive crop, used as evidence, in a randomized block design, with four replications. The physical quality of the soybeans was determined in terms of water content, the mass of a thousand grains, apparent specific mass, the electrical conductivity of the exudate solution, and color indices (Hue angle and chroma). There was no difference between the integrated systems and the exclusive crop in terms of water content, the electrical conductivity of the exudate solution, and color (Hue angle and chroma) of the grains. The ICLF increased the mass of a thousand grains and the apparent specific mass of soybeans.

Key words: Crop livestock forestry system; *Glycine max*; physical properties

INTRODUCTION

The physical quality of the grains is linked to their characteristics of color, mass, size, and shape. The greater the consumer market demands are, the more important these characteristics are, and influence the final value of the agricultural product (SILVA, 2008). Therefore, it is necessary to learn about the quality of the soybean grown in the integrated crop-livestock and forestry system (ICLF), as not much is known on how the variables used in the integrated systems can affect the quality of the grains.

ICLF is an innovative agricultural system to the traditional models of agricultural production and it is associated with the principles of crop rotation and consortium or succession of grains, forage, and tree crops, combined with livestock farming in the same area. The purpose of this system is to seek synergistic effects between the components for environmental adequacy, the valuing of men, and the economic viability of the agricultural enterprise (BALBINO et al., 2012). Inserting a tree component in the agricultural area causes several changes in the local microclimate, such as the reduction of the incidence of direct light, the decrease in the temperature and wind speed, increasing the relative humidity of the air, reducing the evapotranspiration of the agricultural cultivation and the increased soil moisture (BERNADINHO; GARCIA, 2009). These differentiated environmental conditions can directly influence plant development, embryo formation, and dry mass gain, and, consequently, the soybean quality (CARVALHO; NAKAGAWA, 2000).

In this sense, it is important to assess whether the quality of grains produced in integrated systems can positively or negatively interfere with their competitiveness in the market. Thus, the adoption of the ICLF could be expanded, based on solid, long-term, and farm-scale research results. Therefore, we aimed to evaluate the effect of the integrated crop-livestock forestry system on the physical quality of soybeans.

MATERIAL AND METHODS

To evaluate changes in the physical quality of soybean grown in consortium with eucalyptus, we obtained some grain samples from an integrated crop-livestock forestry system (ICLF) area with simple and triple rows (treatments) and another sample with exclusive crops (control), located at the experimental field of Embrapa Agrossilvipastoril, in Sinop, Mato Grosso, in the 2018/2019 harvest. To establish the eucalyptus trees (*Eucalyptus urograndis* - clone H13) in the integrated crop-livestock forestry system (ICLF) with simple rows (ICLF-S), we planted them in bands, with 37 m spacing between rows × 3, 0 m between trees. In an integrated crop-livestock forestry system (ICLF) with triple rows (ICLF-T), eucalyptus *(Eucalyptus urograndis* - clone H13) we planted bands at a 30 m spacing between rows × 3.5 m between rows and 3, 0 m between trees. We planted the eucalyptus lines, for both systems, in 2011 following the east-west orientation and used the area between rows for soybean cultivation (cultivar BRS7380RR).

We arranged the treatments (ICLF-S and ICLF-T) and the control (exclusive crop) in randomized blocks (5 ha each), designed with four replications, and distributed within each block in the following manner: 2 ha of ICLF-S + 2 ha of ICLF-T + 1 ha exclusive crop). To analyze the physical quality of the grains, we applied samples from eight positions in the plot (in the form of a transect), that is, four distances from the eucalyptus row (3, 6, 10, and 15 m) and two production faces (north and south). The sampling points were composed of two lines of 5 m. The grains produced in the exclusive crop (control), were also harvested in two rows of 5 m, but in five random positions in the cultivation area.

The grains were harvested between February 10th and 15th, 2019, and, after being traced, they were manually cleaned to remove all types of impurities and unexpected material and, when necessary, we submitted the samples to dry in the greenhouse until they reach the commercial water content (14%).

After that, we evaluated the samples for water content, by the gravitational method (BRASIL, 2009), for the mass of a thousand grains, by grain count (BRASIL, 2009), for apparent specific mass, on a hectoliter scale (BOTELHO et al., 2018), for electrical conductivity of the exudate solution (BRASIL, 2009) and also for color index (Hue angle and chroma), calculated after directly reading the L *, a * and b * coordinates in a tristimulus colorimeter. The data were submitted to analysis of variance and the means between the ICLF systems and the exclusive crop compared by the Tukey test ($p < 0.05$).

RESULTS AND DISCUSSIONS

The experiments showed that there was no statistical difference between the integrated systems (ICLF-S and ICLF-T) and the exclusive crop for the following physical properties: water content, the electrical conductivity of the grain imbibition solution, chroma, and Hue angle. They presented a general average of 12.98%, 142.15 µS cm^{-1} g^{-1}, 17.25° and 74.15. Thus, the environmental conditions of the integrated systems (lower incidence of light, temperature, competition for nutrients, and evapotranspiration) did not influence these physical characteristics in the grains when compared to soybeans produced in exclusive crops (Table 1).

There was a qualitative improvement in the mass of a thousand grains and in the bulk density in the integrated systems compared to the exclusive crop. The average observed in the exclusive crop was 156.67 g and 679.78 kg m^{-3} while in the ILPF it was 168.95 g and 700.06 kg m^{-3}, respectively, for the mass of one thousand grains and apparent specific mass. Therefore, the conditions imposed by the integrated systems may have favored the grain formation, justifying higher mass indexes.

Table 1. Averages of the physical properties in soybeans in different production systems.

Production systems	WC (%)	M100 (g)	BD (kg m^{-3})	ECE (µS cm^{-1} g^{-1})	Hue (º)	Croma
EC	12.32 A	156.67 A	679.78 A	138.37 A	17.15 A	75.05 A
ICLF -S	13.95[1] A	167.62 B	694.13 B	152.45 A	16.84 A	73.66 A
ICLF -T	12.67 A	170.29 B	705.99 B	135.63 A	17.35 A	73.86 A
ICLF Average	13.31	168.95	700.06	144.04	17.09	73.76
General average	12.98	164.86	693.0	142.15	17.25	74.45
c.v. (%)	11.96	2.15	1.70	11.20	4.13	0.60

Where: WC = water content; M1000 = mass of a thousand grains; BD = bulk density; ECE = electrical conductivity of the exudate solution; Hue = angle Hue; EC = exclusive crop; ICLF-S = integrated crop-livestock forestry system with simple lines; ICLF-T = integrated crop-livestock forestry system with triple rows. [1]Means followed by equal capital letters in the columns do not differ statistically from each other, by the Tukey test, at 5% probability.

The water content of soybeans grown in the ICLF systems was 13.31%. The water content is widely pointed out in the literature as the factor that most influences the physical properties of grains (SOUSA et al., 2016; BOTELHO et al., 2015), which was not the case in this study since the water content in the samples showed no difference. The average mass of a thousand grains of soybean grown in the integrated systems was 168.95 g. The low light conditions of the most shaded areas, especially close to the eucalyptus row, did not compromise the filling of those grains that these plants set out to granulate. This is because, according to Magalhães et al. (2019), the number of pods and grains is lower in those plants located in the most shaded areas. Also, according to Fioreze et al. (2013), for having C3 metabolism, soybean plants seem to be more adaptable when subjected to this limitation.

The apparent specific mass of grains of the integrated systems was 700.06 kg m^{-3}. This result is important, as it shows that, even though it is not used as an indicator for the commercialization of soybeans, increments in the apparent specific mass can be associated with a higher quality of grains. Seeds with a higher specific mass are those that are better nourished during the development phase, thus presenting better-formed embryos and reserve tissues (CARVALHO; NAKAGAWA, 2000). Therefore, the results found show that the changes in the light conditions, imposed by the eucalyptus trees crowns, did not interfere in the physical aspects of the grains, maintaining their quality. For the exudate solution electrical conductivity, the average obtained in the integrated systems was 144.04 µS cm^{-1} g^{-1}. This result indicates that there was no change in the formation of soybeans, maintaining their quality, both physical and physiological, corroborating the data presented for the mass of a thousand grains and apparent specific mass. In other words, the tree component associated with the crop contributed to the production of higher quality grains.

Chroma and Hue angle showed averages of 73.76 and 17.09º, respectively. The environmental conditions inside the integrated systems did not influence the color of the soybean. This result is important because, although the color is a genetic factor for each cultivar, it is one of the main physical characteristics used in classifying a sample. By evaluating the color of the grains, it is possible to identify possible damage caused while still in the field, in addition to the separation of immature, moldy, and burnt grains.

CONCLUSIONS

Soybean grown in the integrated systems and the exclusive crop shows no difference in terms of water content, the electrical conductivity of the solution of the grain exudates, and color. ICLF increases the mass of a thousand grains and the apparent specific mass of soybean.

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ECONOMIC GAINS FROM INTEGRATED CROP-LIVESTOCK SYSTEM VERSUS CONVENTIONAL SYSTEMS

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ABSTRACT

The aim was to calculate the total cost of maize production and beef cattle, in pasture, in conventional systems compared integrated systems (maize production plus beef cattle), as well as to verify economic gains explained by the economy of scope. Six experimental treatments were studied: corn grain production, beef cattle in single pasture and four integrated systems, based on intercropping sowings. After collecting field data, calculation and allocation of variable and fixed costs to estimate costs of production in the systems were perfomed. Integrated Crop-Livestock Systems (ICLS) shows economic gains in relation to conventional systems, which can be explained by the dilution of fixed costs and the presence of shareable inputs, which result in economies of scope. In addition, it has been demonstrated that the total unit costs of the crop, as well as livestock, are lower in ICLS, reinforcing the idea that integrated systems result in economic benefits as compared to conventional systems. In addition, the present study contributes suggesting a method of analysis to demonstrate the economy of scope theory in Animal Science.

Key words: economic analysis; economy of scope; integrated systems

INTRODUCTION

Monoculture is the prevailing system conventional of plant and animal production in Brazil, which is based on the intense use of natural resources, chemical formulas, and nonrenewable energy. On the other hand, in Integrated crop-livestock systems (ICLS), intercropping sowings is more used for the production of agriculture and livestock, to minimize the use of fertilizers and reduce the environmental impacts.

In this context, different studies have demonstrated benefits of integrated systems in relation to soil properties (FRANZLUEBBERS; STUEDEMANN, 2008), decreased fertilizer use (ENTZ et al., 2002), and nutrient cycling (HENDRICKSON et al., 2008). However, the economic efficiency of integrated systems, however, has yet to be demonstrated (WILKINS, 2008).

In the economic theory, eventual economic gains obtained by the diversification of production systems are justified by the so-called “economy of scope”, which occurs when the cost for producing two items in a given production system is lower than that when the same items are produced separately (PANZAR; WILLIG, 1981). However, measuring and demonstrating the economy of scope in production systems are not that simple (GAMEIRO et al., 2016), probably due to the difficulty in calculating the cost of production of an integrated system, especially for farmers.

The different possibilities of ICLS settings in relation to the implemented cultures and managements performed are challenged to demonstrate the economic advantages of this system. Although integration between maize and grass of the genus Brachiaria has been explored, there are not many studies exploring the type of system implementation method that leads to better productive and economic advantages. Most of the results refer to the simultaneous implementation of corn and grass seeds. However, other possibilities, such as grass sown during maize crop cover fertilization, have been little discussed in literature. We aimed to calculate the total cost of production of crop (maize grains) and livestock (fattening of beef cattle in Marandu grass pasture) in conventional systems and crop-livestock integrated systems to verify eventual integrated system economic gains explained by the economy of scope.

MATERIAL AND METHODS

The experiment was conducted in Sertãozinho, São Paulo, Brasil, (21°08'16" S latitude, 47°59'25" W longitude, and mean altitude of 548 m), from December 2015 to December 2016. The experimental design consisted of three randomized blocks and six treatments, two of which represented conventional systems (Crop and Livestock) and four, ICLS (intercropping sowings). The Crop System was used maize (*Zea mays*) for grain production; The Livestock System was used *Brachiaria brizantha* cv Marandu for fattening beef cattle in pasture. The treatments that represented ICLS were: ICLS1: maize plus Marandu grass seeded simultaneously; ICLS2: maize plus Marandu grass plus Nicosulfuron; ICLS3: maize plus Marandu grass seeded in maize cover fertilization; and ICLS4: maize plus Marandu grass seeded on maize rows and interrows plus Nicosulfuron. In all experimental treatments, except for ICLS3, the crops were sown simultaneously.

The experiment was implemented in no-tillage system in December 2015. The area destined for each experimental treatment covered 0.89 ha, with a total experimental area of 16.02 ha. For the calculation of crop yield, the quantity of kilograms of grains per hectare, with 13% moisture, was converted into bags of maize containing 60 kg each. Livestock productivity was calculated from the final weight of the animals, considering 50% carcass yield.

The allocation of fixed and variable costs of the experimental treatments is described:

Crop System

Fixed costs (US$) = Labor; Depreciation; Income (Opportunity cost of fixed asset; Opportunity cost of land).

Variable costs (US$/bag; US$/kg) = Cost of maize crop: Maize seed, Planting fertilizer, Cover fertilizer, Preparation herbicide, Other herbicides, Maize seed treatment, Insecticide, Grain harvest, Diesel.

Livestock System

Fixed costs (US$) = Pasture exhaustion: Grass seed, Planting fertilizer, Preparation herbicides, Diesel (pasture implementation); Labor; Depreciation; Income (Opportunity cost of fixed asset; Opportunity cost of land).

Variable costs (US$/bag; US$/kg) = Pasture management: Cover fertilizer, Diesel (fertilizer application); Animal production: Animal purchase, Mineral salt, Medication

Integrated Crop-Livestock System

Fixed costs (US$) = Pasture exhaustion: Grass seed, Planting fertilizer (1/2), Preparation herbicide (1/2), Diesel (pasture implementation); Labor; Depreciation; Income (Opportunity cost of fixed asset; Opportunity cost of land).

Variable costs (US$/bag; US$/kg) = Cost of maize crop: Maize seed, Planting fertilizer (1/2), Preparation herbicide (1/2), Cover fertilizer, Other fertilizers, Maize seed treatment, Insecticides, Grain harvest, Diesel (maize management); Pasture management: Cover fertilizer; Diesel (fertilizer application); Animal production: Animal purchase, Mineral salt, Medication.

For the calculation of the total cost of production, it was necessary to define a representative area for the extrapolation of costs related to depreciation. If this extrapolation had not been carried out, the costs of production would have been overestimated, since experimental implementation improvements would not be justifiable for a productive area such as experimental plots. The defined representative area of 75 ha was based on the possession of a tractor similar to the one used in the base project (100 hp), since this machine is an essential production factor for a production system to be developed. To verify the occurrence of the economy of scope, the following equation (1) suggested by Panzar and Willig (1977) was used: $C\ (a, b) < C\ (a, 0) + C\ (0, b)$, (1) in which $C\ (a, b)$ represents the cost of production of hypothetical products (a and b) in a multi-product enterprise (ICLS), and C (a, 0) and 0, b) represent the cost of production of the same products separately (conventional systems).

RESULTS AND DISCUSSIONS

The total cost of production of the treatments that represent crop and livestock differs statistically from each other, in addition to differing from the total cost of production of other treatments. The difference of the total cost of production between the treatments may be explained by the superior fixed costs, since for the development of the integrated system, there were varied costs related to the vegetable and animal production. The difference of the total cost of production between the treatments may be explained by the superior fixed costs added the variable cost, because for the development of the integrated system, there were varied costs related to the vegetable and animal production.

From the total cost of production, it is possible to validate the hypothesis that ICLS showed economic gains in relation to conventional systems. These gains can be justified by the theory of the economy of scope, since the sum of the total cost of production of treatments that represented conventional systems (crop + livestock) resulted in a higher value (US$ 305,530.06) than that of the total cost of production of any of the ICLS treatments (US$ 218,915.31).

Table 1. Fixed costs (FC), variable costs (VC), and total cost of production (TC) per experimental treatment (US$) representative area of 75 ha.

	Crop	**Livestock**	**ICLS1**	**ICLS2**	**ICLS3**	**ICLS4**
Total FC	52,840.10b	57,343.77b	60,163.58a	60,163.58a	60,007.22a	59,972.42a
Total VC (Crop)	75,573.25a	-	62,037.00a	63,918.00a	63,042.46a	63,747.50a
Total VC (Livestock)	-	116,854.88a	97,812.00b	93,532.73b	97,200.00b	94,539.15b
TC[4]	128,454.95c	174,075.11b	219,916.39a	217,480.11a	219,829.12a	218,435.64a

a-c - Different letters mean statistically different results ($P<0.05$) by Tukey's test.

The exchange rate of US$ 0.3119 = R$ 1.00 is suggested. As there were no statistical differences between the total costs of production of the treatments that represented ICLS to demonstrate the other results, the ICLS4 treatment was chosen to represent the integrated systems for the demonstration of other results to focus the discussion of the present study on its central issue: monoculture versus crop integration. The ICLS4 treatment was selected because it provided better results related to pasture production and growth during the evaluated period.

The average fixed cost demonstrates the cost to produce one kilogram of the product of interest (whether maize grain or fat cattle). This cost was lower in the crop treatment, since the total fixed cost of this treatment was also lower. Although the total fixed cost of ICLS4 was higher compared with the livestock treatment, the average fixed cost of this treatment was lower, since the total amount of ICLS4 produced was higher (maize and cattle) (Table 2).

Table 2. Total fixed cost (US$), total maize and fat cattle production (kg), and average fixed cost (US$/kg) per experimental treatment.

Item	Unit	Crop	Livestock	ICLS4
Total FC[1]	US$	52,840.10	58,588.86	61,350.98
Maize production[2]	kg	1,032,052	-	1,022,431
Fat cattle production[3]	kg	-	96,975.00	67,800.00
Total production	kg	1,032,052	96,975.00	1,090,231
Average FC[4]	US$/kg	0.05	0.60	0.06

[1]Total fixed cost; [2]Total maize production (100% moisture); [3]Total cattle production; [4]Average fixed cost. The exchange rate of US$ 0.3119 = R$ 1.00 is suggested.

CONCLUSIONS

Integrated Crop-Livestock System shows economic gains in relation to conventional systems, which can be explained by the dilution of fixed costs and the presence of shareable inputs, which result in economies of scope. In addition, it has been demonstrated that the total unit costs of the crop, as well as livestock, are lower in CLI, reinforcing the idea that integrated systems result in economic benefits as compared with conventional systems.

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DIFFERENT PASTURE SYSTEMS AFFECTING CANOPY HEIGHT, FORAGE MASS AND VOLUMETRIC DENSITY OF BRS PAIAGUÁS

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ABSTRACT

The objective of the experiment was to evaluate the effect of pasture systems grazed by cattle on canopy height, forage mass and volumetric density of *Urochloa brizantha* cv. BRS Paiaguás from June of 2020 to March of 2021 in Uberaba, MG, Brazil. The grazing method was rotational stocking and forage allowance of 6 kg of dry mass/100 kg of live weight/day during dry and wet season. The treatments were SPS - Silvopastoral System with *U. brizantha* cv. BRS Paiaguás shaded by eucalyptus trees (*E. citriodora* and *E. cloeziana* clones) planted in 2013, in triple rows spaced 30 to 35 metros and 1.5 m among trees, east-west direction, and pastures seeded in 2015/2016 mixed with maize for silage and FS **-** Full sun pastures of *U. brizantha* cv. BRS Paiaguás, planted mixed with maize for silage in 2019/2020, with twelve repetitions. The full sun pastures allowed greater forage mass throughout the year.

Key words: Pasture; grazing management; silvopastoral system

INTRODUCTION

Pastures are the main basis of cattle livestock systems in Brazil and maintaining a suitable forage allowance is important to optimize cattle performance and to reduce the period of the productive cycle. The intensification of grazing system could increase the farmers' profit. The proper grazing management prevents the culm elongation, leaf senescence e flowering, maintaining the nutritive value of forage and animal forage intake. So, the forage mass estimates enable the grazing management and help to diagnose changes in forage accumulation during the year. These measures support the farmers to maintaining the adequate grazing management, with positive consequences on animal production (ARRUDA et al., 2011)

The use of *Urochloa* grasses for agrosilvopastoral systems occurs because of its easier grazing management with wide canopy height targets, fast regrowth and greater soil cover. Besides that, these grasses do not grow as tussocks and decease easily when dissecting herbicides were applied (ALMEIDA et al., 2014). The Brazilian Association of Zebu Cattle Breeders (ABCZ) and partners develops the "Zebu Program of Meat Quality": beef quality production with efficiency and sustainability that evaluates the production systems of Brazilian beef cattle using Zebu males, raised in pastures, finished in feedlots and slaughtered to evaluate meat quality. The agricultural research institutions Epamig and Embrapa support this project, especially forage (pasture and silage) and nutritional management components.

The objective of the experiment was to evaluate the effect of pasture systems grazed by cattle on canopy height, forage mass and volumetric density of *Urochloa brizantha* cv. BRS Paiaguás.

MATERIAL AND METHODS

The experiment was conducted in the Experimental Farm of ABCZ - Orestes Prata Tibery Júnior, located in MG 427 road, Uberaba, MG, Brazil (19º45´56” S, 47º57´ W, 774 m altitude). The experimental period lasted from June of 2020 to March of 2021. The climate in Uberaba is considered tropical semi-humid with mean temperature of 21.4º C. In the warm months the mean temperature is 23.2º C, while in the cool months, the mean temperature is 19.4º C. The annual rainfall is 1685 mm and the mean humidity of the air is 71% (EPAMIG/INMET, 2019).

The soil type in the experimental area is classified as Sandy Dystrophic Red Latosol, (SANTOS et al., 2018) in a flat topography. It was applied limestone to elevate the saturation of bases to 60%, according to the previous chemical soil analysis. The fertilization was based in the forage production and nutrient extraction (WERNER et al., 1997), with complete fertilization of macro and micronutrients to obtain a stocking rate of approximately 4 AU/ha (AU = 450 kg live weight) during the wet season. The stocking management was rotational based on a forage allowance of 6 kg dry matter/100 kg live weight/day for dry and wet seasons, considering the forage mass at the soil level, regulating the grazing management for both treatments. The treatments were: SPS - Silvopastoral system with *U. brizantha* cv. BRS Paiaguás pastures shaded by eucalypt trees (*E. citriodora* and *E. cloeziana* clones) planted in 2013, in triple rows spaced from 30 to 35 m and 1.5 m between trees, at east-west direction (18% of the area was occupied by trees). The pasture was seeded in 2015/2016 mixed with maize for silage and FS - Full Sun Pasture of *U. brizantha* cv. BRS Paiaguás, seeded mixed with maize for silage in 2019/2020. The experimental design was completely random with twelve repetitions. Both treatments received topdressing nitrogen fertilization of 150 kg/ha split in three times during the wet season. To maintain planned forage allowance samplings of forage mass in the pre-grazing were made. The canopy height (cm) and forage mass were randomly sampled in 6 sites of 1 x 1 m at pre-grazing (kg DM ha^{-1}). The volumetric density of forage (kg DM cm^{-1} ha^{-1}) was estimated based in forage mass and canopy height. During experimental period 6 grazing cycles were conducted: 19/06/2020 – 22/08/2020, 22/08/2020 – 29/10/2020, 29/10/2020 – 04/12/2020, 04/12/2020 – 14/01/2021, 14/01/2021 – 22/01/2021 and 22/01/2021 – 23/03/2021, respectively for cycles 1, 2, 3, 4, 5 and 6.

Data were evaluated with repeated measures in time (grazing cycles) as split plot arrangement. Means were tested with Scott-Knott test using SISVAR 5.6, 2011.

RESULTS AND DISCUSSIONS

The pasture systems treatments and their previous management affected the canopy height and volumetric density of forage (P<0,05) (Table 1). There was not difference (P<0,05) for canopy height between treatments considering all the experimental period. There was effect of grazing cycles on canopy height in the cycles 1, 3 and 6. In the grazing cycles 2, 4 and 5 there was no effect of treatment on canopy height, period of greater solar radiation and rainfall. These factors influence positively the growth of tropical grasses. There was not variation of canopy height for full sun pastures during all experimental period (P>0,05). On the other hand, it was observed a decrease of canopy height for SPS during grazing cycle 3. In the same way, the volumetric density of forage did not presented variation in full sun pastures, while for SPS pastures, the forage density increased in the grazing cycles 4 and 6.

For the entire experimental period, the volumetric density of forage in full sun pastures was 56% greater than observed in SPS pastures. This increase could be linked with the greater photosynthetic rate in the full sun pastures, due to greater availability of solar radiation compared to SPS pastures. This increase was also a result of the greater tillering, because the mean canopy height did not differ between treatments. In the grazing cycles 1, 2 and 3 the volumetric density was superior in the full sun pastures when compared to SPS pastures. The grazing cycles 4, 5 and 6 were different, which is associated with the period of rainfall and greater temperature and radiation, affecting the forage accumulation.

Table 1. Canopy height (cm) and volumetric density of forage (kg DM cm^{-1}) in *Urochloa brizantha* cv. BRS Paiaguás pastures at pre-grazing from June of 2020 to March of 2021, in different pastures systems in Uberaba, MG, Brazil.

Grazing cycles	**Canopy height (cm)**		**Volumetric density (kg DM cm^{-1})**	
	FS	**SPS**	**FS**	**SPS**
1	53 B d	66 A b	54 A c	23 B c
2	51 Ad	49 Ac	120 A a	74 B a
3	68 A b	49 B c	78 A b	57 B b
4	62 Ac	57Ac	32 Ad	36 Ac
5	83 Aa	83 Aa	74 A b	26 B c
6	59 B c	71 A b	54 Ac	52 Ab
Mean	63 A	62 A	70 A	45 B

FS **-** Full sun pastures with *U. brizantha* BRS Paiaguás seeded mixed with maize for silage in 2019/2020. SPS **-** Silvopastoril System with *U. brizantha* BRS Paiaguás pastures shaded by eucalypts trees (*E. citriodora* and *E. cloezianaI* clones) planted in 2013, in triple rows spaced from 30 to 35 m and 1.5 m between trees, Pastures were seeded in 2015/2016 mixed with maize for silage; Cycle 1: 19/06/2020 – 22/08/2020, Cycle 2: 22/08/2020 à 29/10/2020, Cycle 3: 29/10/2020 – 04/12/2020, Cycle 4: 04/12/2020 – 14/01/2021, Cycle 5: 14/01/2021 – 22/01/2021 and Cycle 6: 22/01/2021 – 23/03/2021. Means followed by the same lowercase letters in the line and the uppercase letter in the column do not differ by Scott-Knott test (P<0,05).

The forage mass was greater in the full sun pastures during all the experimental period (Figure 1). The greater incidence of solar radiation in the full sun pastures probably increased the canopy photosynthetic rate, producing more forage. The mean forage mass was 4337 and 2428 kg DM ha^{-1}, respectively for full sun and SPS pastures, an increase of 90%. Assuming this difference, these pastures are capable to increase twofold the stocking rate and animal production in full sun condition. The planting trees technology used in this experiment should be considered in the income increase and the benefits to the animal welfare and environment. Similar results were verified by Santos et al. (2014), that associated the forage mass decrease with the solar radiation constraint. Thus, the inclusion of trees in pasture areas must consider tree density (i.e., space between lines) and the planting trees orientation, factors that will contribute to increase the light availability for the grass plants.

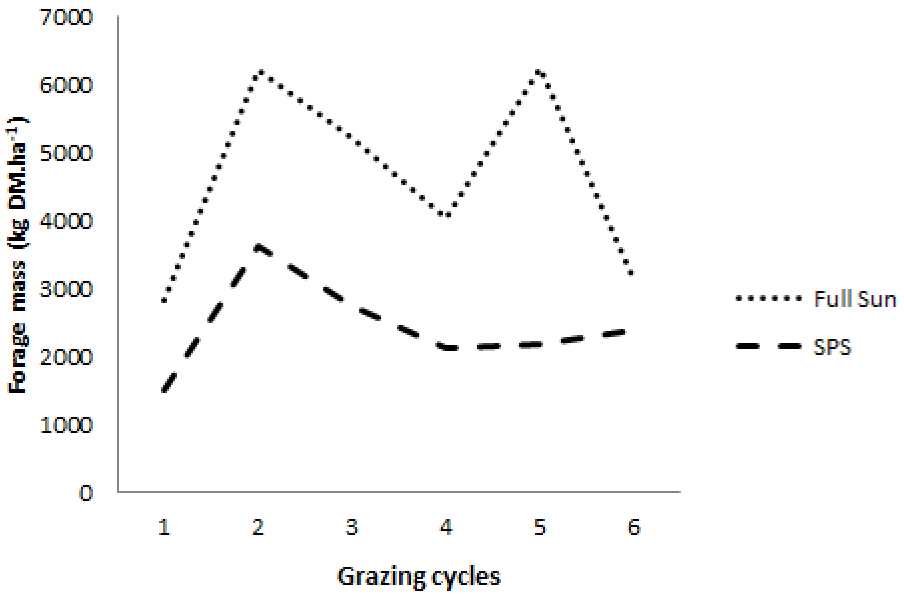

Figure 1. Pre-grazing forage mass (kg DM ha^{-1}) of *U. Brizantha* cv. BRS Paiaguás in different pasture systems from June of 2020 to March of 2021 in Uberaba, MG, Brazil. FS - Full sun pastures with *U. brizantha* cv. BRS Paiaguás seeded mixed with maize for silage in 2019/2020. SPS - Silvopastoril System with *U. brizantha* cv. BRS Paiaguás pastures shaded by eucalypts trees (*E. citriodora* and *E. cloezianaI* clones) planted in 2013, in triple rows spaced from 30 to 35 metros and 1.5 m between trees, Pastures were seeded in 2015/2016 mixed with maize for silage; Cycle 1: 19/06/2020 – 22/08/2020, Cycle 2: 22/08/2020 à 29/10/2020, Cycle 3: 29/10/2020 – 04/12/2020, Cycle 4: 04/12/2020 – 14/01/2021, Cycle 5: 14/01/2021 – 22/01/2021 and Cycle 6: 22/01/2021 – 23/03/2021.

CONCLUSIONS

In the conditions of the experiment, the full sun pastures provided greater forage mass during the year.

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PERFORMANCE AND ECONOMIC POTENTIAL OF EUCALYPTUS PLANTS GROWN IN SILVIPASTORAL SYSTEMS IN PAMPA BIOME

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ABSTRACT

The aims of the current study are to assess the performance of genetic materials of eucalyptus trees planted in different arrangements, to measure the stock of forest multiproducts and to investigate the financial viability of these plantations in silvopastoral systems in Bagé (RS). Data were collected between June 2018 and August 2019, in 15 family livestock properties in 2013 and 2014. Data about plant growth (diameter at breast height, height, total and comercial volume) and mortality were collected. The economic viability of eucalyptus plantations was analyzed based on a market study and Net Present Value (NPV) and Equivalent Annual Cost (EAC) methods. It was possible concluding that the introduction of this forestry component in pastoral systems can increasing income in rural properties, both by trading forest products and using it in the property. The investment in afforesting native fields with eucalyptus has great potential to generate financial surpluses at significantly younger cutting ages than that of the economic rotation often applied to this genus in the region.

Key words: Integration systems; *Eucalyptus dunnii*; economic viability.

INTRODUCTION

Pampa biome covers an area of approximately 176,496 km², which corresponds to 62.2% of Rio Grande do Sul State territory and 2.07% of the Brazilian territory (MMA, 2019). Fields are the original and prevalent landscape in this biome, where the main economic activity lies on extensive livestock farming on native pasture – this activity accounts for approximately 70% of beef herd in the state (BOLDRINI et al., 2010; BARCELOS et al., 2016).

However, the low productivity and profitability observed for the traditional livestock farming practiced in the region has been instrumental at the time to make decisions about converting these fields into other economic activities such as crops and forestry (RIBASKI et al., 2012), which results in landscape mischaracterization process. Nowadays, fields cover 35.73% of the biome area (TRINDADE et al., 2018).

Accordingly, silvopastoral systems – which are based on the association between trees and livestock activity - can be used as alternative integrated land-use, as well as to diversify the productive matrix of rural properties by adding value to the production system already implemented in them. It can be done through timber exploitation, which (indirectly) enables avoiding livestock devaluation and its conversion into other productive activities (RIBASKI et al., 2012).

Eucalyptus is the forest species traditionally used in the region. It is associated with the rural landscape due to large forest plantations implemented under monoculture systems that were established based on financial incentives since the early 2010s, as well as to small stands “capões” implanted as windbreaks, promoting livestock thermal confort, as well as to wood reserve often without commercial purposes (ASSOCIAÇÃO GAÚCHA DE EMPRESAS FLORESTAIS, 2016). In both cases, they disregard the livestock production process in the property.

Thus, the silvopastoral system implemented with eucalyptus explores the potential of silviculture, as well as its economic and environmental benefits, based on the coexistence between native fields and livestock operations, without overlapping or replacing one another. This system can be considered innovative in the investigated region, since it has several applications in rural properties, such as producing firewood, platforms, posts, poles, as well as round and sawn wood for rural buildings, self-consumption or trading purposes.

Despite its potential advantages, this production system remains poorly used in the region. There are cultural and economic barriers to the adoption of this technology in rural properties, since these systems require greater initial financial and labor investment accounting for mid-to-long term return. Lack of knowledge about the forest product market and the difficulty to assess the wood produced in a quantitative and qualitative way are obstacles to the implementation of this system (DIAS FILHO; FERREIRA, 2008; CAMPANHA et al., 2018).

Since the adoption of this production system requires long-term resource immobilization, it must be planned in such a way to enable the production of a wide range of forest products over time. In order to do so, it is necessary previously understanding the specifications and requirements of the forest product market.

Thus, from 2013 onwards, Embrapa Pecuária Sul - in partnership with institutions such as Emater, Ministry of Agriculture, Livestock and Supply (MAPA), Bagé City Hall, Federal Institute of Rio Grande Sul and State Secretariat for the Environment - has established experimental areas and Technological Reference Units in Bagé County (RS) to allow producers to experience the implementation and management of silvopastoral systems, as well as to measure the economic outcomes from this activity to boost the adoption of this system in the region. The monitoring process adopted in these areas resulted in the current study, whose aims were to assess the performance of different genetic materials of eucalyptus trees planted at different arrangements, as well as to measure the stock of forest multiproducts and to investigate the financial viability of these plantations.

MATERIAL AND METHODS

Data were collected between June 2018 and August 2019, in 15 Technological Reference Units (TRUs) implemented in the silvopastoral project of Campanha region, Bagé County (RS). Technological reference units (TRUs) were installed in 15 family farms (area = 3 ha each) and one TRU was implemented in the experimental field of Embrapa (area = 11 ha).

The herein selected arrangement lied on trees planted in simple lines spaced 8 m, 16 m and 24 m apart, 2-m distance between plants in the rows. This arrangement corresponded to the initial number of 625, 312 and 208 trees ha^{-1}, respectively. Technical details about the implementation and management of these systems can be seen in Lucas et al. (2015).

Three eucalyptus materials - one seminal (*Eucalyptus dunnii*) and two *Eucaluptus grandis* clones (1071 and EC 06) were used in the current study. All 15 evaluated TRUs have totaled 54.5 planted hectares: 16.5 ha were planted with *E. dunnii* and 38 ha, with *E. grandis* (27 hectares planted with clone 1071 and 11 hectares planted with EC06).

One in every five rows at each planting arrangement was randomly selected in order to measure the trees. Approximately 20% of trees in each location were measured; 4.018 trees were measured, in total.

Mortality rate (%) was calculated based on the inventory carried out in the entire site. Total and commercial volume were based on rigorous cubing application to standing trees by using the Criterium RD 1000 equipment. Sample trees used for cubing were selected based on diameter class in 11 TRUs, which were defined as representative of both the species and planting arrangement. The population in each TRU was divided into 10 diametric classes; 2 trees per class were cubed - 220 trees, in total.

Stofells (1) and Spurr's combined variable (2) models were selected to estimate unmeasured trees height and volume; these models were adjusted to each TRU and planting arrangement. Subsequently, general equations were defined based on genetic material and spacing in order to estimate the volume in TRUs where trees were not cubed.

$$lnh = b_{(}o+)b_1 lnd \qquad \text{Eq. (1)}$$

$$logv = b_{(}o+)b_{(}1)log\,(d^2h) \qquad \text{Eq. (2)}$$

Forest assortments were obtained through market research conducted at sawmills located in the region; assortment estimates were obtained through adjustments applied to a tapering function - in this case, the fifth-degree polynomial -, which allowed estimating the volume of forest assortments.

Usable stem was optimized for the longest logs presenting the greatest commercial value, whereas the remainders were classified in lower classes presenting shorter logs. Stems showing diameter smaller than 11.0 cm (down to the limit of 5 cm) were classified as volume for firewood in 1-meter logs. Next, log volumes were obtained and the number of pieces was calculated in electronic spreadsheet generated for this purpose.

The number of individuals in each diametric class was estimated based on genetic material and spacing. It was done by adjusting the Weibull frequency distribution model with three parameters, based on the percentile method.

Adjustment criteria such as the Adjusted Coefficient of Determination (R^2_{aj}), and Standard Error of the Estimate (in %) were used to evaluate the selected models. Standard Error of the Estimate was recalculated in case of logarithmic equation and waste distribution analysis.

Table 1 shows the costs with forestry component implementation and maintenance in silvopastoral systems based on spacing per hectare in the first two years - year 0 refers to the implementation year and year 1 refers to the post-implementation period. Technical details on operations can be seen in Lucas et al. (2015).

Table 1. Costs with forestry component implementation and maintenance per hectare, at different spacings, in silvopastoral systems located in Bagé region (RS).

Activity	**Year**	**Cost (R$)** **(8 x 2 m)**	**Cost (R$)** **(16 x 2 m)**	**Cost (R$)** **(24 x 2 m)**
Ant control	0	161.64	161.64	161.64
Soil preparation	0	426.0	331.3	236.7
Seedling planting and replanting*	0	974.2	422.55	545.2
Baseline fertilization	0	197.01	110.645	75.39
Chemical weeding	0	342.57	267.86	193.15
Cover fertilization	0	193.02	130.21	90.6
Chemical weeding	1	342.57	267.86	193.15
Ant control	1	75.0	75.0	75.0
Cover fertilization	1	193.02	130.21	90.6
Ant control	1	37.5	37.5	37.5
Total		2,905.03	1,897.27	1,661.40

Net Present Value (NPV) and Equivalent Annual Cost (EAC) methods were used to investigate the economic viability of the plantations, by taking into consideration interest rate of 7% a year - as provided for in the Low Carbon Agriculture Plan -, as well as duration of 5 or 6 years, which corresponded to the age of plantings at survey time.

$$NPV = \sum\nolimits_{(}j = 0)^{n} \llbracket R_j (1+i)^{(} - j) - \rrbracket \ \sum\nolimits_{(}\ j = 0)^{n} \llbracket C_j (1+i)^{(} - j)\rrbracket$$
$$EAC = (NPV * i)/[1 - \ \llbracket (1+i) \rrbracket\ ^{(} - n)]$$

Wherein: Rj = revenue at the end of the year or in period-of-time *j*; Cj = costs at the end of the year or in period-of-time *j*; n = duration of the project in years or in number of periods-of-time; i = annual interest rate, expressed in units.

The cost with the land was not taken into consideration, since producers already owned the land and their goal was not to convert livestock into forest plantations, but to introduce trees in natural pastures.

RESULTS AND DISCUSSIONS

Mean growth values based on location, genetic material, cutting age and spacing (Table 2) have indicated lower variation in mortality rates recorded for *E. dunni*. The mean annual increase (MAI) in diameter recorded for this species reached 3.5 ± 0.34 cm, although it has changed depending on location and spacing. Mean annual increase in plant height reached 2.8 ± 0.22 m. On the other hand, volumetric production has decreased as spacing between lines increased - mean annual volumetric production increase reached 20.5 ± 3.4 m^3 ha^{-1} $year^{-1}$ for the smallest spacing and 5.2 m^3 ha^{-1} $year^{-1}$ for the largest one.

Table 2. Mean growth values and standard deviation recorded for estimates set for planting parameters based on genetic material, cutting age and spacing.

Species	**T**	**Np**	**Esp. (m)**	**N (ha)**	**M (%)**	**DBH (cm)**	**Height (m)**	**Total volume (m^3 ha^{-1})**
		5	8x2	526±64	19.2±9.9	17.3±1.8	15.0±1.9	105.83±17.9
E. dunnii	58 to 63	5	16x2	247±18	20.6±5.8	19.7±1.3	14.5±0.3	53.13±11.9
		1	24x2	171	17.8	15.2	12.8	25.08
		4	16x2	234±43	24.8±13.7	14.8±1.5	12.3±1.5	26.03±8.8
	56 to 58	5	24x2	149±17	25.4±12.1	14.5±1.2	11.5±1.8	17.01±7.5
E. grandis	70	2	8x2	397±184	36.5±29.5	17.6±0.1	17.1±0.7	87.05±28.1
		4	16x2	180±51	42.3±16.3	19.4±2.6	16.4±3.2	46.13±22.6
		2	24x2	137±59	34.3±28.2	19.05±3.9	15.2±2.5	31.06±18.7

Wherein: T = cutting age (months); Np = Number of evaluated plantings; Esp. = spacing; M = mortality; DBH = diameter at breast hight.

E. grandis clones recorded greater variability in the evaluated parameters due to planting in some improper areas, which led to high plant mortality and reduced growth rates.

Mean annual increase in plant diameter at 58 months reached 3.0 ± 0.27 cm, mean annual increase in plant height reached 2.6 ± 0.33 m. Mean annual increase in volume recorded 5.38 ± 1.82 and 3.51 ± 1.54 m^3 ha^{-1} $year^{-1}$ for the smallest (16 x 2 m) and largest (24 x 2 m) spacings, respectively.

Mean annual increase in plant diameter at 70 months reached 3.0 ± 0.27 cm, whereas MAI in height reached 2.6 ± 0.33 m. Volume per hectare recorded MAI equal to 5.38 ±1.82 and 3.51 ±1.54 m^3 ha^{-1} $year^{-1}$ for the smallest (16 x 2 m) and largest (24 x 2 m) spacings, respectively.

Therefore, volumetric production was overall higher in smaller spacings due to larger number of planted trees, whereas the highest productivity was observed in plantations with *E. dunnii*, which recorded the lowest mortality rate.

NPV recorded positive outcome, except for *E. grandis* (planted at spacing 24 m x 2 m) at 58 months. This outcome has indicated the financial viability of eucalyptus planting, which is capable of returning the initial investment within 5 to 6 years, at the evaluated interest rate, as well as of generating financial surplus in standing timber trading processes.

This outcome corroborates studies about the financial feasibility of eucalyptus plantations in silvopastoral systems in the Pampa biome. Oliveira et al. (2008) observed positive NPV for *E. grandis* in silvopastoral system presenting initial tree density of 500 trees ha^{-1}, at 4 years, based on interest rate of 6% a.y. Weimann et al. (2017) have analyzed the financial viability of silvopastoral systems planted with *E. grandis* in Nova Esperança do Sul County (RS) and has concluded that the implementation of the forest component in rural properties under silvopastoral system was economically viable for producers.

The potential profitability recorded for eucalyptus planting in the current study ranged from R$ 92.10 to R$ 6,062.14 per hectare and from R$ 22.5 to R$ 1,478.50 ha^{-1} $year^{-1}$, in 5 to 6-year-old trees. The highest profitability was observed for the smallest spacing, which recorded mean value of R$ 1,134.5 ha^{-1} $year^{-1}$ and the lowest profitability was observed for the largest spacing, which recorded mean value of R$ 79.75 ha^{-1} $year^{-1}$.

However, it is worth emphasizing that, despite the higher profitability, if one only takes into consideration the forest component, the 8 x 2 m spacing suppressed the native field, which is an undesirable outcome, since the production system should preferably avoid the suppression or replacement of one component by the other. It should also be capable of increasing producers' income without generating major impact on natural or cultivated forage resources and, consequently, of ensuring respect for the historical and cultural vocation of rural producers in the region, namely: livestock (VARELLA; RIBASKI, 2008).

The profitability of the herein investigated silvopastoral system was not evaluated, since the costs with, investments in, and revenues resulting from, livestock were not taken into consideration. The assessment age adopted in the current study did not express the economic rotation for timber, which is the one capable of maximizing the return from investments made in the activities of the system and in providing maximum profit to producers, which often happens at older cutting ages.

Overall, final cutting age of 7 years is often adopted as parameter for eucalyptus forests aimed at providing wood for cellulose production, as well as of 15 to 20 years for wood to be used in sawmills (WREGE et al., 2009). However, cutting age changes depending on forest management goals, growth rate, forest species, market prices for different timber uses and on production costs.

Management systems comprising older rotation age and the production of forest multiproducts are significantly profitable due to diversification in forest use and to value addition to forest products (SOUZA et al., 2007; OLIVEIRA et al., 2008; WEIMANN et al., 2017).

Ribaski (2007), Oliveira et al. (2008) and Weimann et al. (2017) conducted studies about the economic feasibility of silvopastoral systems planted with *E. grandis* in Pampa biome, based on rotation age ranging from 7 to 9 years for cellulose production, as well as on rotation ages of 14, 15 and 21 years for sawn wood production – plants were subjected to 1 or 2 thinning procedures at intermediate ages.

However, the decision about the right time to harvest the wood depends on producer's planning in terms of need of financial resources and market opportunities. It is worth emphasizing that larger and older trees reach bigger dimensions and they can be used to produce more noble products, with higher added value.

CONCLUSIONS

The introduction of the forestry component in traditional pastoral systems practiced in Bagé region can help increasing income in rural properties, both through forest product trade and through the use of such a product in the property.

If one only takes into consideration the economic benefits resulting from timber trading, the investment in afforesting native fields with eucalyptus trees has great potential to generate financial surpluses at significantly younger cutting ages than that of the economic rotation often used for the investigated genus in the region.

Although the spacing of 8 x 2 meters presented the highest profitability, it is not recommended if the goal is to maintain livestock activity in the area, since excessive shading has suppressed native forage plants.

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ECONOMIC PERFORMANCE OF CROP-LIVESTOCK INTEGRATED SYSTEMS WITH DUAL-PURPOSE WINTER CROPS

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ABSTRACT

Adopting dual-purpose wheat cultivars in a crop-livestock integrated systems (CLIS) may be an economic alternative to the improving of the traditional southern brazilian farm system, soybean and winter fallow. The aim of this study was to evaluate economically some CLIS. Six CLIS treatments were tested: I (wheat/soybean and common vetch/maize); II (wheat/soybean and black oat pasture/maize); III (wheat/soybean and black oat pasture/soybean); IV (wheat/soybean and pea/maize); V (wheat/soybean, triticale pasture/soybean and common vetch/soybean); and VI (wheat/soybean, oat/soybean and dual-purpose wheat/soybean). The trial was a randomized complete block design with four replicates. Calculation of operational costs and net returns of the six CLIS were compared using the technical coefficient matrix. Prices inputs and machinery costs were based on 2016 market prices at Passo Fundo, Rio Grande do Sul state, Brazil. CLIS II and III, whith cool season winter pastures, were more profitable than CLIS I and IV, with annual cool season legumes as cover crops. CLIS VI, with oat and double-purpose wheat had a higher economic return when compared to the CLIS V, with triticale. Overall, we indicate CLIS II that stood out due to better net return.

Key words: cool season forages; costs; crop rotation

INTRODUCTION

It is worth emphasizing that crop-livestock integration, composed by systems for producing grains and pastures, is an efficient alternative in terms of soil and pasture recovery, in addition to provide a greater production diversity, generating opportunities to increase the economic return over time (BALBINO et al., 2011). Furthermore, the use of this technology is associated with an expected improvement in chemical, physical and biological properties of the soil, as well as the possibility of reducing the occurrence of pests, diseases and weeds (KUNDE et al., 2018; BONETTI et al., 2019).

However, in the economic return context, it is necessary to conduct studies focused on the long term, which consider the combination and succession of crops in a production system with crop-livestock integration. Within this scope, consolidated information can be obtained in long-term experiments, as these are essential when considering parameters characterized by slow temporal dynamics. It is notable that short-term experiments only focus on the initial trajectory, while long-term experiments describe the mechanisms involved in the temporal dynamics and in the variation of trajectories over time (KNAPP et al., 2012).

Studies in this line should also consider that, although some crops have high grain yields, the higher economic return may be associated to those with lower grain yields if they are better remunerated (SANTOS et at., 2003). Using soil cover cropping contributes in reducing the use of inputs and/or to improve the yield of the systems in which they are inserted to, acting as a necessary part for adequately complementing the production systems.

In the study region, there is a growing interest in using annual winter grasses and legumes, either alone or in mixtures. In this context, the use of oat, rye, ryegrass, vetch, wheat, triticale and clover has been standing out, both for soil cover cropping and grazing, with them also pointed out as possible alternatives when aiming to promote economic return for the rural producers (FONTANELI et al., 2016). This alternative is of fundamental importance because it provides an opportunity to produce food for cattle at a period of the year with a recognized forage shortage.

The integration of crops with annual winter pastures (black oat or black oat + vetch) or with dual-purpose cereals (white oat, rye, barley, wheat and triticale) has been successful because this agricultural practice also has been conducted in crop rotation under no-tillage system (FONTANELI et al., 2015). However, it is essential to establish the profitability of integrating crops with dairy or beef cattle breeding, in these same regions, as this activity requires grazing practically over all year. Moreover, the identification of the CLI system with the best economic performance, low risk and feasible adoption by the farmers, becomes a necessity.

Therefore, the use of CLI technology, understood as a productive process involving the activities of agriculture and livestock in consortium, crop succession or rotation, can generate additional profit by increasing the production and the income flow stability of the rural property, in addition to maximizing and distributing the use of labor during the year (DE MORI et al., 2015; REIS et al., 2017). This technology can contribute to a greater herd productivity and provision of products of high protein value in the off-season, with reduced production costs and losses. Furthermore, this same system can collaborate in maintaining and improving the physical, chemical and biological characteristics of the soil, with positive effects on the yield of subsequent crops.

The aim of this study was to evaluate economically some crop-livestock integration system in comparition with grain system.

MATERIAL AND METHODS

The test was conducted at Embrapa Trigo, in the Coxilha county, RS (28º07’S, 52°17’W and 721 m of altitude), in a soil classified as an Oxisol, a typical Dystrophic Red Latosol. The results presented in this study comprise the crops harvesteds from 2005/2006 to 2015/2016.

The CLIS treatments were : I [wheat (*Triticum aestivum* L.)/soybean (*Glycine max* (L.) Merrill) and common vetch (*Vicia sativa* L.)/maize (*Zea mays* L.)]; II [wheat/soybean and black oat pasture (*Avena strigosa* Schreb.)/maize]; III (wheat/soybean and black oat pasture/soybean); IV [wheat/soybean and pea (*Pisum sativum* L. subspecies *arvense*)/maize]; V [(wheat/soybean, dual-purpose triticale (*X Tricosecale* Wittmack)/soybean and common vetch/soybean)]; and VI [wheat/soybean, dual-purpose oat (*Avena sativa* L.)/soybean and dual-purpose wheat/soybean]. Summer and winter crops alike were all established under the no-tillage system.

Sowing time, weed control and other treatments were all performed according to the indication for each crop, while the grain harvesting was with a thrasher adapted for plots. Maize was oversown on pea and common vetch on vegetative cycle, burned-down soon after with herbicide. The plots were 20 m by 10 m (length × width). Grain yield (oat, maize, soybean, wheat and triticale) was determined by harvesting 1/3 of the central area from each plot and adjusting to 13% moisture. In pea and common vetch, the dry matter (DM) yield was evaluated by cutting, and N concentration of the dry matter was converted into urea.

The steer live weight gain (LWG) was calculated base on forage DM ingested. Each 10 kg DM ingested was computed 1 kg of LWG to oat, wheat and triticale dual-purpose crops as well as to black oat pasture.

The trial was a randomized complete block designs, with four replicates. The net return evaluated the economic performance of the production systems in the six grain-production systems with cool season forages (black oat), dual-purpose crops (oat, wheat and triticale), cover crops (pea and common vetch) and crops (maize, soybean and wheat). The understood concept of net return is the difference between gross income (yield from grain, dry matter of pea or common vetch, converted into urea and LWG multiplied by its selling price as a commercial product) and the total cost. The total cost is the sum of the variable costs (inputs + field operations costs) and the fixed cost (example: depreciation of facilities, machinery and equipment, and interest on the capital). The gross income was accounted through the average sales prices of the products with the mean from 2016, with the costs calculated from information obtained in November 2016, according to the data estimated for the production cost, the annual crop cycle, winter or summer, and each studied species. Economic performance of production systems with crop-livestock integration in no-tillage systems.

The statistical analysis was of the net return within each year (winter + summer) and average of the years, in the periods from 2005/2006 to 2015/2016. In the total analyzes, treatments with a fixed effect and the year effect were considered to be random. The parameters under study were subjected to the analysis of variance, by employing the SAS statistical program, version 9.4. The means were evaluated by the Duncan´s test and sphericity tests, at 5% probability.

RESULTS AND DISCUSSIONS

The joint analysis of the data for net return per hectare, regarding the agricultural harvests from 2005/2006 to 2015/2016, demonstrated that there is significance for the year effect and for the production system. Climatic conditions, which vary from one year to another, interfere in the yields of grain and dry matter from the studied species. There was no significance between the joint analyzes of the results from the annual net return per hectare for the interaction year x production systems.

For evaluations repeated over time, there was no significance for year or the interaction of year x production systems, by the sphericity test.

Winter and summer grain crops had their mean grain yield with a wide variation range. Wheat from 2005 to 2015, ranged from 2,027 to 2,570 kg ha^{-1}. Regarding maize, in the agricultural harvests from 2005-2006 to 2015-2015, the mean grain yield varied from 7,731 to 8,173 kg ha^{-1}, while in soybean it varied from 2,498 to 2,789 kg ha^{-1}. The species intended for dual-purpose (white oat, wheat and triticale) had a relatively low mean dry matter and grain yields, of 715, 1,314 and 1,728 kg ha^{-1}, respectively.

Some winter grain (wheat) or dual-purpose (wheat and triticale) crops had higher total production costs than the summer grain crops (maize and soybean). On the other hand, cover crops and fertilization (pea and vetch), as well as pasture (black oat), had the lowest production costs. Based on these data, net return per hectare per year was determined for the species as well as the studied production systems.

In the annual analysis, there were significant differences in net return for the studied crops. Of the eleven studied agricultural crops, maize had a higher net return than the other crops, both from winter and summer, in seven agricultural harvests (2005-2006, 2007-2008, 2008- 2009, 2009-2010, 2010-2011, 2011-2012 and 2012-2013). However, in the 2013-2014 agricultural harvest, soybean had higher net return than the other crops studied, while in three agricultural harvests (2006-2007, 2014-2015 and 2015- 2016) there was no difference between the crops. In most agricultural harvests, the net return from soybean, wheat and dual-purpose wheat were in an intermediate position while the dual-purpose triticale had the lowest net return among the evaluated grain crops.

In the joint mean of the agricultural harvests from 2005-2006 to 2015-2016, there was a significant difference in the net return associated with studied crops. Considering the net return of the crops individually, maize stood out while soybean and dual-purpose wheat had intermediate values. The lowest revenues were from wheat, black oat, dual-purpose white oat, vetch, pea and dual-purpose triticale. This is an outlook from the perspective of each crop and must be cautiously evaluated, since it composes the target production systems of the following discussions.

Net return differed between the CLI systems adopted in four harvests evaluated. In this case, system II stands out in the years of 2009/2010 (U$ 529.15) and 2010/2011 (U$ 497.64), with revenue higher than the other systems, which difference can be attributed to the rotation composition (maize, soybean, black oat and wheat). In this case, maize may have been fundamental in explaining this difference, since it had the highest grain yield in relation to production systems with legumes for ground cover and green manure. Moreover, maize grown after pea and vetch did not receive nitrogen top-dressing fertilization, which may have limited the grain yield of these systems, since they provided, on average, from 49 (pea) to 92 (vetch) kg of N per hectare, a lesser quantity than that required by maize.

When taking the means of the years into account, the highest net return was in system II, attaining U$ 279.34 per hectare. This revenue is notably 561% higher than that of system V, consisting of wheat, soybean, triticale and vetch. This result may be associated with the presence of maize in the rotation composition, where its high yield contributed to increasing net return. In this case, it is observed that, despite the lower sale value of maize (U$ 5.85 x 8,173 kg ha^{-1} and U$ 1,183.81) in comparison with the soybean (U$ 20.93 x 2,719 kg ha^{-1} and U$ 948.32) its higher grain mean yield per hectare compensated that said value.

In the comparison between systems I and II, considering the mean of the years, system II with black oat pasture preceding maize had a greater net return in relation to the system I, where vetch preceded maize. In this same line, when comparing systems III and IV, it was found that system III, which had black oat pasture preceding soybean, attained a higher net return than system IV, with pea preceding maize. This was probably due to the greater animal weight gain in relation to the value of systems nitrogen incorporated into the soil by the legume species. System VI was favored by the rotation composition, based on grains, even after grazing (double-purpose wheat and white oat) and thus attained a higher net return than the V system, which had a component not used for grazing: vetch, whose revenue is associated with the N added to the soil.

In this study, the production systems were carried out with annual winter pastures (black oat) and dual-purpose species (white oat, wheat and triticale), subjected to cuttings or grazing, with subsequent grain harvesting. Cover cropping was also used as a way of adding N to the soil (pea and vetch). In systems I (wheat/soybean and vetch/maize), II (wheat/soybean and black oat/maize pasture) and IV (wheat/soybean and pea/ maize) the purpose was to cover the soil and incorporate N to it during winter, and then sow the maize at its optimal sowing time. In systems III (wheat/soybean and black oat/soybean pasture), V (wheat/soybean, vetch/soybean and dual-purpose triticale/soybean) and VI (wheat/soybean, dual-purpose white oat/soybean and dual-purpose wheat/soybean), the purpose was to cover the soil during winter, incorporate nitrogen in the case of vetch, and also to establish soybean, in its optimal growing period. However, system II was the highlight of this study because, after the black oat cultivation, maize received nitrogen top-dressing fertilization, increasing its yield and translating into a higher net return of this system. In the leguminous/maize systems, no nitrogen fertilizer was applied in succession, resulting in lesser maize yield and net return.

The importance of this research was associated with the study of production systems centered on grain and forage production in the crop-livestock integration model. Several crops for cover, grazing and grains were tested in combinations, and demonstrated using potential for the producer, within the scope of annual net return. Maize, which had its area gradually reduced in the State of Rio Grande do Sul, played an important role in the production system performance, and it was pointed out as fundamentais in increasing the net return of the production system.

CONCLUSIONS

The crop-livestock integration system based on maize, succeeding black oat pasture, that stood out due to better net return.

The system with oat and dual-purpose wheat preceding soybean had an intermediate and superior profitability respectively when compared to the system with dual-purpose triticale and common vetch preceding soybean.

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SILAGE QUALITY OF CULTURAL REMAINS OF PEARL PINEAPPLE IN DIFFERENT PARTICLE SIZES AND FERMENTATION TIMES

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ABSTRACT

The Triângulo Mineiro accounts for the largest pineapple production in the State of Minas Gerais, the rest of the culture is used as an alternative in animal nutrition. This work aimed to evaluate the quality of the pineapple silage produced from pearl pineapple cultural remains. A completely randomized design in a 4 x 2 factorial scheme was used, with four fermentation times (30, 60, 90 and 120 days after silage) and two particle sizes (20 and 50 mm), with the content of dry matter (DM) being determined, mineral matter (MM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemi cellulose (HEM), total digestible nutrients (TDN), total carbohydrates (TC), non-fibrous carbohydrates (NFC) and pH values. There was a 42% increase in the EE content in the silage stored for 60 days with particle sizes of 50 mm. There was a 7% increase in pH values at 90 days of fermentation in relation to the two particle sizes. In the silage composition of the pineapple cultural rest, the particle size and fermentation time influenced the crude protein, ether extract and pH.

Key words: animal nutrition; *Ananas comosus L. Merril*; alternative food

INTRODUCTION

Minas Gerais stands out as the third largest pineapple producer in the country, accounting for about 95% of production, located in the Triângulo Mineiro region. In 2019, production reached 179.3 thousand tons in 6000 ha of planted area (SEAPA, 2020).

The cultural remains of the pineapple plant are a source of forage of limited use in the places where it is grown, however, it has the potential to increase animal production (MARIN et al., 2002). Feeding is the cost that most burdens livestock production. Thus, the use of alternative foods is increasingly used in the current scenario. The increase in productivity requires greater use of food inputs to cover the critical periods of the annual forage production cycle and better expression of the genetic potential of cattle. The use of silage of pearl pineapple crop remains, therefore, a viable alternative aiming at the reduction of the feeding costs as well as a way to minimize the environmental contamination, since the amount of vegetal residues produced is great (SANTOS et al., 2010).

In this context, pineapple crop remains could serve as food in the form of silage, including contributing to lower the cost of feed for dairy cows. The silage process follows the same procedure for the corn plant, and trench or surface silos can be used. Silage has been used empirically, and studies are needed in order to enable its rational use as roughage, so that its use by the animal is more efficient, which basically depends on the knowledge of the chemical composition and the digestibility of its nutrients. The present study aimed to evaluate the quality of pineapple silage produced from pearl pineapple cultural remains.

MATERIAL AND METHODS

The pearl pineapple cultural remains were chopped in a mobile forage chopper with precision hydraulic drive for cutting height (JF92 Z10), equipped with 10 knives for cutting according to the regulation. The material was ensiled in artificial silos consisting of double plastic bags 50 cm x 80 cm in size and weight around 30 kg, with 32 artificial silos being prepared, 16 with particle sizes of 20 mm and 16 with particle sizes of 50 mm; with opening times scheduled for every 30 days.

The artificial silos were kept indoors, free from moisture, covered with dark canvas, labeled with data such as fermentation days, particle sizes and opening dates; being placed in order of withdrawal for the collection of samples thus avoiding the incidence of light in the other silos. Every 30 days, 4 silos with particle sizes of 20 mm and another 4 with 50 mm particles were opened until 120 days were completed. Samples of about 500g were taken from the central part of the silo, properly packed in a plastic bag, identified and frozen for further bromatological analysis. At each collection period, approximately 50 g of fresh sample was taken from each treatment, which was sent to the laboratory of the State University of Minas Gerais, Frutal Campus, for the determination of pH, according to the methodology described by Silva and Queiroz (2009).

At the end of the 120-day period, the silage samples of pearl pineapple crop remains were thawed, using 300 g for bromatological analysis. The samples were pre-dried in an oven with forced air ventilation at 55 ° C for 72 hours and ground in a Willey mill in sieves with 1 mm mesh, stored and identified in plastic pots. Then, they were sent to the Animal Nutrition Laboratory for bromatological analysis, with the determination of dry matter, mineral matter, crude protein, ether extract according to AOAC (1990), neutral detergent fiber, acid detergent fiber according to Van Soest et al. (1991) and hemi cellulose due to the difference between the levels of neutral detergent fiber and acid detergent fiber.

The values of total carbohydrates were determined according to the methodology described by Sniffen et al. (1992), in which: CHOT = 100 - (PB + EE + ASHES) and non-fibrous carbohydrates (CNF) were calculated according to Mertens (1997), where CNF = 100 - (FDN + PB + EE + ASHES). The total digestible nutrients were obtained using the formula NDT = 87.84 - (0.7 x FDA), where FDA is acid detergent fiber (RODRIGUES, 2010).

For the bromatological analyzes, a completely randomized design was used, in a 4 x 2 factorial scheme, with 4 fermentation times (30, 60, 90 and 120 days of fermentation) and 2 particle sizes (20 and 50 mm) with 4 repetitions.

RESULTS AND DISCUSSIONS

Table 1 shows the chemical composition of the silage of pearl pineapple cultural remains with 4 fermentation times and 2 particle sizes.

Pinto et al. (2005), found similar results in the chemical composition of what they called pineapple hay, which is composed of plants crushed with a forage machine and exposed to the sun for 3 days. The average of 5.95% of crude protein, did not differ much from the results found in the 4 fermentation times, 2.54% of ether extract, a result 30% higher than that found at 30 days of fermentation time in the present experiment.

Acidity is an important factor in silage conservation, as it acts by inhibiting or controlling the development of harmful microorganisms, such as bacteria of the genus Clostridium. The pH value indicates whether the fermentation was satisfactory, its determination being used in the evaluation of silage quality (PEREIRA et al., 2007).

Table 1. Average values in Dry Matter (DM), in percentage, of Organic Matter (OM), Etheric Extract (EE), Crude Protein (CP), Neutral Detergent fiber (NDF), Acid Detergent Fiber (ADF), Hemi cellulose (HEMI), Mineral Matter (MM), Total Digestive Nutrients (TDN), Total Carbohydrates (TC), Non-Fiber Carbohydrates (NFC) and pH, of silage of pineapple cultural remains. Frutal-MG. 2012/2013

	Treatments						**Treatments**					
	Fermentation times, days (T)				F test	MSD	Particle size, mm (TP)		F test	MSD	F for interaction	
	30	60	90	120			20	50			TxTP	CV
DM	18.91^{a}	18.16^{a}	18.40^{a}	19.28^{a}	1.89^{NS}	1.43	18.8^{a}	18.58^{a}	0.36^{NS}	0.76	2.69^{NS}	5.57
OM	94.69^{a}	94.93^{a}	94.93^{a}	95.12^{a}	0.34^{NS}	1.37	94.60^{a}	95.20^{a}	2.97^{NS}	0.72	0.32^{NS}	1.04
EE	1.94^{a}	2.33^{a}	2.25^{a}	2.06^{a}	1.96^{NS}	0.50	2.10^{a}	2.19^{a}	0.30^{NS}	0.26	4.16*	17.04
CP	5.27^{a}	5.43^{a}	5.51^{a}	5.40^{a}	0.73^{NS}	0.46	5.53^{a}	5.28^{b}	4.30*	0.24	0.82^{NS}	6.23
NDF	52.46^{a}	53.49^{a}	49.91^{a}	54.39^{a}	2.20^{NS}	5.09	52.96^{a}	52.95^{a}	0.37^{NS}	2.69	1.45^{NS}	7.02
ADF	20.02^{a}	31.48^{a}	30.40^{a}	31.77^{a}	2.90^{NS}	2.85	30.81^{a}	30.52^{a}	0.16^{NS}	1.51	1.03^{NS}	6.75
HEM	23.44^{a}	22.01^{a}	19.50^{a}	22.62^{a}	1.29^{NS}	5.83	22.14^{a}	21.65^{a}	0.11^{NS}	3.08	0.59^{NS}	19.29
MM	5.37^{a}	5.06^{a}	5.07^{a}	4.88^{a}	0.34^{NS}	1.37	5.40^{a}	4.79^{a}	2.97^{NS}	0.72	0.32^{NS}	19.48
pH	3.81^{b}	3.87^{b}	4.17^{a}	3.87^{b}	17.66**	0.14	3.94^{a}	3.92^{a}	0.31^{NS}	0.08	3.39*	2.75
TDN^{+}	67.53^{a}	65.80^{a}	66.55^{a}	65.60^{a}	2.89^{NS}	1.99	66.27^{a}	66.47^{a}	0.16^{NS}	1.06	1.03^{NS}	2.18
TC^{++}	87.42^{a}	87.17^{a}	87.16^{a}	87.65^{a}	0.34^{NS}	1.57	86.96^{a}	87.74^{a}	3.70^{NS}	0.83	0.72^{NS}	1.30
NFC^{+++}	34.95^{a}	33.68^{a}	37.25^{a}	33.26^{a}	2.06^{NS}	4.87	34.00^{a}	35.56^{a}	1.55^{NS}	2.58	1.84^{NS}	10.16

Averages followed by the same letter on the line, do not differ, by Tukey's test (P> 0.05). NS: not significant; * and ** significant at 5 and 1% probability by the Tukey test, respectively. CV (%) = Coefficient of variation MSD (%) = Minimal significant difference $^{+}$Averages calculated according to RODRIGUES (2010), where TDN = 87.84 - (0.7 x ADF), in% in the DM; $^{++}$Means calculated according to McDOWELL et al. (1974), where TC = 100 - (CP + EE + MM), in% in the DM; $^{+++}$Means calculated according to Mertens (1997), where CNF = 100 - (CP + EE + MM), in% in the DM.

Note that there was no interaction (P> 0.05) between the levels of dry matter, organic matter, crude protein, neutral detergent fiber, acid detergent fiber, hemicellulose, mineral matter, total digestible nutrients, total carbohydrates and carbohydrates non-fibrous, except for ether extract (P <0.05) and pH (P <0.05), in relation to fermentation time and particle size.

The unfolding of the interaction between fermentation time and particle sizes for the ether extract contents (Table 2) showed that the average ether extract contents were higher when the silage remained in fermentation longer, the biggest difference being 1.91 and 2.44% of ether extract (P <0.01). This difference corresponds to an increase of 27.74% in the time of 90 in relation to 60 days of fermentation with a particle size of 20 mm. From the point of view of the ether extract content, it is interesting that the fermentation period is 90 days, this is when the pineapple cultural remains are ensiled with particle sizes of 20 mm. If the chipping is done allowing particle sizes of 50 mm, it becomes interesting to keep the silo closed until the fermentation period of 60, since the increase in the ether extract content from 30 to 60 days of fermentation was 42%. Considering the values of ether extract at 30 days of fermentation, regardless of particle size, if there is a need to open the silo, the silage will have lower levels of ether extract.

Table 2. Unfolding of the interaction between fermentation times and particle size for the ether extract and pH of the silage of pearl pineapple cultural remains.

Particle Size (mm)	**Fermentation time (days)**				**F test**	**MSD (5%)**
	30	**60**	**90**	**120**		
			Ethereal Extract			
20	1.95aA	1.91aB	2.44aA	2.12aA	1.74^{NS}	0.71
50	1.93bA	2.75aA	2.06bA	2.01bA	4.32*	
F test	0.01^{NS}	10.52**	2.15^{NS}	0.19^{NS}		
MSD (5%)		0.53				
			pH			
20	3.73bB	3.88bA	4.19aA	3.96bA	12.35**	0.21
50	3.89bA	3.85bA	4.15aA	3.78bB	8.70**	
F test	4.64*	0.18^{NS}	0.27^{NS}	5.37*		
MSD (5%)		0.15				

Averages followed by the same letter in the column (uppercase) and in the line (lowercase), do not differ from each other, by the Tukey test (P> 0.05). NS = not significant; * (P <0.05); ** (P <0.01); MSD = minimum significant difference; TP = Particle sizes.

By unfolding the interaction between fermentation times and particle size to pH, it was found that there was no difference (P> 0.05) at 90 days of fermentation in relation to the particle sizes of 20 and 50 mm. The pH showed values of 8.04% and 6.68% higher in relation to the values of 30 and 60 days of fermentation, returning to the same level with 120 days of fermentation (Table 2).

Possenti et al. (2005) studying the bromatological and fermentative parameters of corn and sunflower silages, observed that a stable pH is not obtained in the silages, which is due to the deficiency of soluble carbohydrates or due to the excessive moisture of the material, which can be seen in the silage of pineapple crop remains. The appropriate pH value to promote an efficient conservation of ensiled forage depends on the moisture content of the silage (CUNHA et al., 2009).

Tomich et al. (2004), reported that pH values between 3.8 and 4.2 are considered adequate for well-preserved silages, since in this range there is a restriction of proteolytic enzymes in the plant and enterobacteria and clostridia.

In the present experiment, the pH of the silage of pineapple crop remnants varied, at different fermentation times, between 3.73 and 4.19. The lowest average obtained at 30 days of fermentation, with a particle size of 20 mm, approaches the ideal range of 3.8 reported by Tomich et al. (2004) and Cunha et al. (2009), so it is recommended to open the silo the period of 60 days for the particle size between 20 and 50 mm, however higher values were found at 90 days of fermentation. Similar values were also found by Cunha et al. (2009) when comparing silages of different proportions of industrial waste from pineapple and maniçoba fruit, and Pereira et al. (2007) in evaluation of corn silages.

CONCLUSIONS

In the silage composition of the pineapple cultural rest, the particle size influences the crude protein; ether extract and pH were influenced by particle size and fermentation time. The crude protein and pH in particle size between 20 to 50 mm at 90 days of fermentation and for the ether extract the greatest value was in the size of 50 mm at 60 days of fermentation of silage of pearl pineapple cultural remains.

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CHEMICAL CONSTITUTION OF SOYBEAN GRAINS PRODUCED IN INTEGRATED SYSTEMS

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ABSTRACT

The integrated crop-livestock forestry system (ICLF) seeks to produce grains, milk, meat, and timber products in the same agricultural area in a conscious, intensive, and sustainable way. Although analyses point out its advantages and disadvantages for agricultural and wood production, animal welfare, and soil characteristics in integration systems, more research about their peculiarities regarding the grains' chemical composition is still needed. Thus, our goal was to evaluate the effect of the integrated crop-livestock forestry system in the chemical constitution of soybeans. For this, we evaluated two treatments: integrated crop-livestock forestry system with single jack (ICLF-S) and integrated crop-livestock forestry system with triple jack (ICLF-T); an exclusive crop was used as a control, in a randomized block design, with four replications. The soybean chemical quality was determined in terms of their chemical composition: ether extract, crude protein, ash, crude fiber, moisture, and carbohydrates. As a result, there was a variation in the chemical composition of grains produced in ICLF regarding those produced in the exclusive crops. In integrated systems, the grains had a higher protein content and a lower ash content.

Key words: Crop-livestock forestry system; *Glycine max*; quality

INTRODUCTION

The agricultural system has been looking for new production alternatives that meet the demands for food, fiber, energy, and other products with a minimal negative effect on the environmental resources. In this context, the integrated crop-livestock forestry system (ICLF) can be an appropriate alternative due to greater efficiency in the use of land and water resources, which enhanced the agricultural area productivity and reduces the consumption by inputs (NAIR, 2011; BALBINOT JUNIOR et al., 2011).

The ICLF is based on the concepts of crop rotation and the consortium between grain, forage, and tree species, to produce grains, milk, meat, and wood products in the same area throughout the year. Thus, integrated systems use the soil intensively, through the spatial and temporal integration of the components in the production system, to leverage the maximum quality and competitiveness of the product produced in a safe environment (BALBINO et al., 2011).

Commercial interest in soy is linked to its high protein (40%) and oil (20%) content, and its productivity. Besides, the grain has 34% carbohydrates and 5% minerals, making it an important raw material for the production of animal feed, bran, oil, and biodiesel (FARIA et al., 2018; HIRAOKA, 2008). While eucalyptus is related to wood sales, energy production, and sawmill (BALBINO et al., 2012).

Despite the interest in integrated systems, there is still little scientific information about the development of crops and, consequently, the chemical composition of grains in these systems. ICLF has exclusive environmental conditions, such as the reduction in the incidence of direct light in the area, the decrease in the temperature and wind speed, the increase in the relative humidity of the air, and the reduction in the evapotranspiration of agricultural cultivation (GOMES et al., 2015). Therefore, even if the proximate composition of soy is genetically defined (DELARMELINO-

FERRARESI et al., 2014), the climatic factors of the environment, such as temperature and precipitation (BARBOSA et al., 2011) and the shading in the cultivation area (BELLALOUI; GILLEN, 2010) can directly influence the content of its components and, subsequently, its commercial value.

Due to the complexity of the system after the introduction of the forestry component, studies are needed to assess the influence of trees on crops and the proximate composition of the grains produced. Thus, our goal was to evaluate the effect of the integrated crop-livestock forestry system on the chemical quality of soybeans.

MATERIAL AND METHODS

To evaluate the changes in the chemical constitution of soybeans grown in an integrated system, we obtained samples of grains from an area with an integrated crop-livestock forestry system (ICLF) with simple and triple rows of eucalyptus (treatments) and other samples from exclusive crops (control) in the experimental field of Embrapa Agrossilvipastoril, in Sinop, Mato Grosso, in the 2018/2019 harvest.

To establish the eucalyptus trees (Eucalyptus urograndis - clone H13) in the integrated crop-livestock forestry system with simple rows (ICLF-S), we planted them in bands, with 37 m spacing between rows × 3, 0 m between trees. In the integrated crop-livestock forestry system with triple rows (ICLF-T), eucalyptus (Eucalyptus urograndis - clone H13) we planted them in bands at a 30 m spacing between rows × 3.5 m between rows and 3, 0 m between trees. For both systems, we planted the eucalyptus lines following the east-west orientation, in 2011. The area between rows was used for soybean cultivation (cultivar BRS7380RR).

We arranged the treatments (ICLF-S and ICLF-T) and the control (exclusive crop) in a randomized block design with four replications, each block of 5 ha, and distributed them within each block as it follows: 2 ha of ICLF-S + 2 ha of ICLF-T + 1 ha exclusive crop). To analyze the physical quality of the grains, we applied samples from eight positions in the plot (in the form of a transect), that is, four distances from the eucalyptus row (3, 6, 10, and 15 m) and two production faces (north and south). The sampling points were composed of two lines of 5 m. The grains produced in the exclusive crop (control were also harvested in two rows of 5 m, but in five random positions in the cultivation area.

The grains were harvested between February 10th and 15th, 2019 and, after being traced, they were manually cleaned to remove all types of impurities and unexpected material and, when necessary, we submitted the samples to dry in the greenhouse until they reach the commercial water content (14%). To determine the proximate composition (ether extract, crude protein, ash, crude fiber, moisture, and carbohydrates) of the soybeans, a subsample composed of at least 200 g of each sample was grounded in a cryogenic mill and the determinations carried out in triplicate, according to Instituto Adolfo Lutz (1985).

The data were submitted to analysis of variance and the means between the ICLF systems and the exclusive crop compared by the Tukey test ($p < 0.05$). The comparison between the positions in the transects and the production faces was also performed with the Tukey test ($p < 0.05$) considering the mean square of the Anova residue, according to the experimental design.

RESULTS AND DISCUSSIONS

The experiments showed that there was no difference between the integrated systems (ICLF-S and ICLF-T) and the exclusive crop in terms of ether extract, crude fiber, moisture, and carbohydrates, with an overall average of 25.75%, 5.14%, 17.25%, and 22.08%, respectively. Therefore, the production conditions of the integrated systems (lower incidence of light, temperature, competition for nutrients, and evapotranspiration) did not influence these soybean chemical characteristics when compared to the exclusive crop (Table 1).

We observed differences for the crude protein and ash content between the ICLF systems with single and triple rows, and the exclusive crop. The grains grown in the ICLF systems showed higher averages for crude protein content (34.63%) when compared to exclusive crops (33.85%). For the ash content, the average in the exclusive crop (5.87%) was higher than in the ICLF systems (5.62%).

Table 1. Average proximate composition of soybeans in different production systems.

Production Systems	**EE (%)**	**CP (%)**	**A (%)**	**CF (%)**	**UM (%)**	**CA (%)**
EC	25.72[1] A	33.85 A	5.87 A	5.67 A	6.91 A	21.98 A
ICLF-S	25.65 A	35.00 B	5.65 B	5.13 A	6.89 A	21.64 A
ICLF -T	25.88 A	34.27 B	5.59 B	4.62 A	6.99 A	22.63 A
Average ICLF	23.76	34.63	5.62	4.88	6.94	22.13
General average	25.75	34.37	5.7	5.14	6.93	22.08
c.v. (%)	0.63	1.03	0.57	7.43	0.73	5.13

Where: EE = ether extract; CP = crude protein; A = ash; CF = crude fiber; UM = humidity; CA = carbohydrates; EC = exclusive crop; ICLF-S = integrated crop livestock forestry system with simple lines; ICLF-T = integrated crop livestock forestry system with triple row. [1]Means followed by equal capital letters in the columns do not differ statistically from each other, by the Tukey test, at 5% probability.

Integrated systems were not a limiting factor for protein synthesis in soybeans, with the average protein content in the ICLF of 34.63%. This result was similar to that reported by Werner et al. (2017) who evaluated the quality of soybean grown in consortium with eucalyptus and concluded that the position concerning the row and the production face (east-west) did not influence the protein content in the grains, obtaining averages of 36.5% and 41.6% for the first and second year of production.

The ICLF systems did not show variation for crude fiber, moisture, and carbohydrate content in soybeans, with averages of 4.88%, 6.94%, and 22.13%, respectively. According to Faria et al. (2018), soybeans with 5% moisture content, present, on average, 4% fiber and 25% carbohydrate, corroborating the data found in this study.

There was no difference concerning the distances in the eucalyptus rows (3, 6, 10, and 15 m) and the production faces (north and south) in the ICLF systems for the content of crude protein, crude fiber, moisture, and carbohydrates. However, the same did not happen for the content of ether extract and ashes (Tables 2).

The integrated systems provided variation in the ether extract content averages. On the ICLF-S south face, the 10 m distance showed the highest average, differing from the others, while the grains grown near the eucalyptus rows obtained the lowest averages. On the north face, no difference was observed concerning the distance from the row.

On the ICLF-T south face, the highest ether extract averages were recorded at distances of 15 and 3 m, with no difference between them. On the north face, the distances of 6, 10, and 15 m showed no difference between them, with an average of 26.27%. The lowest average was recorded at the distance of 3 m, but this did not differ from the distance of 15 m.

Table 2. Ether extract and ash content averages (%) in soybeans produced in the integrated systems concerning the production faces and the distances of the eucalyptus rows.

Distances (m)	**Ether Extract (%)**				**Ashes (%)**			
	ICLF-S		**ICLF -T**		**ICLF-S**		**ICLF-T**	
	SF	**NF**	**SF**	**NF**	**SF**	**NF**	**SF**	**NF**
3	24.84[1] C	25.71 A	25.87 AB	25.68 B	6.36 A	5.28 C	5.70 A	5.65 B
6	25.18 C	25.81 A	25.07 C	26.28 A	5.47 C	5.29 C	5.51 B	5.47 C
10	26.12 A	25.91 A	25.46 BC	26.40 A	5.88 B	5.46 B	5.59 B	5.21 D
15	25.65 B	25.99 A	26.14 A	26.11 AB	5.51 C	5.96 A	5.36 C	6.21 A
Averages	25.45	25.86	25.64	26.12	5.80	5.50	5.54	5.64

Where: ICLF-S = integrated crop-livestock forestry system with simple lines; ICLF-T = integrated crop-livestock forestry system with triple row; SF = south face; NF = north face. [1]Means followed by equal capital letters in the columns do not differ statistically from each other, by the Tukey test, at 5% probability.

Integrated systems, also promoted differences in ash contents. On the ICLF-S south face, the highest average was at the 3 m position, differing from the other averages. On the north side, it was the opposite, the 15 m distance presented the highest average, therefore, differs from the others. The ICLF-T south face was similar when compared to the south face of the ICLF-S, the greater the distance from the furrows the lower the ash content. Thus, the 3 m position had the highest ash content, differing from the other distances. On the north face, there was a greater variation in the average values, with the distances of 15 and 3 m obtaining the highest averages for the ash content, differing from each other and the other distances.

We noted that for both systems there was no definite trend for the ash content variation concerning the distances of the eucalyptus rows. However, we observed an ash content reduction due to the distance between the trees, towards the south face, and the north face, and that there was an increase in the ash content as the distance from the trees increased.

CONCLUSIONS

There is variation in the chemical composition of grains produced in ICLF concerning those produced in exclusive crops.

In integrated systems, the grains have higher protein content and less ash content.

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PASTURELAND RECLAMATION IN BRAZIL: IMPLICATIONS FOR CARBON SEQUESTRATION AND SOIL QUALITY

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ABSTRACT

Brazil is the world's largest beef producer and will represent 23% of the world's total beef exports by 2028. Brazilian pastures occupy land area 6.4 times the size of São Paulo state. Most of the Brazilian pastures has low productivity and pasture reclamation is a crucial way of potentially reducing deforestation and improving carbon sequestration. Thus, the country has unique opportunity for greenhouse gas (GHG) emissions mitigation and improving multiples soil functions associated to higher soil organic carbon (SOC). Livestock is an important livelihood activity practiced extensively within Brazil and Integrated systems [i.e., the crop-livestock integration (ICL) and integrated crop livestock–forestry (ICLF)] is the main pastureland reclamation in Brazil and they were widely motived by national and regional Government across the last decade. Agroecosystems intensification through integrated systems adoption decreases new opening over natural ecosystems for livelihood and/or agriculture. Integrated system adoption improves soil quality indicators (i.e., chemical, physical and biological) SOC and optimizes agricultural inputs managed within the agroecosystems. Despite the well-known benefits for soil quality indicators, there is scarcity of studies in which integrated approaches about soil quality were performed. Such holistic approaches about soil quality are required to better comprehension multiple-soil functions as well as the soil ecosystem service delivered by the soil.

Key words: crop-livestock integration; integrated crop livestock–forestry; soil quality indicators

INTRODUCTION

Brazilian pastures occupy land area 6.4 times the size of São Paulo state, accounting for the vast majority of land use (45%) [i.e., ~160 Mha (IBGE, 2017)]. Brazil is the world's largest beef producer (*i.e.*, 9.9 million metric tons in 2018) and will represent 23% of the world's total beef exports by 2028 (USDA, 2019). Brazil has around 232 million head of cattle (USDA, 2019), more than its human population [i.e., ~212 million, (IBGE, 2021)]. Thus, Brazil is an important global food producer and supplier.

Pasture reclamation is a crucial way of potentially reducing deforestation and improving carbon sequestration (STRASSBURG et al., 2014; OLIVEIRA SILVA et al., 2015; OLIVEIRA SILVA et al., 2017). Thus, Brazil presents considerable opportunity for greenhouse gas (GHG) emissions mitigation and carbon uptake, making the country an important player to tackle climate change (WORLD BANK, 2019). At the 2009 United Nations Climate Change Conference, the Brazilian Government voluntarily committed to reduce emissions and enacted Law no. 12.187 (Dec. 2009). A national plan (Plano ABC) was launched (2012), aiming for an economy of low carbon emissions in agriculture, including reclamation of 15 million ha of degraded pastures for mitigation of 83 to 104 Mg CO_{2eq} by 2020 (BRASIL, 2012; NOGUEIRA et al., 2015). In addition, in 2015 the country assigned the agreement to take actions in the Nationally Determined Contribution, thus it was established the Paris Agreement, in December 2015. Brazil took part on the Agreement through the

Decree nº 9.073 (June, 2017) (BRAZIL, 2017). As part of the actions to be taken in this agreement plus that established in Plano ABC, the Brazilian Government compromised stimulate strategies to sustainable agriculture intensification though recovering 15 Mha of degraded pasturelands and increasing integrated crop livestock–forestry in 5 Mha by 2020 (FERRAZ and SKORUPA; 2017; CONCEIÇÃO et al., 2017).

The ICL and ICLF systems - forestry (integrated systems) are preferred and indicated strategies for pasturelands recovery in Brazil (DIAS-FILHO, 2006). Currently, the area under ICLF system in Brazil has sharply increased over the past 15 years, accounting for more than 15 million hectares (Figure 1A), the majority of the area is within the Brazilian Central-West region (EMBRAPA, 2016; SOARES and BALBINO, 2019). The integrated systems are attractive for the farmers under economic and agronomic aspects, in the first condition, the integrated system adoption diversifies agricultural productivity in the farm and, under such situation, risks inherent to agricultural activities are reduced, whereas under agronomic aspects, integrated systems adoption is associated with better soil attributes (physical, chemical and biological), beyond breaking up pests' cycle in the agroecosystem (BARBOSA et al., 2015; COSTA et al., 2015; FERRAZ e SKORUPA, 2017). Moreover, crucial function associated to integrated systems is the agriculture intensification, which reduces livestock and farming activities over natural ecosystems, especially pressure over Amazon and Cerrado Biomes (DIAS-FILHO, 2006; DIAS-FILHO, 2014).

Due to several motivations (at national and state levels) for integrated systems adoption across the previous years (CORDEIRO e BALBINO et al., 2019), little is known about the implications of integrated systems adoption on carbon sequestration and soil attributes (i.e., soil quality indicators) changes under pastureland reclamation or agroecosystem intensification. Thus, the aim of this study was to gather published studies regarding the influence of integrated systems adoption on carbon sequestration and soil quality.

MATERIAL AND METHODS

The literature review was conducted using a systematic search (i.e., Web of Science, Plubons, Scielo [library of Brazilian journals], Scopus, Science Direct and Google Scholar) for publications in English and Portuguese.

RESULTS AND DISCUSSIONS

From the rancher's view point, the main motivations for adopting integrated systems were to have their farmers according to the Brazilian environmental laws as well as to attend markets and society's pressure, whereas farmers (i.e., grain producers) realized higher yields under integrated systems adoption (SALTON et al., 2014; EMBRAPA, 2016).

Diversification of activities performed within the farmer (livestock, forestry and agriculture) increases the incoming resources (COSTA et al., 2017) and reduces the risks of losses inherent to agricultural/farming activities (SALTON et al., 2015). Under ILPF system adoption, the crop amortizes the initial investments made with forestry component (WRECK et al., 2019). From agronomic point of view, the performance of crops/pasture will be better as the diversity of plants in rotation or succession also increases (SALTON et al., 2015). The grasses (pasture) planted in succession with crops benefit from the conditions remaining in the soil (i.e., inputs applied and higher pH) that were improved for crop establishment, usually crops require better condition (suitable pH and nutrients contents) than grasses (WRECK et al., 2019). Thus, planting grasses after crop optimizes fertilizers managed for crops (COSTA et al., 2017; FERRAZ and SKORUPA; 2017) and reduces the agroecosystems' dependence on external inputs (BANAUDO et al., 2014). Additionally, integrated systems adoption decreases pests and weeds occurrence, beyond potentially increase animal and crop yield (VILELA et al., 2011). In this sense, integrated system adoption is highlighted as a promising strategy for agriculture intensification within Amazon and Cerrado Biomes (GIL et al., 2015; CORTNER et al., 2019).

Under integrated systems adoption, crops benefit from better soil attributes and carbon stocks (SOC) (Table 1), parameters intrinsically associated with several soil functions (REEVS, 1997; MILNE et al., 2015). While within tropical regions, the absence of suitable managements favors pasturelands degradation and under such condition, the carbon content decreases between 3 and 9% (MEDEIROS et al., 2021).

Table 1. Studies performed in Brazil presenting the relationship between integrated system adoption and soil quality indicators improvement

Reference[#]	**DOI**	**Soil quality indicators**			
		Chemical	**Physical**	**Biological**	
				SOC	**Other**
Macedo (2009)		x	x	x	x
Souza et al. (2009)	10.1590/S0100-06832009000600031	x		x	
Vilela et al. (2011)	10.1590/S0100-204X2011001000003	x	x		x
Assad et al. (2013)	10.5194/bg-10-6141-2013		x	x	
Salton et al. (2014)	10.1016/j.agee.2013.09.023	x	x	x	
Cordeiro et al. (2015)		x	x	x	x
Costa et al. (2015)	10.1590/01000683rbcs20140269		x	x	
Assis et al. (2015)	0.1590/1807-1929/agriambi.v19n4p309-316		x		
Fidalski (2015)	10.1590/S0100-204X2015001100013		x	x	
Silva et al. (2016)			x	x	
Deiss et al. (2016)	10.1016/j.geoderma.2016.03.028	x			
Conceição et al. (2017)	10.4236/as.2017.89066			x	
Moreira et al. (2018)	10.1590/1806-90882018000200013		x		
Assis et al. (2019)	10.30612/agrarian.v12i43.8520		x		
Serra et al. (2019)		x	x	x	x
Damian et al. (2020)	10.1016/j.scitotenv.2019.135463	x			
Bieluczyk et al. (2020)	10.1016/j.geoderma.2020.114368	x		x	
Freita et al. (2020)	10.1016/j.rama.2020.08.001			x	
Damian et al. (2021)	10.1016/j.catena.2021.105238			x	
Damian et al. (2021)	10.1016/j.apsoil.2020.103858	x		x	x

#References presented at table 1 can be obtained directly with authors.

In conclusion, integrated system has sharply been adopted in Brazil and the implications from the adoption of those systems on soil indicators are presented within Table 1. Despiste this fact most of the evaluations performed is focused on physical indicator, followed by chemical and biological indicators, in this order. Thus, there is scarcity of studies conducted under integrated systems, which biological indicators, such as macrofauna soil organisms and enzymatic activities were the main subject. Moreover, very few studies did holistic approaches about soil quality, in which soil-chemical, -biological and -physical indicators were integrated (LUZ et al., 2019). Integrated approaches about soil quality are crucial to understand multiple-soil functions as well as the ecosystem services associated to the soil.

CONCLUSIONS

Integrated systems adoption is highlighted as sustainable path to increase agriculture intensification and for pasturelands recovering across Brazilian Biomes. The area under integrated system has been sharply increased over the past decades and goals established by Brazilian Government for greenhouse mitigation has been achieved. Moreover, integrated system adoption is associated with better soil quality indicators (i.e., physical, chemical and biological). Across the studies performed about soil quality under integrated system, soil physical indicator is the most assessed followed by chemical and biological indicators. Despite this fact, few studies did integrated approaches about soil quality, where soil-chemical, -biological and -physical indicators were integrated. Such approaches are crucial to comprehension multiple-soil functions as well as the soil ecosystem service delivered by the soil.

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MINERAL COMPOSITION OF CORN LEAVES CULTIVATED IN INTERCROPPING WITH FORAGE SPECIES

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ABSTRACT

The study objective was to evaluate the corn nutrition through macronutrients levels in leaves of corn intercropped with forage species. The trial was conducted in second crop season in 2020, in Rio Verde city, GO, Brazil. The treatments were: corn (single), corn intercropped with *Urochloa ruziziensis* (*Syn. Brachiaria ruziziensis*), corn intercropped with *Megathyrsus maximum* (*Syn. Panicum maximum*) cv. BRS Tamani, corn intercropped with *M. maximum* cv. BRS Quênia and corn intercropped with *M. maximum* cv. BRS Zuri. The experimental design was in randomized blocks with four repetitions. For analysis of macronutrients content, it was collected five leaves of corn in flowering stage. The data was submitted to analysis of variance and compared by Tukey test at 5% of probability using SISVAR software. There was no difference in N, P, K, Ca, Mg and S content in corn leaves between intercropping systems. It indicates no interspecific competition for nutrients between corn and forage species intercropped. The forage species intercropping did not affect the macronutrients absorption of corn.

Key words: crop-livestock integrated system; nutrients; fertilization

INTRODUCTION

Under Brazilian tropical conditions, the corn intercropping with perennial *Urochloa* grasses is an option to cash crop production coupled with a cover crop establishment (PARIZ et al., 2016; ALMEIDA et al., 2017). The introduction of forage species in production systems may proportionate high biomass production, nutrient recycling efficiency, and improving of soil physical conditions due the aggressive root system, which can reach up to two meters deep (CRUSCIOL et al., 2012).

Nitrogen (N) is one of the main nutrients related to corn yield, as it is part of proteins and affects directly the photosynthetic process (ANDRADE et al., 2003). According to ARNON (1975), corn demand for N increase according to growth, reaching the maximum at the flowering stage and begining of grain formation. Potassium (K) is the second most demanded nutrient by corn, and had several peaks of absorption during crop cycle, reach up mean absorption higher than N at initial phases of corn (BORGES, 2006). Phosphorus (P) absorption occurs during all corn growth cycle, with the peak at reproductive phase, close to 80 days after sowing (ANDRADE et al., 1975; BÜLL, 1993). Calcium (Ca), Magnessium (Mg) and Sulfur (S) are extracted in small amounts by corn plants. There is a high demand for Ca at flowering and physiological maturity and for Mg at the end of corn cycle (VON PINHO et al., 2009).

Some authors (PORTES et al., 2000; JAKELAITIS et al., 2005) stated that viability of corn-palisadegrass intercropping is related to different initial growth rate and by different nutritional demand peaks. It becomes possible to meet the demands of two species without exceed the maximum nutrient rate that environment could supply. Therefore, the present study aimed to evaluate the macronutrients levels in leaves of corn intercropped with grass species.

MATERIAL AND METHODS

The trial was conducted during the agricultural year of 2020 in Rio Verde city, Goiás State (17º 47' 53" latitude and 50º 55' 41" longitude, 715 m of height), in experimental field of GAPES (Grupo Associado de Pesquisa do Sudoeste Goiano). The experimental field was cultivated with soybean and corn was sown in second crop. Corn was cultivated in monoculture and intercropped with (treatments): *Urochloa ruziziensis* (*Syn. Brachiaria ruziziensis*), *Megathyrsus maximum* (*Syn. Panicum maximum*) cv. BRS Tamani, *M. maximum* cv. BRS Quênia and *M. maximum* cv. BRS Zuri.

The experimental design was in randomized blocks with four repetitions and each experimental unit had 60 m^2. Corn (Pionner hybrid 3898) was sown with seed drill at 0.5 m spaced rows at 60,000 seeds per hectare. Sowing was realized in February 25th of 2020 with the forage species spread superficially at seeding rate of four quilograms of pure viable seeds per hectare. It was realized cover fertilization with nitrogen (N) at 28 days after the crop seeding at rate of 90 kg ha^{-1} of N using cover urea (SuperN®) as N source.

In order to evaluate the nutritional analysis of the corn, it was collected five leaves of corn at flowering stages at central points of the plot. The collected leaves were the leave immediately below and opposite to the corn ear. After sampling, the midrib, tip and ends were removed, using the central part of the leaf to further analyses. The samples were place ta forced air oven (55 °C) during 72 hours. Then, macronutrients composition (N, P, K, Ca, Mg and S) were measured (MALAVOLTA et al., 1997).

The data obtained were submitted to analysis of variance (ANOVA) and means were compared by Tukey test at 5% of probability, using the software SISVAR (FERREIRA, 2008).

RESULTS AND DISCUSSIONS

There was no difference in mineral composition (N, P, K, Ca, Mg and S) between the treatments. The intercropping systems did not affect the macronutrient absorption (Table 1).

Management mistakes of the corn-grasses intercropping can led to interspecific competition between the plants. Situations that promote higher light availability to the grass favors the forage growth, which led to higher nutrient absorption by the grass specie and may decrease the corn yield. Corn intercropped with *U. ruziziensis* can affect the nutritional status of the corn, and, consequently, corn yield (JAKELAITIS et al., 2005). According to Silva et al. (2007), the intensity of the competition varies according to soil and climatic conditions, cultivars and management. In the conditions of this study, corn grow without limitations and was able to dusk the grass, preventing any competition by nutrients, similar to observed by Borghi & Crusciol (2007).

There was no competition by nitrogen, even though both species have a high N demand when cultivated in monoculture. Almeida et al. (2018) observed that palisadegrass shaded by corn intercropping, in well managed intercropped system, absorbed up to 1.4% of N-fertilizer applied on the system, without impairing the amount of N absorbed by corn.

Table 1. Corn leaf chemical composition N (nitrogen), P (phosphorus), K (potassium), Ca (calcium), Mg (magnessium) e S (sulfur) at flowering stages in different intercropping systems.

Treatment	**N**	**P**	**K**	**Ca**	**Mg**	**S**
				g kg^{-1}		
Corn[1]	31.11 a	2.96 a	38.69 a	2.75 a	0.86 a	1.60 a
Corn + *U. ruziziensis*[2]	30.27 a	2.73 a	36.26 a	3.39 a	1.15 a	1.59 a
Corn + *M.* cv. BRS Tamani[3]	26.04 a	2.76 a	39.81 a	3.02 a	1.00 a	1.66 a
Corn + *M.* cv. BRS Quênia[4]	27.33 a	2.47 a	32.58 a	2.54 a	0.92 a	1.78 a
Corn + *M.* cv. BRS Zuri[5]	33.42 a	2.46 a	32.02 a	2.37 a	0.84 a	1.64 a
MSD*	8.98	1.19	17.72	1.63	0.40	0.26
CV**	13.44	19.81	21.91	25.68	18.71	6.85

a: there was no difference between means in the same column by Tukey test at 5% of probability. *MSD: minimal significant difference. **CV: coefficient of variation.
[1]Corn in monoculture; [2]Corn + *U. ruziziensis* – Corn intercropped with *U. ruziziensis*; [3]Corn + *M.* cv. BRS Tamani - Corn intercropped with *M. maximum* cv. BRS Tamani; [4]Corn + *M.* cv. BRS Quênia - Corn intercropped with *M. maximum* cv. BRS Quênia; [5]Corn + *M.* cv. BRS Zuri - Corn intercropped with *M. maximum* cv. BRS Zuri.

CONCLUSIONS

The grass species intercropped with corn did not impair the macronutrients absorption by corn, demonstrating there was no competition between intercropped crops. The forage species evaluated in this study are able to grow in intercropping system without negatively impact the corn crop.

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ENZYMATIC ACTIVITY AS AN EARLY SENSOR IN THE EVALUATION OF SOIL QUALITY IN SILVOPASTORAL SYSTEMS

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ABSTRACT

The demand for food has intensified at the rate that the world population has grown, requiring production models capable of meeting world needs, through high productivity and conciliating with sustainable practices. In this scenario, the silvopastoral system (SPS) has been introduced as an alternative to current production models. Thus, this study aimed to evaluate the current soil condition in an SPS using chemical and microbiological parameters as indicators of soil quality, using a native forest and degraded pasture as a positive and negative reference, respectively. For this, soil samples were collected at a depth of 0-10 cm, and the total carbon and β-glycosidase activity (BGL) were determined. Both SPS sub-areas, in the tree rows (SPS-R) and between rows (SPS-BR) showed potential to store carbon over time. The BGL activity was the parameter that showed greater sensitivity to the land use management, the biological potential of the SPS, and the increased enzymatic activity in the SPS-R as a function of adding trees. The current results showed that low productivity pasture areas' conversion into integrated systems improved both chemical and microbiological soil quality.

Key words: soil quality; enzymatic activity; β-glycosidase

INTRODUCTION

The predicted population increase and the demand for food on the planet, with a role expected from Brazil to meet part of this demand, have driven the expansion of agricultural activities and livestock (BOMMARCO; KLEIJN; POTTS, 2013). However, several environmental problems can be triggered with the expansion, such as the increase in natural resources exploitation.

In this context, the development of sustainable systems has become a topic of global interest and has been used to reverse this situation to satisfy human needs and increase environmental quality. Conservationist practices, such as the use of integrated production systems, have gained prominence, as the adoption of these practices has shown positive effects on both soil chemical and biological attributes (CASTRO LOPES et al., 2018; MENDES et al., 2021, 2019).

The elements and energy contained in organic waste are recycled to maintain balance on Earth. Decomposition and mineralization are processes carried out by enzymes released by living soil organisms (microorganisms and plants) and with outstanding contribution from the microbiota (GHOSH et al., 2020; ZHOU and STAVER, 2019). Furthermore, the abiotic component also contributes to the total sum of enzyme activity, coming from past generations of organisms that lived on the site (non-viable cells). Such enzymes accumulate in the soil and are protected from proteases' action through adsorption on clays and organic matter. In this regard, about 40% to 60% of enzyme activity may come from stabilized enzymes and not necessarily be related to living organisms (WALLENSTEIN and BURNS, 2015).

In the soil, cellulose decomposition is performed synergistically between three cellulases, the endoglucanase, exoglucanase, and β-glycosidase, where the first two enzymes act in the cleavage of polysaccharides, and β-glycosidase completes the final hydrolysis stage converting cellobiose to glucose (SATYAMURTHY et al., 2011; SINGHANIA et al., 2013). With these processes in mind, great emphasis has been given to β-glycosidase (BGL), one of the most found enzymes in the soil, which acts in the final stage of cellulose degradation, and decides the rate of conversion of cellulosic compounds into glucose (TABATABAI, 1994). In general, BGL has demonstrated the ability to respond quickly to the adopted management and has been considered important as a bioindicators of soil quality (MENDES et al., 2021).

A series of studies must be carried out to validate and promote the adoption of silvopastoral systems. Therefore, this study aimed to evaluate two sub-areas of a silvopastoral system under conditions of tropical climate, in the Atlantic Forest biome, in the chemical (total carbon) and microbiological (enzymatic activity) attributes.

MATERIAL AND METHODS

The field experiment was installed at Embrapa Southeast Livestock (21º58 'S and 47º50' W), located in São Carlos, São Paulo state, Brazil. The experimental design was completely randomized and counted with two grazing systems with two replicates per system plus a native forest, here called: i) degraded pasture (DEG); ii) Silvopastoral system with moderate animal stocking rate (SPS) and iii) native forest (NF).

Pastures in the DEG area were established in 1996 with *Brachiaria decumbens* cv. Basilisk under continuous stocking, extensive management and has not been limed or fertilized. Pastures in the SPS were established in same conditions of DEG system. However, in 2008 were planted native forest species. Since then (2008), this system is being managed in a rotational grazing system with six days of occupation and 30 days of rest cycles, as well as being corrected and fertilized with phosphorus and potassium. Each grazing unit (replica) comprises 3.3 ha divided into six paddocks, managed in a rotating system with 6 x 30 days cycles, receiving applications of 40 kg of N-urea ha^{-1} during the rainy season. The SPS trees were planted in sets of three rows, with a distance between 2.5 m x 2.5 m, and spaced 17 m apart from each other, resulting in 545 trees ha^{-1}. The native species planted on the mead row were: "Angico-Branco" (*Anadenanthera colubrina*); "Canafístula" (*Peltophorum dubium*); "Ipê-Felpudo" (*Zeyheria tuberculosa*); "Jequitibá-Branco" (*Cariniana estrellensis*) and "Pau-Jacaré" (*Piptadenia gonoacantha*). To ensure that these species grew straight boles with a minimum of lower branches, the two species "mutambo" (*Guazuma ulmifolia*) and "capixingui" (*Croton floribundus*) were planted in an alternating sequence in the two outer lines of each tree strip. In July 2016, trees were thinned, which consisted of cutting 50% of the trees in each external row, resulting in 350 trees ha^{-1}. Also, the systems were compared with natural vegetation, the Atlantic Forest (Subcaducifolia Tropical Forest).

The soil samples were collected in the dry season at a depth of 0-10 cm. In the SPS system, soils were collected in the tree rows (SPS-R) and between rows (SPS-BR) at three random points along each sub-area. Three samples were also collected for the DEG and NF systems. The soil samples were air-dried and ground to pass through a 2 mm sieve. Then they were stored under refrigeration at ± 4 ºC until analyzed.

The total carbon (TC) content was determined by dry combustion using an elemental analyzer as chemical analysis. As a microbiological analysis, the β-glycosidase (BGL) enzyme activity was measured according to the procedure described by TABATABAI (1994). These procedures are based on the determination of the p-nitrophenol formed after adding the specific substrate, the p-nitrophenyl-β-D-glycopyranoside for BGL.

RESULTS AND DISCUSSIONS

The different land uses and management had significant effects on the carbon content and enzymatic activity in the topsoil, as shown in Table 1.

Table 1. Total carbon (TC) and β-glycosidase (BGL) activity in the evaluated systems. Silvopastoral system in the tree rows (SPS-R) and between rows (SPS-BR); native forest (NF) and degraded pasture (DEG). The same letters on the same line do not differ at the 5% level of significance.

	SPS-R	**SPS-BR**	**NF**	**DEG**
TC (g kg^{-1})	20.9±3.3 a	19.0±2.1 a	37.4±2.6 b	16.2±1.7 a
BGL (μg p-nitrophenol g^{-1} soil h^{-1})	111±4 a	85±3 b	104±6 a	50±4 c

The carbon content varied according to the soil use. The highest content was found in the native forest and the lowest in the degraded pasture (Table 1). The low carbon content in the degraded pasture may be due to the decline in the entry of organic material, concomitantly with the trampling caused by grazing, making the soil vulnerable to degradation. The higher carbon content in the native forest, on the other hand, is due to the continuous supply of organic matter and decreased anthropic disturbance in this area (QIAO et al., 2014).

Also, the soils in the SPS showed no statistical difference compared to the DEG, and the same behavior was observed between the sub-areas SPS-R and SPS-BR. On the other hand, this management's adoption caused an increase of 17% and 29% in the carbon content in SPS-R and SPS-BR, respectively, to degraded pasture. Conservation systems induce changes in the percentages and carbon stock in the soil in the medium and long term, in transition and consolidation stages (LOSS et al., 2016). Freitas et al. (2020) reported that the conversion of degraded pastures to agrossilvipastoral systems promoted an increase in carbon and nitrogen stocks after three years of implementation in the Brazilian Cerrado. On the other hand, VERGUTZ et al. (2010) showed that the soil's carbon stock occurred only after 12 years of adoption and good management practices. In this study, after 12 years of collecting these soils, it is possible to infer that if good management practices continue, this system has great potential for storing carbon in the soil.

Besides carbon, the enzymatic analysis showed different behaviors among the different soil uses but with greater sensitivity in the differences (Table 1). The BGL activity was higher in the SPS-R system and native forest, where both showed no statistically significant difference, whereas the degraded system showed the lowest enzymatic activity. As much as SPS-R showed lower carbon content than the native forest, both soils showed similar enzymatic activity. One possible explanation may be since the microbiological fauna of this location is more selective and promotes greater conversion of substrate into the product over time (OH et al., 2018). Another hypothesis may be because a large amount of these enzymes are stabilized by humic substances or clays, forming complexes, where the enzymatic activity is independent of microbial regulation (WALLENSTEIN and BURNS, 2015).

Also, studies show that organic matter changes can take years to be detected, whereas enzyme activity can provide reliable results of changes in less time (MENDES et al., 2021; 2019). Therefore, the increase in enzyme activity reflects the increase in biological activity in this soil. This over time, indicates that this system favors the accumulation of carbon, even though the increase in the enzyme activity in the initial stages is not linked to the effective increase in the organic matter content (MENDES et al., 2020).

Additionally, a significant difference ($p < 0.05$) was detected for BGL between the sub-areas of the SPS system (SPS-R and SPS-BR), but this effect on the carbon content was practically negligible. Not only quantity, but the substrate's quality is also a factor to be considered in the enzyme activity, and, according to its composition, be easier or more difficult to degrade (SIX et al., 2006). More easily oxidizable compounds released by tree exudates, which have a lower degree of lignification, may increase the enzyme activity in SPS-R compared to SPS-BR.

Another fact to consider is that the lower carbon content in the degraded system is accompanied by the lower entry of matter labile organic content for the microbial population, which explains the lower enzymatic activity compared to the other systems.

CONCLUSIONS

Both SPS-R and SPS-BR showed potential to store carbon over time. In addition, through the enzymatic activity it was possible to highlight the role of trees in increasing the BGL activity in the soils collected between the rows of trees. This observation indicates biological income for this type of management that has been gaining prominence over the years. Therefore, among the indicators, the enzymatic activity showed greater sensitivity in the results, and was the parameter that most readily responded to different uses and soil management.

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CORN PRODUCTIVITY WITH THE USE OF ORGANOMINERAL FERTILIZER IN CONSERVATION MANAGEMENT

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ABSTRACT

Associated with the supply of food and sustainable agriculture are integrated systems. One of the concerns of agricultural production is the destination of residues from animal production, with an alternative to organic mineral fertilizers. The objective of this work was to verify the use of organomineral fertilizer in the development and productivity of corn in conservationist systems. The work was carried out at the UniEvangélica experimental unit, Anápolis - GO, evaluating graniferous corn in the first harvest. The experimental design used was randomized blocks, five treatments and four repetitions, given that the treatments were organized according to the applications of mineral and organomineral fertilizer in planting and covering. At 30, 60 and 90 DAE, the stem diameter (DC) and plant height (AP) variables were obtained. At 90 DAE, the stalk insertion height (IEA) was obtained. The productivity determination was carried out by evaluating the stalk length (CE), stalk diameter (DE), number of rows of grains (NF), number of grains per row (NGF) and mass of 1,000 grains (MMG). There was a small change in the development of plants with the use of organomineral fertilizer, however when using it in planting and cover there was an increase in productivity.

Key words: organic matter; sustainability; *Zea mays*

INTRODUCTION

The theme of food security, combating hunger and food security, has become an extremely discussed topic in recent years (CONTERATTO et al., 2020). Therefore, Sartorello et al. (2020) report the low efficiency of Brazilian livestock compared to agricultural production, as well as the high demand for fertilizer production.

Considering the supply of food and agriculture profitable both in the environmental, cultural and social aspect, there are integrated production systems. Characterized by the diversification of agricultural and livestock activities, being in consortium, succession or rotation. Corn is an important crop for this integration, due to the diverse applications of this cereal. In addition, when in consortium with forages it is competitive because of its size, control and competition with other plant species (ALVARENGA et al., 2006).

Knowing that, the crop-livestock-forest integration refers to the incorporation of agricultural, livestock and forestry elements, these elements have synergy in their interaction, promoting sustainability to the system (QUEIRÓS, 2020). In the case of sustainable agricultural production, a concern in this sector is the impact of the elimination of animal waste in the environment. Therefore, an alternative for the use and adequate destination of the residues is the organic mineral fertilizers (CRUZ et al., 2017).

With the incorporation of organic matter, these fertilizers have benefits in the soil structure and allow an increase in the absorption of nutrients. Associated with the disposal of nutrients obtained from residues, organomineral fertilizers portray significant potential for nutrient savings and, thus, there is a reduction in the external dependence of the agricultural sector on the acquisition of mineral fertilizers (CRUZ et al., 2017).

Santos et al. (2019) highlight that organomineral fertilizers combine the advantage of high solubility and rapid availability of nutrients from mineral fertilizer with the longer-lasting action of organic fertilizer. Macedo et al. (2020) found that the variable height and number of leaves are influenced by different fertilizations, however, by reducing 20% of the recommendation for organomineral fertilization, it has the same efficiency as total mineral fertilization.

According to Mutumba et al. (2020), the use of organomineral fertilizers showed an increase in grain yield per hectare (ha) compared to organic and mineral fertilizers. Pereira (2019) states that there was an increase in length and ear diameter, number of rows of grains and grains per row in treatments using organomineral fertilizer in corn.

Given the above, the objective with this work was to verify the use of organomineral fertilizer in the development and productivity of corn in conservationist systems.

MATERIAL AND METHODS

The work was carried out at the UniEvangélica experimental unit, Anápolis, GO, Brazil, at coordinates 16º19”36’S and 48º27”10’W, at an altitude of 1,030 m. The regional climate is characterized as tropical with a dry season, rains concentrated between October and April and an average annual rainfall of 1,450 mm, with an average annual temperature of 22ºC, with a minimum of 18ºC and a maximum of 32ºC.

In the Köppen climate classification, the regional climate is Aw. The experiment was developed under a dystrophic Red Latosol (SANTOS et al., 2018), with 33% clay, 19% silt and 48% sand, medium texture and smooth wavy relief. Presenting the following fertility profile according to the soil analysis (0.0-0.20 m): pH $CaCl_2$ = 5.0; Al = 0.0 $cmol_c$ dm^{-3}; Ca = 3.8 $cmol_c$ dm^{-3}; Mg = 1.1 $cmol_c$ dm^{-3}; H+Al = 5.61 $cmol_c$ dm^{-3}; K = 74 mg dm^{-3}; P (Mehl) = 3.3 mg dm^{-3}; OM = 4.0%; CTC = 10.7 $cmol_c$ dm^{-3} and V = 47.2%. Liming was carried out with 2.5 t ha^{-1} two months before planting.

The crop under evaluation was granular corn, LG 3040 PRO2, in the first harvest. The area was managed with corn / Braquiária decumbens / pigeon pea in the previous harvest, under no-tillage system. The weeds present in the area [Glyphosate (3.0 L ha^{-1}) + 2.4-D (1.5 L ha^{-1})] were carried out two weeks before planting.

Sowing was carried out in November 2019 under no-tillage, distributing 4.1 seeds m^{-1}, at a depth of 0.04 m, aiming at a final population of 63,076 plants ha^{-1}. The experimental plot was organized with five cultivation lines spaced 0.65 m with 5.0 m in length, totaling 16.25 m^2. 400 kg ha-1 05-25-15 + 50 kg FTE Gran 12 were applied during planting for chemical fertilization and for 400 kg ha^{-1} 02-15-15 for organomineral fertilization.

The trial, with five treatments and four repetitions, was ordered in a randomized block design. The treatment arrangement was carried out by combining the application of mineral and organomineral fertilizer in planting and covering respectively, being T1: chemical + chemical (Q + Q); T2: chemistry + organomineral (Q + O); T3: organomineral + chemistry (O + Q); T4: organomineral + organomineral (O + O) and T5: control (test - without fertilization).

The coverage was divided into two plots, at the V3 stage, with 75 kg ha^{-1} urea in treatments T1 and T3, and 72 kg ha^{-1} of Orgamax® NK + S in T2 and T4. And in the second application with 150 kg ha^{-1} urea in treatments T1 and T3, and 143 kg ha^{-1} of Orgamax® NK + S in T2 and T4. The witness did not cover.

At 15 days after emergence (DAE) weed control was performed using atrazine (5.0 L ha^{-1}). Phytosanitary applications were carried out according to the need to control the crop during its development.

At 30, 60 and 90 DAE, the variables under analysis were obtained, with the measurement of ten plants per plot to determine stem diameter (DC) (mm) and plant height (AP), with the diameter being evaluated at the second internode and the evaluated height of the neck until the insertion of the flag leaf. At 90 DAE, the ear insertion height (IEA) (first viable ear) was obtained.

The determination of productivity was carried out by the method proposed by Emater-MG. Three ears (13% of grain moisture) were collected per plot, performing four replications per plot, attenuating the error. Thus, each treatment had 12 ears harvested for analysis. Subsequently, the ear length (CE), ear diameter (DE), number of rows of grains (NF), number of grains per row (NGF) and mass of 1,000 grains (MMG) were evaluated. The statistical program used was Sisvar 5.6 (FERREIRA, 2015), and the data submitted to analysis of variance and the means compared by the Tukey test ($p < 0.05$).

RESULTS AND DISCUSSIONS

Few changes were observed in the development of the plants as a result of the use of the organomineral in planting or cover, being that only at 30 DAE can we observe statistical differences between the different treatments in the variables height and diameter of the plants (Figure 1), being that the fertilization use Q + Q and Q + O were the ones that stood out the most. There was no influence on the different sources of fertilization at 60 and 90 DAE.

Martins et al. (2017) working with maize submitted to maintenance fertilization with organic mineral fertilizers based on chicken litter and phosphates did not show differences in plant height and diameter. The authors also point out that in soils that are already cultivated, corn characteristics are little influenced by the sources and doses in maintenance fertilization.

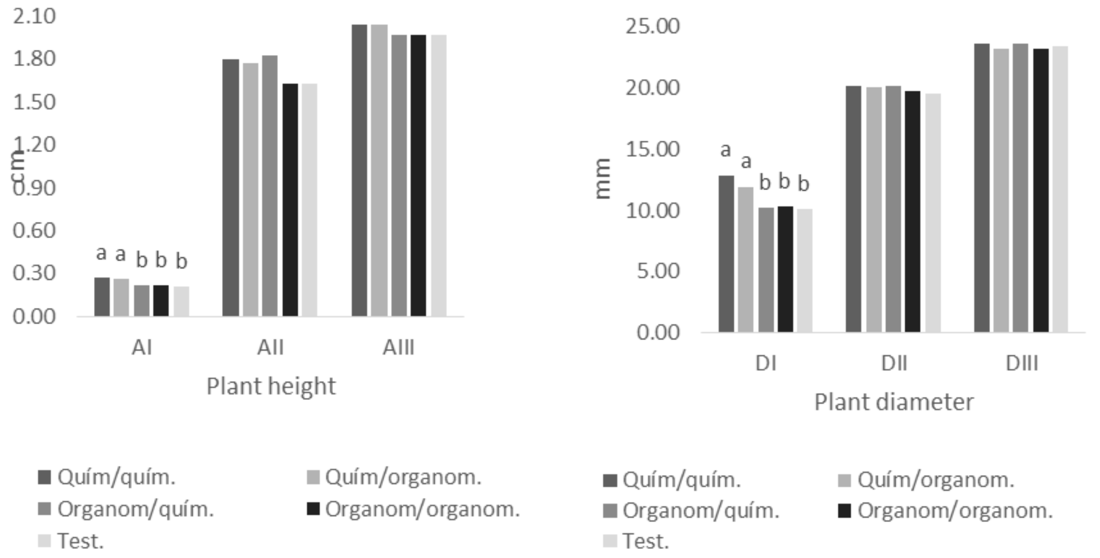

Figure 1. Height (A) and diameter (D) of corn plants at 30 (I), 60 (II) and 90 (III) days after emergence, grown with different sources of fertilizers in planting and cover. * averages followed by the same letter in the column do not differ by the tukey test at 5% probability.

According to Martins et al. (2017), the use of organic waste in agriculture enables greater productivity, reduction of production costs and sustainable use of resources. In this work, the culture showed different behavior in relation to the different treatments used for productivity in relation to the control (Table 1). Corn showed the highest average grain yield for treatment with the use of organomineral fertilization in planting and cover. This fact shows that the mineral fertilizer promoted a greater vegetative development of the plant while the organomineral promoted a greater productivity of the culture.

For productivity parameters, stalk length (CE), number of grains per row (GF) and number of grains per stalk (NGE), no difference was observed between treatments. As for the stalk diameter (DE), mass of 1,000 grains (MMG), number of stalks in 10 m (NE10m) and average weight of stalks (PME), the treatment with O + O stood out from the others (Table 1).

Table 1. Average values of stalk length (CE), stalk diameter (DE), number of rows of grains (NF), number of grains per row (NGF), mass of 1,000 grains (MMG), number of stalks in 10 m (NE10m), number of grains per stalk (NGE), the average weight of the stalks (SME) and productivity (PROD - kg ha^{-1}) depending on different sources of fertilizers in planting and cover.

Treatments	**CE**		**DE**		**NF**		**GF**		**MMG**	
	mm		**mm**		**-**		**-**		**g**	
Quim+Quim (Q+Q)	122.0	a	47.00	b	16.50	b	28.91	a	244.0	b
Quim+Orgm (Q+O)	123.0	a	46.50	b	18.08	a	29.41	a	254.8	ab
Orgm+Quim (O+Q)	112.5	a	45.83	b	18.16	a	28.08	a	240.6	b
Orgm+Orgm (O+O)	118.8	a	49.75	a	18.00	a	27.33	a	277.3	a
Evidence (test)	110.8	a	45.41	b	18.16	a	26.91	a	225.6	b
Test F	0.02		0.00		0.00		0.25		0.00	
CV (%)	13.6		6.94		10.3		15.6		16.5	

Treatments	**NE10m**		**NGE**		**PME**		**PROD**	
	-		**-**				**kg ha^{-1}**	
Quim + Quim (Q+Q)	34.3	b	479.3	a	118.2	ab	6,218.68	b
Quim + Orgm (Q+O)	30.8	c	542.0	a	135.4	ab	6,425.43	b
Orgm + Quim (O+Q)	35.3	ab	517.0	a	125.3	ab	6,744.54	ab
Orgm + Orgm (O+O)	37.1	a	503.5	a	140.7	a	7,936.90	a
Evidence (test)	26.1	d	492.5	a	112.3	b	4,489.89	c
Test F	0.00		0.14		0.02		0.00	
CV (%)	9.27		17.55		26.39		26.71	

* averages followed by the same letter in the column do not differ by the tukey test at 5% probability.

Cavalcante et al. (2020) state that organomineral fertilization can be used to reduce the use of chemical fertilizer and increase productivity. Like Martins et al. (2017) who observed that organomineral fertilizers increased grain production in corn, obtaining average productivity equal to or higher than that obtained with the exclusive chemical source.

CONCLUSIONS

The organomineral fertilizer did not influence the morphological development of the plants. It presented efficiency equivalent to mineral fertilization when used in planting in conservation systems. Corn showed the highest average grain yield in the treatment using organomineral fertilization in planting and cover.

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EFFECT OF INTEGRATED SOYBEAN WITH SORGHUM AND BRACHIARIA SYSTEM ON SOIL CARBON AND NITROGEN

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ABSTRACT

The objective of this work was to analyze the effect of the integrated soybean system with sorghum and brachiaria on the levels of organic carbon, total N and mineral N in the soil. Super short cycle soybean BRS 7580 was planted, and subsequently, forage sorghum BRS 655 and BRS Piatã brachiaria were planted between the lines of the soybean. The levels of organic carbon, total nitrogen, ammonium, nitrate and mineral nitrogen/total nitrogen ratio were evaluated. The soil under Cerrado showed higher levels of organic carbon at all depths. There were no significant differences between treatments and the Cerrado for total nitrogen content in the deepest layers of the soil. All treatments showed a stratified distribution for the ammonium content, with higher values in the more superficial layers, decreasing in the deeper layers. Nitrate was not detected in the soil under Cerrado. Integrated crop treatments showed higher nitrate values than singles systems. In general, nitrate values were higher in the more superficial layers, with a significant decrease in the intermediate layers, increasing again in the 40-60 cm layer. The mineral nitrogen/total nitrogen ratio treatments with single or intercropped soybean maintained the same nitrate results pattern.

Key words: Super short cycle soybean;; intercropped system;; agroecosystems.

INTRODUCTION

Intercropped systems with legumes and grasses usually tend to increase the soil organic carbon and nitrogen content and alter other properties. On the other hand, agricultural systems based on monoculture and continuous soil plowing negatively affect soil physical, chemical and biological quality (COSTA et al., 2003; FENG et al., 2020). For this reason, management systems that maintain soil quality have been required, and integrated crop-livestock (ICL) system has stood out and is increasingly being adopted due to the various benefits previously mentioned. This system can increase the organic carbon content in the soil over the years due to the continuous growth of plants, crop rotation and greater nutrient cycling (TRACY and ZHANG, 2008). According to Amado et al. (2001), legumes in rotation or succession systems increase carbon and nitrogen retention in the soil, promoting better environmental quality.

The increase in the soil carbon content under ICL initially occurs in the most superficial layers (RUSSELL and ISBELL, 1986; SOARES et al., 2019). However, over time, there is also an increase in the deeper layers (HAYNES and WILLIANS, 1999; MARCHÃO et al., 2009), which is a consequence of correct soil management, which also has a positive effect on the system productivity (DUBEUX et al., 2004; MORAES et al., 2014). The soil carbon content is closely linked to the nitrogen content. Nitrogen is the nutrient most demanded by plants, and most of it is found in organic form. The transformation of organic nitrogen into mineral forms (ammonium and nitrate), which are absorbed by plants, is done through the decomposition and mineralization processes of organic matter (SCIVITTARO and MACHADO, 2004). The availability of this nutrient for plants in addition to other factors is essential for good crop productivity hence the importance of quantifying the mineral nitrogen content in the soil.

Soybean has a low C/N ratio, which, combined with soluble compounds presence, favors decomposition and mineralization by soil microorganisms, promoting nutrient cycling (SHOLIHAH et al., 2012). Intercropped systems with grasses provide an increase of soil organic matter, which directly influences mineralized nutrients. Thus, the soil management may alter soil total N with consequent changes in soil mineral N and soil ammonium and nitrate content (BUSO and KLIEMANN, 2003).

The objective of this work was to analyze the effect of the intercropped system of soybean with forage sorghum and brachiaria on the soil organic carbon, total nitrogen and mineral nitrogen.

MATERIAL AND METHODS

The experimental design was in randomized blocks, with seven replications. The super-short cycle soybean cultivar was planted in November 2012 and, 30 days after planting, forage sorghum and brachiaria were sown among the soybean lines. The treatments were as follows: 1. Single soybeans 2. Single brachiaria; 3. Single forage sorghum 4. Consortium soybean - brachiaria; 5. Consortium soybean - forage sorghum; 6. Forage sorghum in the off-season. The blocks were implanted between rows of native trees. The native species used were red angico (Anadenanthera colubrina var. Cebil), cedar (*Cedrela fissilis*), guapuruvu (*Schizolobium parahybae*), jequitibá (*Cariniana estrellensis*) and mahogany (*Swietenia macrophylla*). Seedlings were planted from January to March 2009. The spacing was 12 meters between rows and 4 meters between plants. The seedlings were sent using seeds from the Embrapa Cerrados nursery. The area's soil was a red latosol with a clay texture.

The super-short cycle soybean, variety BRS 7580, was planted mechanically on November 21, 2012, and the seeds had a cultural value of 90%, spacing of 50 centimeters and 20 plants/meter. The soybean seeds were inoculated with *Bradyrhizobium japonicum* at a dose of 500 grams of inoculant for each 60 kg of seed. Fertilization was done at planting, applying 420 kg ha^{-1} of NPK 0-20-20. On December 12, 2012 the plots were demarcated, each with 12 m2 (3 x 4 meters). In early January, glyphosate was applied at a dose of 1.5 l ha^{-1} in the area for weed control before planting other crops. On January 7 and 8, 2013, brachiaria and forage sorghum were planted manually. The cultivar of *Brachiaria brizantha* used was BRS Piatã, with a cultural value of 50%, and 0.014 kg of seed/plot was used. Three furrows were made between the lines of soybeans for planting the brachiaria, and the seeds were sown.

The cultivar of forage sorghum used was BRS 655, and 17 seeds/meter was used. A groove was made between the lines of the soybeans for planting the sorghum. This cultivar is a simple hybrid with a cycle of 100 to 110 days, a plant height of 250 cm, resistance to drought, lodging, and a high potential for green mass production. On January 18 and 19, 2013, the sorghum plots were fertilized with 300 kg ha^{-1} of NPK 4-30-16, and additional fertilization of 80 kg ha^{-1} of urea was used. On March 21, 2013, cover fertilization was applied to the forage and brachiaria sorghum plots, using 100 kg ha^{-1} of urea. On March 28, 2013, the planting of forage sorghum in the off-season was carried out in the plots planted with soybean in a single system. The variety used was BRS 655, and 300 kg ha^{-1} of NPK 4-30-16 was fertilized. On April 15, the cover fertilization was performed with 80 kg ha^{-1} of urea. In early April 2013, soybean was harvested manually, shredded, and the beans were weighed. On May 5 and 6, forage and brachiaria sorghum plants were harvested with a manual brush cutter. The fresh weight of plant biomass was done in the field, and a small sample was stored in a paper bag and then taken to the oven at 65 ºC for 72 hours for drying and weighed. At the end of May, forage sorghum was also harvested in the off-season, adopting the previously described harvesting practices.

For the determinations of organic carbon, total nitrogen, nitrate and ammonium samples were collected in three of the seven blocks of the experiment. Samples were collected in the soybean, forage and brachiaria plots in a single system, soybean in a consortium with sorghum and brachiaria and in the off-season sorghum plots. Soil samples were also collected in a native Cerrado area as a reference. The samples were collected after harvesting each culture with the aid of an auger in the soil layers: 0-5; 5-10; 10-20; 20-40, and 40-60 cm. For each composite sample, five simple samples were collected. These were placed in a bucket, crushed and homogenized, removing approximately 500 grams of soil, which were stored in plastic bags and identified. A small amount of soil was removed from each sample, stored in a plastic bag, identified, and placed in a polystyrene box with ice. These samples were kept frozen until the time of nitrate and ammonium analysis.

All samples were taken to the Soil Biochemistry Laboratory at the University of Brasília for further analysis. The samples were air-dried, macerated, and sieved through a 0.5 mm sieve and stored to analyze organic carbon and total nitrogen. For the nitrate and ammonium analysis, 10 grams of soil were removed from each sample and placed in the oven for two days at 105 ºC to determine the humidity. Soil organic carbon was determined by the method of Walkey and Black (1934). The total N was determined by the Kjeldahl method (BREMNER and MULVANEY, 1982). The nitrate and ammonium analysis were determined by the Kjeldahl method, described in EMBRAPA (2010). The data were analyzed using the statistical program Sisvar (FERREIRA, 2003), and the comparison of means was performed by the Tukey test at the level of 5% probability.

RESULTS AND DISCUSSIONS

Soil organic carbon

The soil organic carbon content was higher in the 0-5 cm layer than a 40-60 cm layer for all treatments (Table 1). Higher levels of organic carbon in the most superficial layer were also found by Salton et al. (2011) in a crop-livestock integration experiment carried out in Mato Grosso do Sul and this is due to the greater accumulation of crop residues on the surface and the absence of soil disturbance in this system (BAYER et al., 2002). The Cerrado was used as a reference, and a more stratified distribution of organic carbon in the soil can be observed, with a higher value in the 0-5 cm layer (51.28), lower value in the 40-60 layer (22.17) and intermediate values in the other depths (39.66; 29.25; 29.78). In general, the Cerrado showed the highest values of organic carbon in relation to the other treatments.

The decrease in C-org in cultivated soils may be the result of the management adopted and the consumption of carbon by microbial biomass (JAKELAITIS et al., 2008). There were no significant differences, in any of the depths, between the intercropped treatments and those in the single system, except for the 0-5 cm layer in which the soybean + sorghum consortium provided the highest values than in the treatments with single soybean (Table 1). The short period of time may explain this result (PILLON et al., 2007). In long-term experiments, as in Salton et al. (2011), with areas of 9 and 11 years in ILP system, differences differences between treatments, in which the treatments with secondary pasture have carbon contents in comparison to the systems of single tillage. The cultural residues of forages have a higher C/N ratio, which generates a slower degradation and favors the accumulation of soil organic carbon. In this work, only in the 0-5 cm layer differences were observed between treatments with single soybean and as a single or intercropped forage (brachiaria and sorghum) and despite being the first year of implementation of this system, the soy+sorghum consortium improved soil carbon contents. However, this effect was not observed in the other soil layers, possibly due to the short period of time and the uniform distribution of organic matter throughout the area, once that before the installation of the experiment, the experimental area was planted with sorghum and was desiccated before the work.

Total Nitrogen

The native Cerrado soil showed the highest levels of total nitrogen in the soil layers 0-5, 5-10 and 10-20 cm in comparison to the other treatments. In the deeper layers, there was no statistically significant difference between treatments. Among the treatments, there was a significant difference only in the 0-5 cm layer in which the single soybean presented a lower total N than the soybean + sorghum. These same treatments showed behavior similar to the organic carbon of the soil.

Table 1. Soil organic carbon and total nitrogen (g kg^{-1}) under soybean and forage cultivated in single system and intercropped.

Treatments	**Depth (cm)**				
	0-5	5-10	10-20	20-40	40-60
			C (g kg^{-1})		
Soybean	23.24Ca(1)	21.13Bab	19.14Bab	20.31Bab	16.32abB
Sorghum	24.59bcA	22.87Ba	20.16Bab	19.50Bab	16.56abB
Soybean + Sorghum	30.41Ba	21.76Bb	21.49Bb	19.02Bb	16.79abB
Sorghum off-season	28.19bcA	22.06Bb	17.85Bbc	17.11Bbc	17.29Bc
Brachiaria	26.03bcA	24.15Bab	22.47Bab	19.27Bbc	15.06Bc
Soybean+brachiaria	23.96bcA	21.95Ba	19.41Bab	18.78Bab	15.88Bb
Cerrado	51.28Aa	39.66Ab	29.25Ac	29.78Ac	22.17Ad
			N (g kg^{-1})		
Soybean	1.38cA	1.18bAB	1.07bB	1.05aB	0.78aC
Sorghum	1.49bcA	1.31bAB	1.17bBC	1.04aCD	0.81aD
Soybean + Sorghum	1.66bA	1.28bB	1.18bBC	0.98aCD	0.81aD
Sorghum off-season	1.45bcA	1.19bB	1.08bBC	0.91aCD	0.77aD
Brachiaria	1.47bcA	1.34bAB	1.21bBC	1.04aC	0.75aD
Soybean+brachiaria	1.37cA	1.29bAB	1.10bBC	0.97aCD	0.80aD
Cerrado	2.51aA	1.83aB	1.54aC	1.12aD	0.88aE

(1) Averages followed by the same lowercase letters in the column and uppercase letters in the row do not differ from each other by the tukey test ($p < 0.05$).

Loss et al. (2011), also found a higher total N content in soil under native Cerrado compared to crop-livestock integration systems and, as well as for organic carbon levels, this is due to the greater deposit of plant residues in this soil and less disturbance of this system, which generates greater accumulation of this nutrient in the soil (SIQUEIRA NETO et al., 2009). In the present experiment, no statistical differences were observed between the total N levels in the deeper layers of the treatments and in the Cerrado, and this may be due to the application of nitrogen fertilizers and their leaching, since high levels of nitrate were found in the subsurface, mainly in consortium treatments. In general, the greatest results found were in the most superficial layers, with a decrease in the soil profile. The 0-5 cm layer showed higher nitrogen values than the 10-20, 20-40 and 40-60 cm layers for all treatments.

The decrease in the total nitrogen content was more uniform in the soil under Cerrado (Table 1). The higher values of total N in layers 0-5 and 5-10 cm are due to the greater accumulation of organic matter on the soil surface. There were no significant differences between the treatments in single system and those in consortium, with the exception of the treatments single soybean and soybean + sorghum in the 0-5 cm layer. The treatment with single forage sorghum showed the same levels of total nitrogen as the treatments in consortium with soybean and sorghum in off-season. Similar results were obtained in the treatment with brachiaria. The treatment with single soybeans also did not differ from the others (Table 1). This result shows that the soybean culture did not interfere in the consortium treatments regarding the total nitrogen content in the soil, with the exception of the 0-5 cm layer.

Ammoniacal nitrogen (NH_4^+)

Regarding the ammonium content in the soil in the superficial layers (0-5 and 5-10 cm), the Cerrado showed the highest values and in the other layers, in general, there was no difference in the ammonium contents between the native Cerrado and the others agroecosystems studied. In the layers of 10-20 and 20-40 cm the highest levels of ammonium were found in the plots with forage sorghum off-season. This same treatment, together with sorghum and brachiaria in a single system, exhibited the highest levels in the deepest layer (Table 2). In general, all separation blocks have a uniform distribution in relation to the ammonium content, with higher values in the superficial layers, decreasing the deeper layers (Table 2). Possibly due to the binding of NH_4^+ to molecules of organic matter, which have a negative charge. In general, the consortia between soybean and forage lower ammonium values at different depths. This may be due to the higher rate of nitrification that occurred in treatments.

Table 2. Soil ammonium and nitrate content (mg N kg^{-1}) under soybeans and forage cultivated in a single and intercropped systems.

Treatments	**Depth (cm)**				
	0-5	5-10	10-20	20-40	40-60
	NH_4^+ (mg kg^{-1})				
Soybean	4.89bcAB(1)	5.34bA	3.37bcAB	3.36abB	0.82bcC
Sorghum	5.28bA	5.12bA	3.28bcB	1.61bcC	2.51abBC
Soybean + Sorghum	5.42bA	3.09cBC	3.29bcB	1.55cCD	0.40cD
Sorghum off-season	5.12bAB	3.05bAB	6.29aA	4.15aBC	3.33aC
Brachiaria	4.99bAB	5.91bA	4.24bB	2.18bcB	1.58aC
Soybean+brachiaria	3.12cA	2.61cAB	2.26cAB	1.66bcAB	0.99bB
Cerrado	10.28aA	5.32aB	2.93bcC	1.72bcC	1.53bcC
	NO_3^- (mg kg^{-1})				
Soybean	20.57bA(1)	1.93cD	2.43bD	6.88aC	14.38aB
Sorghum	0.93eA	1.07cA	1.17bA	2.89bcA	2.40bA
Soybean + Sorghum	24.42aA	17.39aB	0.94bD	8.11aC	15.07aB
Sorghum off-season	17.25cA	2.98cC	6.48aB	4.94abBC	2.87bC
Brachiaria	1.14eA	1.37cA	1.76bA	0.79cA	0.30bA
Soybean+brachiaria	6.28dB	8.10bB	1.10bC	1.25cC	14.22aA
Cerrado	ND	ND	ND	ND	ND

(1) Averages followed by the same lowercase letters in the column and uppercase letters in the row do not differ from each other by the tukey test ($p < 0.05$).

Nitrate (NO_3^-)

In the soil under Cerrado the presence of nitrate was not detected (Table 2). There is a low adsorption of nitrate ion causing its leaching to the deeper layers (OLIVEIRA et al., 2000). The treatments with sorghum and brachiaria in a single system did not present significant differences in the levels of nitrate in all depths. In all layers, nitrate values were low in these treatments. These values may be due to the high C/N ratio of these materials and consequently low mineralization.

With regard to intercropped systems and single systems (forage sorghum and brachiaria), in general the intercropped systems showed higher nitrate values in all layers. The treatment with sorghum off-season showed a high nitrate content in the 0-5 cm layer, decreasing in depth (Table 2). This high value in the 0-5 cm layer may be due to nitrogen originating from the soybean planted before sorghum. In general, soybean treatments (soybean in single system and soybean intercropped with forage sorghum and brachiaria) showed the highest nitrate content in all soil layers. The treatments with soy did not show a uniform distribution in relation to the depths. In general, the nitrate values were higher in the more superficial layers (0-5 and 5-10 cm), with a significant decrease in the intermediate layers (10-20 and 20-40 cm), increasing the values in the 40-60 (Table 2). The high nitrate values found in the most superficial layers can be attributed to the mineralization of plant residues and the subsequent action of nitrifying bacteria that transformed ammonium into nitrate. In cases where an increase in nitrate concentration was observed at greater depths, this can be attributed to the inversion of charges in the clay fraction that can occur in soils of the Cerrado environment (Oxisols). Due to the higher concentration of positive charges in depth, nitrate can be adsorbed to soil particles under these conditions.

CONCLUSIONS

Integrated systems did not modify soil carbon and nitrogen content.

The areas under Cerrado showed higher levels of soil organic carbon in all the depths, however nitrate was not detected.

In the deepest layers of the soil, there were no significant differences between treatments and the Cerrado regarding soil total nitrogen content.

For the ammonium content, in general, all treatments showed a stratified distribution, with higher values in the most superficial layers, decreasing in the deeper layers.

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ANIMAL PRODUCTION IN PIATÃ GRASS PASTURE IN AN INTEGRATED SYSTEM

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ABSTRACT

This work aimed to evaluate the average daily weight gain, area gain and stocking rate of beef cattle in Piatã grass pasture in an integrated crop-livestock-forest system. The experiment was carried out at Embrapa Beef Cattle, crop 2018/2019. The experimental design was in randomized blocks with the treatments arranged in subdivided plots, with 3 treatments (ICLF28, ICLF22 and ICL) and 4 repetitions. The evaluation months were from January to May 2019. The paddocks were managed under continuous stocking and variable stocking rate, with the average initial animal load of the paddocks being 1.3 animal unit ha^{-1}. The average daily weight gain, kg day^{-1} was estimated by the difference in weight of the evaluator animals, divided by the number of days between weighings. The stocking rate, animal unit ha^{-1} monthly was estimated as the product of the average weight of the evaluating and regulating animals, by the number of days they remained in the paddocks. The weight gain per area, kg ha^{-1} was obtained by multiplying the average daily gain of the evaluator animals by the animals' number per hectare per month. The stocking rate and daily weight gain was higher in the months of January and February, regardless of the systems.

Key words: Stocking rate; Average daily weight gain; weight gain per area

INTRODUCTION

According to Simeão et al. (2016), in Brazil, there are more than 100 million hectares with cultivated pastures, mainly with *Urochloa* spp. It is estimated that 80% of pastures in Central Brazil are and/or are in some degradation degree (CORDEIRO et al., 2015), which compromises the sustainability of animal production.

The integrated crop-livestock-forest (ICLF) system is a sustainable production strategy, which integrates crop, livestock and forestry activities, carried out in the same area, in intercropped crop, in succession or rotation and seeks synergistic effects between the components of the agro-ecosystem, contemplating environmental adequacy, valuing man and economic viability (BALBINO et al., 2011).

In shaded systems the forage nutritive value can be affected and it becomes a basic factor to be considered, as animal production is influenced by this factor, reflecting in improvements in weight gain. Improvements in the forage composition under intense shading have been observed by several authors (PACIULLO et al., 2007; SOARES et al., 2009).

Gamarra (2015), in the 5th year of evaluation when comparing the ICL system with the ICLF, observed improvements in the forage composition of the forage in the ICLF system in relation to the

ICL, with crude protein (CP) contents of 10% in the ICLF and 7.3% in the ICL; 70.3% NDF in the ICLF versus 72.5% in the ICL in the summer. There were no differences in the average daily gain with an average of 0.403 kg day^{-1}. The stocking rate in the summer was 3.35 and 2.96 animal unit (AU) ha^{-1}, and in the winter, 1.37 and 1.17 AU ha^{-1} for the ICL and ICLF systems, respectively.

Animal production on pastures varies according to the seasonality of forage production. Oliveira et al. (2014) obtained similar weight gains ha^{-1} between the different productive systems, even with shading promoted by the forest component in winter. In the water seasons, spring and summer, and in the fall, however, the weight gain ha^{-1} was reduced as the shade percentage in the system increased. These results show that the differences in animal performance are due to the higher forage masses, and generally due to the greater radiation availability for photosynthesis.

Thus, the aim was to evaluate the weight gain and stocking rate of beef cattle in Piatã grass pasture in an integrated crop-livestock-forest system.

MATERIAL AND METHODS

The experiment was carried out at the Technological Reference Unit (TRU) in Agrosilvipastoral systems, from Embrapa Beef Cattle, in Campo Grande-MS, Brazil. The region is located in the Cerrado biome, with an average annual rainfall of 1,560 mm, with defined seasons of rain from September to April and drought from May to August.

The experimental area used was composed of three systems: Integrated Crop-Livestock-Forest systemwith 28 m of eucalyptus rows (ICLF28); Integrated Crop-Livestock-Forest system with 22 m of eucalyptus rows (ICLF22); Integrated Crop-Livestock system (ICL).

The experimental design was a randomized block with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL) and 4 repetitions. The harvest months were January, February, March, April and May 2019 and the sample points A, B, C, D and E composed the subplots.

The paddocks were implanted in Piatã grass pasture and managed under continuous stocking and variable stocking rate, with the average initial animal load of the paddocks being 1.3 AU ha^{-1}. The stocking rate adjustment was carried out on the days of the animals' weighing. A variable number of regulating animals was used when necessary, according to the forage mass, following the recommendations of Machado and Kichel (2004). All animals received water at will and mineral supplement.

The animals were weighed individually and monthly, the average daily weight gain (ADWG, kg day^{-1}) was estimated by the difference in weight of the evaluator animals, divided by the number of days between weighings. The monthly stocking rate (SR, AU ha^{-1}) was estimated as the product of the average weight of the evaluating and regulating animals, by the number of days they remained in the paddocks. The animal weight gain per hectare (WGA, kg ha^{-1}) was obtained by multiplying the average daily gain of the evaluator animals by the number of animals per hectare per month.

The data were subjected to analysis of variance and the means were compared using the Tukey test at 5% probability. The analyzes were performed using the SISVAR statistical package (Ferreira, 2008).

RESULTS AND DISCUSSIONS

For the stocking rate, average daily gain and weight gain by area (Table 1) there was no difference among the systems, however there was a significant difference among the sampling months.

Table 1. Stocking rate (SR), Average daily weight gain (ADWG) and weight gain per area (WGA) in the sampling months.

Variable	January	February	March	April	May	CV	P value
SR (AU ha^{-1})	2.3 a	2.1 a	1.62 b	1.58 b	1.47 b	8.80	<0.01
ADWG (kg day^{-1})	0.630 a	0.624 a	0.529 b	0.517 b	0.498 b	15.35	<0.01
WGA (kg ha^{-1})	73 a	74 a	74 a	65 b	63 b	22.10	<0.01

Means followed by the same lowercase letter on the row, do not differ by the Tukey test (P> 0.05).

The highest stocking rates and average daily weight gain were found in the months of January and February. The months of January, February and March resulted in the highest values for weight gain per area.

The best results found in the initial months of the experiment, January, February and March, can be related to the environmental conditions in which the Piatã grass was, vigorous and in full development, with regular rains and the beginning of grazing after sealing the pasture.

The lowest values were obtained in the final months of the experiment, April and May, months when the rains were irregular and showing scarcity, typical of the region, causing the Piatã grass development to be limited.

These results demonstrate that the tree component used together with the characteristics that they presented during the experiment did not harm animal production in the different systems (ICL and ICLF), the determining factor occurred in the months of sampling.

Coelho (2011) and Santos (2011), evaluating average daily weight gain in the initial phase of three integrated systems with eucalyptus and Piatã grass, also did not observe any difference. The authors relate to the fact that the trees are in an early development stage, and the shading was not enough to decrease the pasture production and consequently the animals weight gain.

The similar average daily weight gain in the systems can be attributed in part to the Piatã grass quality, since it is the first grazing cycle after the eucalyptus thinning, which provided greater solar radiation and also the year season when the experiment was carried out, as the rains were very well distributed throughout the period.

The lower ADWG and WGA values, observed in the final months, reflect the lower leaf blade percentages and the higher dead material percentages, reducing the Piatã grass nutritional quality.

CONCLUSIONS

The stocking rate and daily weight gain were higher in the months of January and February, regardless of the integration system used.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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HEIGHT AND COVERAGE OF THE PIATÃ GRASS PASTURE IN A SYSTEM IN INTEGRATION AFTER GRINDING EUCALYPTUS

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ABSTRACT

This work aimed to evaluate the green cover and soil percentages; grass height; litter presence in Piatã grass pasture in integrated crop-livestock-forest system. The experiment was carried out at Embrapa Beef Cattle, agricultural year 2018/2019. The experimental design was a randomized block with the treatments packaged in subdivided plots, with 3 treatments (ICLF28, ICLF22 and ICL) and 4 repetitions. The evaluation months were from January to May 2019. In each one of them, with a sample area of 1.0 m x 1.0 m, the canopy height was measured with a graduated ruler starting from the ground level to the leaf tip; visual assessment of soil cover, litter and uncovered soil, by dividing the area into gradients, where each gradient corresponded to 25% of the point. The litter percentage was higher in the ICLF22 and ICLF28 systems, compared to ICLF in all months obtained. As well as higher plant height was also obtained in the Integrated Crop-Livestock system, in the same way as greater green coverage was observed.

Key words: Vgetation cover; soil uncovered; plant height

INTRODUCTION

The ICLF system is the intentional combination of agricultural, livestock and forestry activities, carried out in the same area, in intercropped crop, in succession or rotation. However, there are options for cultivating crops and livestock: ICL; crop and forestry: ICF; livestock and forestry: ILF; of the three activities: ICLF (BALBINO et al., 2011a).

The addition of the forest component to the system, evolving to ICLF, increases the possibilities of use and activities combinations, as well as the environmental benefits, such as covering and enriching the soil, through the deposition of a dense organic material layer, established continuously by the leaves and branches fall, called litter. The litter is important for reactivating nutrient cycling, as it improves conditions for the vegetation establishment and microclimate conditions, such as, for example, relative humidity, thermal amplitude and wind intensity (BALBINO et al., 2011b).

Thus, the aim was to evaluate Piatã grass structural characteristics in an integrated crop-livestock-forest system.

MATERIAL AND METHODS

The experiment was carried out at the Technological Reference Unit (TRU) in Agrosilvopastoral systems, from Embrapa Beef Cattle, in Campo Grande-MS, Brazil. The region is found in the Cerrado biome, with an average annual rainfall of 1,560 mm, with defined seasons of rain from September to April and drought from May to August.

The experimental area used was composed of three systems: Integrated Crop-Livestock-Forest system with 28 m of eucalyptus rows (ICLF28); Integrated Crop-Livestock-Forest system with 22 m of eucalyptus rows (ICLF22); Integrated Crop-Livestock system (ICL).

The experimental design was a randomized block with the treatments arranged in subdivided plots, with 3 treatments in the plots (ICLF28; ICLF22; ICL) and 4 repetitions. The harvest months in January, February, March, April and May 2019 and the sampling points A, B, C, D and E made up the subplots.

The forage assessments were carried out for five months, between January and May 2019, in perpendicular transect to the tree rows in each plot. In each transect, five equidistant points were defined (A, B, C, D and E), where A and E were 1 m from the tree trunks and C corresponded to the intermediate position, totaling 5 samples per plot.

In each of the samples, with a sample area of 1.0 m x 1.0 m, the canopy height was measured using a graduated ruler from the ground level to the leaf tip; visual assessment of soil cover, litter and uncovered soil.

The data were subjected to analysis of variance and the means were compared using the Tukey test at 5% probability. The analyzes were performed using the SISVAR statistical package (FERREIRA, 2008).

RESULTS AND DISCUSSIONS

For the variables green cover and uncovered soil percentages (Table 1) there was interaction among systems and sampling points.

The ICL obtained the highest vegetation coverage, followed by the ICLF28 system at points B and C. The system that showed the lowest vegetation coverage was the ICLF22 system, where only point C was statistically similar to the other systems.

The vegetation cover variable, in the sample points, shows that in the ICL system all points had a higher behavior in relation to the other systems. The ICLF28 system shows the best results compared to ICLF22. The lowest values found were obtained at the points of the ends of the transects (A and E). These values are expected, as they refer to the competition suffered by eucalyptus trees.

For the uncovered soil variable there was also interaction by the Piatã grass with the sampling systems and points. The ICL presented the lowest values, that is, the lowest uncovered soil percentages at all sampling points. In the ICLF28 system, the points with the highest uncovered soil percentages were at the ends (A and E). In the ICLF22 system, the highest uncovered soil values were obtained, and within the system, the points that presented the highest values were also at the transect ends (A and E), within the system, the best result was obtained at the central point C.

The forage species growth is determined by their daily photosynthetic activity, accumulated in view of the available environmental resources. When exposed to shading, the growth rate of these species is quickly restricted due to the energy limitation required for photosynthetic processes (VARELLA, 2008).

Table 1. Vegetation cover and soil uncovered percentages in the sampling systems and location.

Site	ICL	ICLF28	ICLF22	CV (%)	P value
		Vegetation Cover (%)			
A	75.25 Aa	53.66 Bb	54.50 Bc		
B	76.00 Aa	72.30 Aa	65.08 Bb		
C	73.75 Aa	71.50 Aa	71.40 Aa	27.80	0.012
D	73.00 Aa	68.00 Ba	63.75 Bb		
E	77.00 Aa	58.20 Bb	54.17 Bc		
		Uncovered Soil (%)			
A	8.75 Ba	19.10 Aa	22.35 Aa		
B	8.00 Ba	9.50 Bb	13.75 Ab		
C	9.18 Aa	8.25 Ab	9.25 Ac	26.54	0.013
D	8.67 Aa	9.55 Ab	13.50 Ab		
E	6.12 Ba	18.25 Aa	20.75 Aa		

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by the Tukey test (P> 0.05).

The variables plantheightand litter percentage (Table 2), there was a difference among the production systems used.

The plants height statistically higher in the Integrated Crop-Livestock system in relation to the Integrated Crop-Livestock-Forest systems was expected, as it does not suffer any competition for resources.

The system with the highest plant height was the ICL. For the litter variable, the ICLF28 and ICLF22 systems obtained higher percentages, being statistically equal to ICLF28 and ICLF22.

One aspect taken into account in relation to the canopy is related to the forage plants growth, under the shade projection in silvopastoral systems, since the response of any plant to the lower light availability is the stretching, as identified in silvopastoral systems with intense shading (Sousa et al., 2007).

Table 2. Grass plant height (cm) e litter presence (%) in the systems.

Variable	ICL	ICLF28	ICLF22	CV (%)	P value
Height (cm)	53.64 A	47.22 B	44.07 B	16.73	<0.01
Litter (%)	15.18 B	24.70 A	22.30 A	21.01	<0.01

Means followed by the same uppercase letter on the row, do not differ by the Tukey test (P> 0.05).

CONCLUSIONS

The litter percentage was higher in the ICLF22 and ICLF28 systems. Higher plant height was obtained in the Integrated Crop-Livestock-Forest system, as well as greater green coverage.

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DRY MATTER INTAKE, METHANE EMISSIONS AND PERFORMANCE BY BEEF HEIFERS GRAZING TEMPERATE PASTURES IN TWO INTEGRATED CROP-LIVESTOCK SYSTEMS

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ABSTRACT

Dry matter intake (DMI) is a key driver of animal production in pasture-based systems. Sward structure is related to DMI. When forage plants are cultivated under trees, they may change their morphology as a means of avoiding shade and optimizing light interception. Therefore, our aim was to compare the DMI of grass-only temperate forage, animal performance and methane emissions in two integrated crop-livestock systems (ICLS), that is: crop-livestock (CL) and crop-livestock-trees (CLT), crossed with two nitrogen fertilization levels (90 and 180 kg de N ha^{-1}). The experimental design was randomized blocks with three replicates. Two tester animals per paddock were utilized to determine DMI by heifers, using the n-alkanes technique. No significant difference between treatments were observed for methane emissions (34 g kg^{-1} DMI) and sward height (SH), which means were close to the target (20 cm). Despite similar SH, the daily herbage accumulation rate, tiller density and herbage allowance were significantly reduced in CLT compared with CL. An increase in N availability was not enough to overcome these differences. Consequently, DMI was also reduced in CLT (1.5±0.04 % live weight, LW) compared to CL (1.7±0.05 % LW), resulting in decreased animal production (-38%) in ICLS with 7-years old trees.

Key words: agroforestry; alkanes; beef cattle

INTRODUCTION

The interest in integrated crop-livestock systems (ICLS) has increased globally, as they are aligned with principles of a cleaner production (GARRETT et al., 2017). When introducing trees in ICLS systems, understory plants can exhibit alterations in anatomy and physiology to compensate for low light quantity and distinct quality (GOBBI et al., 2009). Any morphological change in sward structure affects the animals' intake behavior (GEREMIA et al., 2018). Therefore, in ICLS typical of southern Brazil (summer cash crop/grazing cattle rotations), dry matter intake (DMI) of winter annual forages and consequently the animal performance and methane emissions, could be affected by the resultant alterations in structure and quality of herbage mass caused by N availability and association with trees. However, little information is available to test this hypothesis. By understanding these factors, ICLS managers can better balance the advantages (e.g. soil amelioration, shade, wood and a habitat for fauna) and disadvantages (e.g. competition for water and nutrients between trees and forage components) of trees incorporation into ICLS in order to maintain an economically and biologically sustainable system that meets production goals. The objective of this research was to quantify DMI, methane emission and animal performance of heifers in two ICLS (with and without trees) with two N levels.

MATERIAL AND METHODS

A field experiment was conducted at the Rural Development Institute of Paraná – IAPAR–Emater, Ponta Grossa-PR (25°07'22''S, 50°03'01''W), in southern Brazil. The local climate is humid subtropical, or Cfb in the Köppen classification system, with frequent occurrence of frosts and a mean annual temperature of 17.6º C ranging from 14º C in July to 21º C in January. The mean annual rainfall is 1400 mm. The soil is a transition from Typic Distrudept to Rhodic Hapludox (SOIL SURVEY STAFF, 1999), with a 4 to 9% slope and 19%, 3% and 78% of clay, silt, and sand in the upper 20 cm, respectively.

The experimental area of 13.1 ha was divided into 12 paddocks (i.e. experimental units) ranging from 0.77 to 1.22 ha. In October 2006, three tree species (eucalyptus, *Eucalyptus dunnii* Maiden; pink pepper, *Schinus terebinthifolius* Raddi; and silver oak, *Grevillea robusta* A. Cunn. ex R.Br.) were planted in 6 of the 12 paddocks, at 3×14 m spacing (238 trees ha^{-1}). During the summer of 2013, the experimental area was thinned to 159 trees ha^{-1} by removing pink pepper trees, many of which had been damaged by cattle activity. Beginning with the winter season in 2010, the production system was integrated cattle grazing on cool-season pasture (black oat + annual ryegrass, *Avena strigosa* Schreb cv. IAPAR 61 + *Lolium multiflorum* Lam.) during the winter followed by warm-season maize or soybean crops during the summer. For the current study, i.e. in 2013, the black oat + ryegrass mixture was sown in rows with a seeding density of 45 and 15 kg ha^{-1}, respectively, in April and 400 kg ha^{-1} of commercial formula 4-30-10 (N-P-K) was applied. The previous culture (i.e. summer 2012-2013) was soybean. Soybean (BRS 232) was sown (55 kg of seeds ha^{-1}, 40 cm row spacing) after the pasture was desiccated with glyphosate (2.5 l ha^{-1}) using 400 kg ha^{-1} of commercial 00-20-20 (N–P_2O_5–K_2O).

Each experimental unit received three tester animals and a variable number of animals periodically adjusted to maintain the desired sward height of 20 cm (“put-and-take” method, Mott and Lucas, 1952). The experimental animals were Purunã (¼ Aberdeen Angus, ¼ Canchim, ¼ Caracu, and ¼ Charolais) rearing beef heifers, with an average age of 10 months and weighing 256 ± 5.1 kg. Grazing started on July 3rd, i.e., when the sward height in all paddocks reached at least 20 cm. Heifers grazed until October 8th in 2013 add up to 97 grazing days for 2013.

The experimental design was randomized blocks with three replicates. Two N fertilization treatments (90 and 180 kg N ha^{-1}, or N90 and N180, respectively) were crossed with two ICLS: crop-livestock only (CL) and crop-livestock with trees (CLT). Nitrogen fertilizer (as urea) was applied in a single procedure 40 days after the pasture was sown.

Sward height (SH) was measured at 100 points per paddock every 15 days using a sward stick (BARTHRAM, 1985). Herbage mass (HM, t DM ha^{-1}) and daily herbage accumulation rate (HAR, kg DM ha^{-1}day^{-1}) were estimated from samples collected every 28 days. In each paddock, three cuts were done at ground level (0.25 m²). From these samples, sub-samples were manually separated into fractions containing leaf blade, stem + sheath, dead material and other species. Five SH measurements were performed inside each sample area, to adjust the HM as a function of the average SH of the paddock, according to Kunrath et al. (2020). HAR was monitored each 28 days using three grazing exclusion cages per paddock (KLINGMAN et al., 1943) and the difference in the amount of dry matter (DM) between sampling dates was considered as the accumulated herbage. Herbage DM content was obtained by oven drying the samples at 60 °C until a constant weight. The herbage allowance (HA, %LW) was calculated according to the following equation: HA (%LW) = ((HM/n + HAR)/SR) × 100, where LW = live weight, HM = average herbage mass of each stocking period (kg DM ha^{-1}), n = number of days of the stocking period and SR = stocking rate of each stocking period (kg LW ha^{-1}).

The samples harvested on August 8 and September 3, 2013 for HM measurements were also milled through a 1-mm screen and analyzed for crude protein (CP), dry-matter digestibility (DMD), neutral detergent fiber (NDF) and acid detergent fiber (ADF) via near-infrared reflectance spectroscopy (FOSS-NIRSystems 5000, scanning over the spectral range of 1100–2500 nm; CEPA laboratory, Passo Fundo-RS, Brazil). Tiller density was estimated by counting tillers on a 50 cm line transect in three random areas inside each paddock.

Stocking rate (kg LW ha^{-1}) was calculated by adding the average LW of the tester animals to the average LW of each 'put and take' animal multiplied by the number of days they remained in each paddock and then divided by the number of grazing days. Average daily gain (ADG, kg animal^{-1}day^{-1}) was calculated as the difference between final and initial live weight of each tester animal, divided by the number of grazing days. Live weight gain per hectare (Gha, kg LW ha^{-1} day^{-1}) was obtained by multiplying the number of animals per hectare and per day by the average ADG of tester animals. Animals were weighed after fasting from solids for approximately 15 h.

To determine daily dry matter intake (DMI) by heifers, two tester animals from each paddock were utilized, using the double n-alkane approach (DOVE & MAYES, 1996). The evaluation period started on August 21, 2013. Twenty-two animals' testers were dosed twice daily (at 8 AM and 4PM) with cellulose pellets containing 164.87± 0.32 mg of dotriacontane (C_{32}) and it was administered for ten days. From the 5th to the 10th day of dosing, fecal samples *per rectum* were collected simultaneously to the pellet's administration of C_{32}. To estimate the amount of forage consumed by the animals, the simulated grazing technique was applied between the 7th and 10th day of C_{32} administration period in each paddock. The determination of n-alkanes in forage and in feces samples followed the methodology proposed by Dove and Mayes (2006) in the range of C-chain between 27 and 35. The dry matter intake (DMI) was then estimated according to the equation number 4 proposed by De-Stefani Aguiar et al. (2013). Please, see Pontes et al. (2018) for estimates of methane emission in the current protocol.

Shading was measured using two ceptometers (Decagon LP-80 AccuPAR, Pullman, WA, USA) with one placed in full sun and the other placed between the rows of trees (1.4, 4.2, 7, 9.8 and 12.6 m from the row). Shading percentage measurements were taken every 30 min from 9:00 to 15:00 hrs at 1 m above ground level. The decrease in light availability for the understory vegetation was calculated as the difference in the values from these two ceptometers.

Analysis of variance were performed for animal- and pasture-related variables using Statgraphics Centurion 19 to test statistical significance of the following main factors and their interactions: block (GL = 2), system (GL = 1) and N supply (GL = 1). Interactions were checked for each variable (except for block) and were removed from the model if they had a p-value > 0.05. All response variables were analyzed using a generalized linear model with block as a random effect, and system and N supply as fixed effects. Where necessary the data were transformed via log, box-cox or arcsine of the square root to normalize residuals. Pasture variables used in the current study were obtained from samples collected between August and September 2013, i.e. close to the period of DMI evaluation.

RESULTS AND DISCUSSIONS

Figure 1 shows the n-alkane contents (mg kg^{-1} DM) for herbage samples at the four treatments. The length of C-chain measured ranged from C_{23} to C_{35} and there were no interactions nor statistic differences between systems. This finding is very important because shadow and N levels could affect the amount of n-alkanes in the different systems (Dove & Mayes, 1996), which could undermine DMI assessments. The odd n- alkanes C_{33}, C_{31} and C_{29} were the most abundant n-alkanes in this kind of pasture (black oat + annual ryegrass).

Pasture shading by 7-year-old trees in the CLT system led to a reduction in the mean percentage of light under the tree canopy compared to the treeless system of 41 ± 1.10%.

The severe drought in August 2013 (precipitation of 29 mm, a value even lower than the historical mean, i.e., 74 mm), which was the main period of the current study, limited forage production (e.g. low HAR values, Table 1) and the herbage nutritive value in both systems, decreased carrying capacity and, consequently, the gain per hectare. However, it was possible to maintain the SH close to the target (20 cm) in both systems without significant differences between them (Table 1).

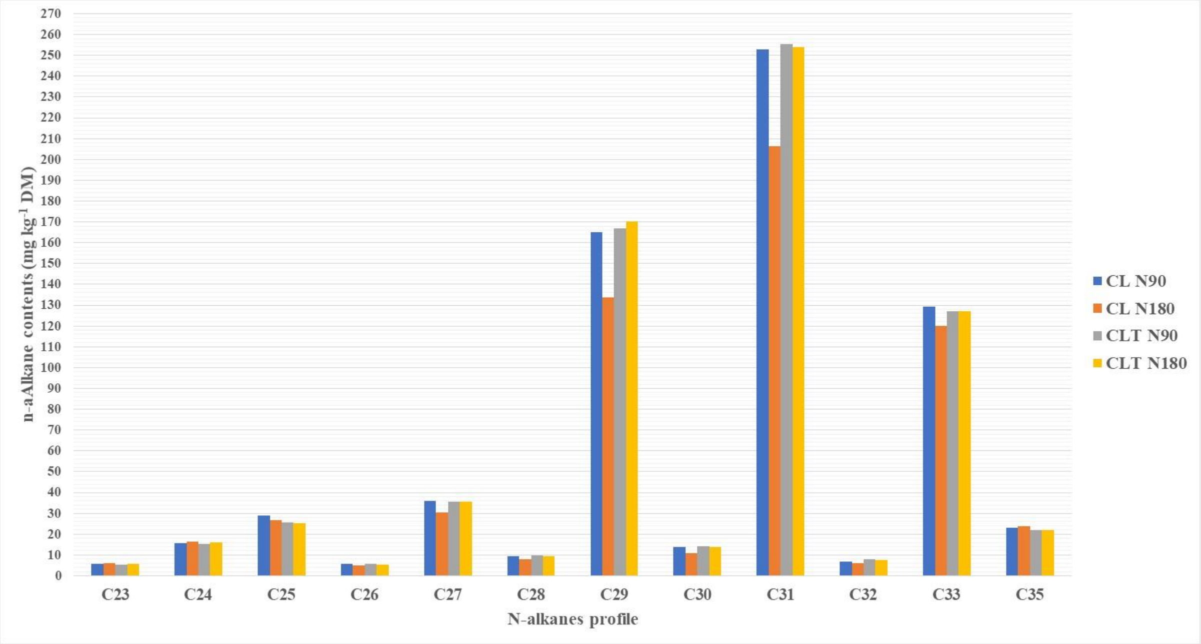

Figure 1. N-alkane (C_{23} – C_{35}) contents in herbage samples in a mixed *Lolium multiflorum* × *Avena strigosa* pasture under different integration systems: CL, crop-livestock and CLT, crop-livestock-trees systems, and two nitrogen levels (90 and 180 kg N ha^{-1}).

Table 1. Pasture and animal performance variables (mean ± standard error) for beef heifers grazing on mixed *Lolium multiflorum* × *Avena strigosa* under different integration systems: CL, crop-livestock and CLT, crop-livestock-trees systems.

	CL	**CLT**	***P***
SH (cm)	20±1.13	18±0.79	0.1057
DMI (% LW)	1.7±0.05	1.5±0.04	0.0191
HM (kg DM ha^{-1})	2766±199.6	1449±90.7	<0.001
HAR (kg DM $ha^{-1}day^{-1}$)	44±10.5	17±4.6	0.0497
HA (%)	15±1.8	9±0.80	0.0205
SR (kg LW ha^{-1})	945±54.8	713±25.5	0.0121
ADG (g $animal^{-1}day^{-1}$)	826±58.3	620±61.4	0.0295
ADG kg DMI^{-1}	0.12±0.03	0.11±0.02	0.7272
Gha (kg LW $ha^{-1}day^{-1}$)	296±16.8	185±15.6	0.0019
TD (50 cm linear)	220±11.4	146±8.5	0.0017
LP (%)	24±2.1	26±1.9	0.4774
CP (%)	16±0.40	15±0.38	0.0298
DMD (%)	64±1.31	61±0.74	0.0555
ADF (%)	34±0.69	35±0.94	0.2384
g CH_4 kg DMI^{-1}	33±2.2	36±3.0	0.3217

P = probability for the system effect; DMI = dry matter intake; LW = live weight; SH = sward height; HM = herbage mass; HAR = herbage accumulation rate; HA = herbage allowance; SR = stocking rate; ADG = average daily gain; Gha = gain per hectare; TD = tiller density; LP = leaf proportion; CP = crude protein; DMD = dry-matter digestibility; NDF = neutral detergent fiber; ADF = acid detergent fiber.

Analysis of variance for sward and animal data showed no effect of N levels, except for CP ($P<0.05$, 15±0.37 and 16±0.42% at N90 and N180, respectively). The interactions system × N level was only significant for FDN ($P<0.05$). While an increase in N level increased the FDN in CL systems (63±1.05 and 65±0.56% at N90 and N180, respectively), the opposite was observed in CLT systems (65±0.72 and 63±1.28 at N90 and N180, respectively).

Lin et al. (1999) stated that C_3 forage grasses grown at 50% sunlight, can sustain productivity at rates comparable to those obtained in full-sun conditions. However, in the current study, important differences were observed in the HM and consequently in the HAR (Table 1) for the two systems during the experimental period, even with increasing N availability. This result indicates that shade provided by trees in the CLT – as high as 41% in relation to the open field – affected pasture growth, mainly by a reduction in the tiller density (Table 1). A reduction in tiller density is one of the main causes of a lower herbage production in shaded areas (PONTES et al., 2017). Further, the drought effect may have been more intense in CLT systems, in contrast to Ford et al. (2017) findings. Ford et al. (2017) observed greater forage production in silvopasture compared to open pasture during times of drought because of increased evapotranspiration rates in the latter system.

Higher herbage mass allowed greater DMI, resulting in increased animal performance in CL systems compared to CLT (Table 1). The greater level of intake of the CL treatments is likely to have been observed due to a combined effect of some sward factors, including increased tiller density and nutritive value (e.g. crude protein). However, for European cattle, most data of daily DMI ranges between 2 and 3% of LW (ZUBIETA et al., 2021). Herbage intake is affected by rates of digestion and passage, which are closely related to the NDF contents (PINARES-PATIÑO et al., 2003). Therefore, the high NDF (63-65%) and low CP content at the current maturity stage seems to have restricted DMI in both systems.

The 7-year-old trees in our experiment reduced beef heifer gains (ADG) on black oat + ryegrass mixture by 25% compared to pastures without trees, regardless of N level (Table 1). Thus, it seems that the possible positive effect of trees on environmental conditions, such as the protection of animals from wind and extreme temperatures (LOPES et al., 2016), was not enough to mitigate the effects of lower forage production. Furthermore, animal performance and SR used to maintain the targeted SH were the determinants of differences in Gha between treatments (Table 1). The presence of trees in our experiment reduced beef heifers Gha by 38% compared to pastures without trees. The higher SR and Gha in CL, compared to CLT systems, can be explained by the higher HM and HAR increasing the pasture carrying capacity.

ADG kg DMI^{-1} was lower when compared to the work of Souza Filho et al. (2019), who used the same type of pasture and four heights as a management goal. In addition, when we compared methane emission per kg of DMI, to the abovementioned author's data, it was higher in the CLT system but close to G40 treatment (30.6 g CH_4 kg DMI^{-1}) in CL system. These differences can be partly explained by the drought that occurred in our work, which reduced quality and quantity of forage and resulted in less DMI, lower animal performance and higher methane emission per kg of DMI. Indeed, the ADG and Gha observed in 2013, in both systems (Table 1), were far below the potential of annual cool-season pastures in ICLS, probably due to the drought. For instance, Kunrath et al. (2020) observed values of around 1.08 kg LW $animal^{-1}$ day^{-1} and 423 kg LW ha^{-1} for a mixture of black oats and ryegrass in ICLS when the targeted SH was 20 cm.

CONCLUSIONS

The 7-year-old trees, with a planting density of 159 trees ha^{-1}, reduced beef heifer gains per hectare on a black oat + ryegrass mixture by 38% compared to pastures without trees, despite maintaining similar sward heights in both systems. Pasture productivity was reduced due to a reduction in tiller density because of a reduction in light availability in a hydric stress period. An increase in the N level did not compensate for these losses. Therefore, silvicultural interventions need to be intensified to reduce the shading level to below 41% and avoid losses to animal intake.

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ECONOMIC INDICATORS AND VIABILITY OF A SILVOPASTORAL SYSTEM AT A FARM IN IVINHEMA/ MS

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ABSTRACT

The general objective of this work was to evaluate the political bias through the inclusion of public policies, which constitute a further link to the economic, social and environmental sustainability in the agroforestry systems in Mato Grosso do Sul and also to verify the technical and economic feasibility of two silvopastoral systems, where one system contains the components tree and animal (beef cattle) and the other only trees on a rural property in the municipality of Ivinhema Mato Grosso do Sul. The reality was analyzed through field research and the elaboration of economic indicators of the property in the period from 2010 to 2017, in order to demonstrate the economic viability of the projects. To make these results possible, the tools were used: Payback period, Net Present Value (NPV), Internal Rate of Return (IRR), these analyzes were made based on one hectare of land and the Minimum Attractiveness Rate of Return (MARR) was 12% per year for a period of 7 years.

Key words: Economic viability; Integrated production systems; Sustainability

INTRODUCTION

Studies on agroforestry systems represent a practice already consolidated in Brazil, but studies on the economic viability of these systems are still little explored in the academic literature. For this reason, the analysis of scientific papers that point to economic possibilities for decision making and that support the study of the economic viability for sustainability of the SSP system in the analyzed property is justified.

By contextualizing the Silvopastoral System (SSP) according to Franke; Furtado, 2001; Lustosa, (2008) it can be said that it is a set of elements such as trees, pastures and animals, seeking to maximize production in a single area. Trees in the middle of pastures and the integration of animal production offer benefits according to the diversification of production, use of land, use of labor, revenue generation and the production of environmental services (LUSTOSA, 2008).

The decisions regarding the spacing between trees is quite significant in relation to the amount of light in the environment and this factor determines the good performance of the forages and the harvest of the trees, with all the attention regarding the distance between tree lines, the better the entry of solar radiation in the forage substrate, benefiting the accumulation of biomass (RIBASKI et al., 2009).

According to Oliveira et al. (2003), the choice of tree species to be implanted in the SSP, should be the right one with multiple exploration options, shading, soil protection, with good financial value and which also has characteristics such as fire resistance, which they are not toxic to animals and the crowns are not very dense, thus being the positive points that the SSP provides through trees, according to Franke and Furtado (2001) is also the presence of insect predatory birds.

According to Machado et al. (2008) and Dias-Filho (2006), the process of implantation of the silvopastoral system in pastures reduces erosion, helps in the conservation of rivers, springs and streams, increases diversity, captures and fixes carbon and nitrogen, improves the quality of pasture and provides a thermal environment for animals, which consequently improves animal efficiency, that is, improves meat and milk production.

Lustosa (2008) points out that if the producer has a diversified production system, he will have a competitive advantage in the face of the challenges of activities and the economy. However, Machado et al. (2008) says that there are other benefits of SSPs with the implantation of trees, they promote shading, windbreak, shelter and alleviate the thermal stress of the animals, reducing the intensity of the heat due to the shadow area.

Negative factors were the adoption of SSPs according to Dias-Filho and Ferreira (2008), it can be mentioned, a low initial return, that is, the need for financial resources and time, which reduce the time rate in which the positive results would return to the farm cash.

Therefore, having a general view of the positive and negative points of the system brings a vision of what can be done in a rural property, with a view to improving the performance of the business.

The objective of this work is to analyze the economic viability of the silvopastoral system with beef cattle and trees, as well as the silvopastoral system with only eucalyptus in a rural property in the municipality of Ivinhema /MS.

MATERIAL AND METHODS

The diagnosis was made on a rural property located in the municipality of Ivinhema in the state of Mato Grosso do Sul, which in this research for ethical reasons will be identified by “Fazenda São João”, located 290 km from the capital Campo Grande-MS. It has a total area of 3,182 ha; of this, 730 ha destined to the silvopastoral system (System 1) and 730 ha destined to the silvopastoral system (System 2), both implanted in 2010. From the moment of implantation and until today, the type of pasture used is MG5 brachiaria; the eucalyptus seedlings used were clone I144. In this study, 735 seedlings were used per ha at a capacity of 1.6 A.U./ha in the silvopastoral system (S1) and in the silvopastoral system (S2) with 1,750 seedlings per ha, for use in firewood / energy, the cost of planting each seedling was R$ 1.60 (own resources). The soil is classified as Quartzarenic Neosol (EMBRAPA, 2006).

The animals used in this system (S1) were those of the Nellore breed crossed with Angus, which enter the system with approximately 180 kg and 12 months of age and remain until completing 30 months reaching an average weight of 380 kg live weight.

Therefore, both systems (S1 and S2) have characteristics that distinguish them, that is, in S1 there are the elements tree, pasture and animal (beef cattle), while S2 is only made up of trees.

Economic indicators used for analysis of rural property (São João Farm)

The indicators used as metrics for evaluating investment projects are Net Present Value (NPV) using a Minimum Attractiveness Rate of Return (MARR) indexed to a country's reference interest base, the Internal Rate of Return (TIR), the Return on Capital (PAYBACK) and Cost Benefit Analysis (CBA) (GITMAN, 2002). The TMA used was 8% per year based on the interest rate (SELIC).

$$V_{PL} = \sum_{n=1}^{n=N} \frac{Fc_t}{(1+i)^n}$$

The NPV is the value obtained by the difference between the present value of the net cash benefits, estimated for the project period, and the present value of the investment where it considers the cash disbursement, in this analysis it is important to define the discount rate a be used in the various cash flows (GITMAN, 2002).

Where: FC = Expected cash flows

I = Minimum Attractiveness Rate (TMA)

If the NPV is greater than zero, the company will obtain a return greater than its capital investment, increasing its value and, consequently, the wealth of its entrepreneur (KASSAI et al, 2000).

$$TIR = \sum_{j=0}^{n} \frac{FC_j}{(1+i)^j} = 0$$

IRR is the discount rate that equates, in a single moment, the inflows to the outflows (KASSAI et al., 2000). It can be said that the investment start date is the zero moment, when using this method in an investment project it is recommended that the calculated internal rate of return is greater than the required return, if the analyzed investment presents a rate lower than the required return, the project must be rejected (GITMAN, 2002).

Payback is the period of return on the investment, that is, it shows the time necessary for the recovery of the invested capital (GITMAN, 2002).

Payback = (Initial Investment)/(Regular cash flows)

The project was implemented in 2010 with Eucalyptus citriodora seedlings and MG5 pasture that was already native in the studied area, the producer contracted technical assistance at a cost of R$ 1.60 per seedling to implement the agroforestry systems, having a total cost of R$ 1,176.00 / ha in the silvopastoral system (S1) and the cost of R$ 2,800.00 in the system (S2).

The spacing used in the Silvipastoril System (S1) is 3 lines with a spacing of 18 meters between lines, containing 3 meters between them and 1,7 meters between trees. The animals can only enter the S1 after one year and leave finished after completing 30 months, for slaughter in refrigerators in the region.

All data referring to the implementation of the production systems were provided by the farm management, in this study the data collection period took place in the year 2010 to 2017 and the diagnoses for implementing the silvopastoral system were considered (System 1 = Eucalyptus + Beef cattle) and also the conventional system (System 2 = Eucalyptus plantation).

The information regarding the costs, expenses and revenues of the property was obtained through accounting and management reports provided by the São João farm manager. The fraction of costs per hectare in both the implementation and maintenance was obtained through apportionment in relation to costs and total investments. Below are some photos that illustrate the S1 in the studied property.

RESULTS AND DISCUSSIONS

Arrangement of the costs of implementation and maintenance of the silvipastoril system (S1)

This system includes the costs of implantation and maintenance of livestock within S1, the animals enter the system after 12 months and leave the system for a total of 30 months. The price used in the acquisition of animals by the producer, was R$ 650.00 per animal, this value is based on the internal cost of the property that used an occupancy rate of 1.60 A.U.

The livestock maintenance costs in the Silvipastoral system (S1), are presented in the item herd, depreciation / exhaustion, employees' salaries, supplements and medications, of which total a total cost per ha of R$ 1,158.99. This index is close to that found by Santos and Grzebieluckas (2014), who used a rate of 1.48 animal/ha.

In relation to the depreciation item of movable and immovable property owned, they were calculated according to the rates available by the Federal Revenue Service (2012). For exhaustion, a rate of 10% was used, resulting from the decrease in the pasture's production capacity. Both depreciation and depletion were deducted from cash flows because these amounts do not pass through cash as they are expendable expenses.

The price per hectare of land traded in the region is R$ 15,000.00 (estimated value for sale), which generated a cost of land of R$ 1,200.00 per year (15,000.00 x 8% = R$ 1,200.00).

The Minimum Attractiveness Rate (TMA) of the traditional financial application, which in agricultural cases is 6% per year, in this case it was considered a rate of 8% based on the Special Settlement and Custody System (SELIC), as it has better representation on the national market.

On the remuneration of capital, a rate of 12% was used. Maintenance refers to machinery and equipment, pastures, fuels, parts, etc. Employees' salaries are included therein, as well as annual charges.

It is noted by the history of entries and exits of animals in the S1 system, in the year 2011, that the system received 1168 animals, totaling 1.6 A.U. per hectare. However, from 2012 there was a decrease in the availability of pasture and consequently the reduction in the entry of animals.

During this period, there was no thinning of the trees or the first cut that normally occurs after the 4th year onwards. The consequence for such strategic decisions was the increase in shading and the consequent degradation of pasture, which culminated in the gradual reduction of stocking in the area. In 2016, due to the grazing capacity for the animals, the decision made was to reduce the stocking capacity in the studied area by 50%.

According to table 1, the costs of implementing S2 were around R$ 2,874.54 and the cost of implementation is R$ 2,800.00 per ha, and maintenance inputs, charges and wages, depreciation and land costs totaled R$ 74.54 per ha.

The costs of implementing and maintaining the S2 system are very close to those studied by Rapassi et al. (2008) who found R$ 2,781.58 (1.84 / plant) with 1,515 plants / ha and between R$ 1,093.76 to R$ 506.24 for maintenance. They also exceeded the costs found by Vale (2004), which had 1,111 plants per ha and cost R$ 1,223.68 (R$ 1.10 / plant).

Table 1. Costs of implementation and maintenance of S2 in R$ / ha at Fazenda São João.

Specifications	R$ / ha	
Deployment Cost / Contracted Services		
1750 seedlings per ha x R$ 1.60 (cost per seedling)	R$	2,800.00
Maintenance		
Glyphosate Herbicide	R$	9.78
Citromax Granules 300 g	R$	13.50
Anthill verification	R$	4.79
Wages and Salaries	R$	32.88
Social charges	R$	1.13
13 salary	R$	3.87
Benefits	R$	0.25
Depreciation	R$	1.64
Land cost	R$	2.47
Maintenance	R$	0.98
Electricity	R$	1.64
General materials	R$	1.37
Communication	R$	0.24
Total	R$	74.54
Total (cost of implementation + Maintenance)	R$	2,874.54

Source: The author, 2018.

When comparing the costs of implementing and maintaining S1 and S2, there is a difference of R$ 539.01 / ha, since in S1 the value was R$ 1,158.99 (Herd) + R$ 1,176.00 (tree planting / implantation) and in S2 of R$ 2,874.00. Therefore, the S1 has a lower implementation and maintenance cost.

According to Table 2, there was an initial investment for the implementation of the system (S2) in 2010 of R $ 2,800.00 / ha with own resources, however in the years 2011 and 2012 the maintenance of the area was R$ 74.54 / ha and from 2013 to 2017 the value was R$ 68.87 / ha.

Table 2. Cash flow - Silvipastoril System (S2) of Fazenda São João in R$ / ha.

Specifications				**R$ / ha**	
Investment value in 2010				-R$	2,800.00
Maintenance	Period	Revenue			
Year 0	2011			-R$	74.54
Year 1	2012			-R$	74.54
Year 2	2013			-R$	68.87
Year 3	2014			-R$	68.87
Year 4	2015			-R$	68.87
Year 5	2016			-R$	68.87
Year 6	2017	R$	10,678.50		

Source: The author, 2018.

For the calculations of NPV, Payback and TIR, the sale of the standing forest was simulated at a value of R$ 45.00 / m^3 (current market value) which totaled a value of R$ 10,678.50 / ha, which value practiced on the market in Mato Grosso do Sul. Table 2 demonstrates the cash flow of the S2 system.

The cost values for the implementation of the S1 were R$ 1,176.00 / ha, and maintenance in the first two years was R$ 39.44 / ha, in the other years they were R$ 36.44 / ha. The costs presented were low due to the use of own resources. In relation to the total sale of trees, a simulation was carried out at R$ 45 / m^3 / ha and resulted in a total of R$ 10,678.50 / ha.

Animals enter the system at 12 months and stay until they are 30 months old.

CONCLUSIONS

S2, on the other hand, showed a positive result, as there was a return on investment from the seventh year on, longer than in S1. However, S2 depends on a feasibility study, planning, profile of the property and the consumer market to become a sustainable alternative.

Further studies of this nature are needed in order to further determine and consolidate these production systems, which also allow for the assessment of environmental services and the direct benefits demonstrated by the study.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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THINNING EFFECT ON TREE GROWTH AND WOOD PRODUCTION IN INTEGRATED SYSTEMS

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ABSTRACT

In crop, livestock and forest integrated system (ICLF) tree thinning management is adopted to add value and minimize competition. This study aims to assess the effect of ICLF and thinning management on eucalyptus growth and wood productivity. The experimental design was in randomized blocks, with four replicates. The treatments were: (I) F, forest with 476 tree ha^{-1} before and 270 trees ha^{-1} after thinning (II) CF-S8, with 270 and 135 trees ha^{-1}; (III) ILF-T, with 270 and 101 trees ha^{-1} (IV) ICLF-S5, with 270 and 90 trees ha^{-1}; (V) ICLF-S4, with 270 and 90 trees ha^{-1} and (VI) ICLF-S8, with 270 and 45 trees ha^{-1}. The ICLF systems increased tree growth and production (clone H13), due to the lower tree density in these systems than homogeneous forest. The total wood production was lower in the integrated systems due to the lower initial tree density than homogeneous forest. The differences observed in the integrated systems are due to the thinning management, such as the season, intensity and type (selection or systematic). The integrated system with the largest number of trees remaining after thinning (ILF-T) presents the highest wood production, equal to 57% of the remaining wood in homogeneous forest.

Key words: land use systems; sustainable intensification; diversification

INTRODUCTION

In Brazil, there are 11.5 million hectares being used as integrated crop-livestock-forestry (ICLF) systems, of which 1.5 million hectares are in Mato Grosso (EMBRAPA, 2016). Among the four possible production configurations, crop-livestock integration (ICL) is the most adopted by producers with 83% rate. The configurations involving the forestry component are little adopted, with crop, livestock and forestry integration (ICLF) with 9% livestock and forestry integration (ILF) 7% and crop and forestry integration (ICF) only 1% (EMBRAPA, 2016). Therefore, the consolidation of the forestry component in the expansion of integrated systems is a major challenge.

The main reasons for these low ICLF adoption configurations is the lack of silviculture information by producer as, the reduction of crop and livestock production (pasture) due to shadow effect, the needs of initial investment with returns in medium and long term, qualified labor, lack of technical assistance and, economic indicators as, market guarantee for wood products.

In ICLF, the forest can compete for water, light and nutrients, impairing the development of crops and forage accumulation (BUNGENSTAB et al., 2019). Therefore, the thinning management aims to reduce competition, both between individual trees and between trees population and other components of system (NICODEMO et al., 2016), maximizing the integrated system productivity and profitability of the integrated system.

Therefore, due to the complexity and dynamism of relationship between the components of ICLF system is necessary to monitor the trees growth and production to understand it, to make inferences about the local productive potential, to identify the optimum age to apply silvicultural practices to plan activities and to estimate production (BATISTA et al., 2014). So, to understand the effect of ICLF and thinning management on tree growth and wood production is important to carry out the proper planning of silvicultural practices and to maintain the synergistic relationship between system components. This study aims to assess the effect of ICLF and thinning management on eucalyptus growth and wood productivity.

MATERIAL AND METHODS

The experiment was carried out with hybrid H13 (*Eucalyptus urograndis*) in the experimental field of Embrapa Agrosilvopastoral, located in Sinop, MT, Brazil (11° 51'S, 55° 35'W, 370 m altitude), at Amazon biome in 2011. The climate is classified as Am (tropical with dry winter) (Alvares, 2014). The annual average temperature is 25,8 °C, the average annual air relative humidity is 82.5% and the accumulated precipitation is 2.250 mm, with higher intensity from December to March (Embrapa, 2019).

The treatments were: 1) F: Eucalyptus forest, with 952 trees per hectare (3.5 m x 3.0 m) which received 50% selective thinning in the fifth year (476 trees) and 50% in the eighth year, remaining 240 trees per hectare (~ 6.0 m x 7.0 m); 2) ICF-S8: Integrated crop and forestry, with triple rows of eucalyptus, spacing 30 m + 3'(3 m x 3,5 m) with 270 trees per hectare. In the fifth year received 50% selective thinning (135 trees ha^{-1}) and in the eighth year, the laterals lines were thinned, remaining 45 trees per hectare (~ 6 m x 37 m); 3) ILF-T: Integrated livestock and forestry, with triple rows of eucalyptus, spacing of 30 m + 3'(3 m x 3,5 m) with 270 trees per hectare. In the fifth year received 50% selective thinning and in the eighth year had 25% selective thinning, remaining 101 trees per hectare (~ 30 m + 3'(8 m x 3.5 m)); 4) ICLF-S5: Integrated crop, livestock and forestry, with triple rows of eucalyptus, spacing of 30 m + 3'(3 m x 3,5 m) with 270 trees per hectare. In the fifth year, the laterals lines were thinned, remaining 90 trees per hectare (~ 3 m x 37 m); 5) ICLF-S4: Integrated crop, livestock and forestry, with triple rows of eucalyptus, spacing 30 m + 3'(3 m x 3,5 m) with 270 trees per hectare. In the fourth year, the laterals lines were thinned, remaining 90 trees per hectare (~ 3 m x 37 m); and 6) ICLF -S8: Integrated crop, livestock and forestry, with triple rows of eucalyptus, spacing 30 m + 3'(3 m x 3,5 m) with 270 trees per hectare. In the fifth year received 50% selective thinning and in the eighth year, the lateral lines were thinned, remaining 45 trees per hectare (~ 6 m x 37 m).

The experimental design was in randomized blocks, with four replicates. The F systems were evaluated in 1 ha experimental plots and the other plots had 2 ha. The data were obtained in 24 plots containing three rows of trees totaling 81 trees, installed in the center of the central row for integrated systems and in the center of the plot for homogeneous forest.

The forest inventory was carried out at 108 months after planting, measuring diameter at breast height (DBH), with diametric tape total height (H), with electronic hypsometer. Basal area was calculated by $BA= \sum(\pi d^2/4)$ and wood volume by $V_{cc} = \sum(gHf)$, where BA, basal area (m^2 ha^{-1}); d, diameter measured at 1.30 m from the soil (cm); g, tree individual area (m); H, total height (m); f, artificial form factor (0,45); and V_{cc}, wood volume with bark (m^3 ha^{-1}).

The statistical analyses were performed after an evaluation of the normality of the data distribution by the Lilliefors test and the homogeneity of variances by the Hartley, Cochran and Bartlett tests. The means were compared by analysis of variance and Tukey's test ($p < 0.05$).

RESULTS AND DISCUSSIONS

The DBH, H, BA and wood volume were significant different between production systems for DBH was higher in integrated system than forest (Figure 1A), possibly due to the lower tree density, which implies less competition between trees (MONTE et al., 2009; MAGALHÃES et al., 2019). Similar results, greater growth in the diameter of a clone of *E. grandis* x *E. urophylla* in an ICLF production system than homogeneous forest also observed in Cerrado conditions (OLIVEIRA et al., 2015).

The ICLF-S4 system, presented highest average DBH (Figure 1A), because the early removal of laterals lines favored trees growth in diameter than to 50% selective thinning in 5th year and removal the laterals lines just in 8th year of ICLF-S8 system. Furthermore, no differences were observed between the ICLF systems treatments and also, between thinning managements (Figure 1A).

The highest height of trees was observed in the ILF-T and lowest in ICLF-S5 (Figure 1B). The ILF-T system received only selective thinning in 5th and 8th years (50 % and 25% respectively), in contrast the ICLF-S5 system was converted to simple rows in the 5th. Therefore, the higher height ILF-T may have occurred due to competition caused by the higher tree density (MONTE et al., 2009), in relation to system converted to simple rows. The greatest development in tree height at agrosilvopastoral systems occurs in the arrangements with thein highest tree density (OLIVEIRA et al., 2009).

Although the integrated systems promote greater individual tree growth, mainly from the DAP, the basal area and the wood volume per hectare are smaller (Figure 1C and 1D). This lower production is reflex of low initial tree density in ICLF systems which represented only 26% trees from homogeneous forest. Also, until the 4th year there was no effect of the integrated systems on trees growth, indicating that there was no effect of eventual trees benefits by fertilization done in annuals crops (MAGALHÃES et al., 2019). Thus, we can affirm that the differences observed at this time within the integrated systems are due to thinning management carried out, such as the season, intensity and type (selective or systematic), resulting in different remnant tree densities in each system.

The F system which presented the highest BA and Vtc at 108 months reflecting the highest tree density (240 trees ha^{-1}), while the ILF-S8 and ILPF-S8 systems which have the lowest averages have the lowest trees densities (45 trees ha^{-1}). In this case the IPF-T with highest tree density (128 tree ha^{-1}) presented wood production equivalent 57% of the remnant wood in the F system (Figure 1D). For eucalyptus trees, there is a high correlation between increase in available area and increase in individual trees dimensions, such as DBH, volume and aerial and radicular biomass (SANTANA et al., 2008; OLIVEIRA et al., 2009; OLIVEIRA et al., 2015; REINER et al., 2011).

The F produces higher wood volume then ICLF systems (OLIVEIRA et al., 2015) and in integrated systems greater BA and Vtc per hectare are observed in arrangements with a higher tree density (OLIVEIRA et al., 2009). These results are explained due to greater number of trees per area in both system, homogeneous and integrated systems with higher tree density. The wood volume is influenced by the height, DBH and tree number reflecting the differences found between systems (Figure 1).

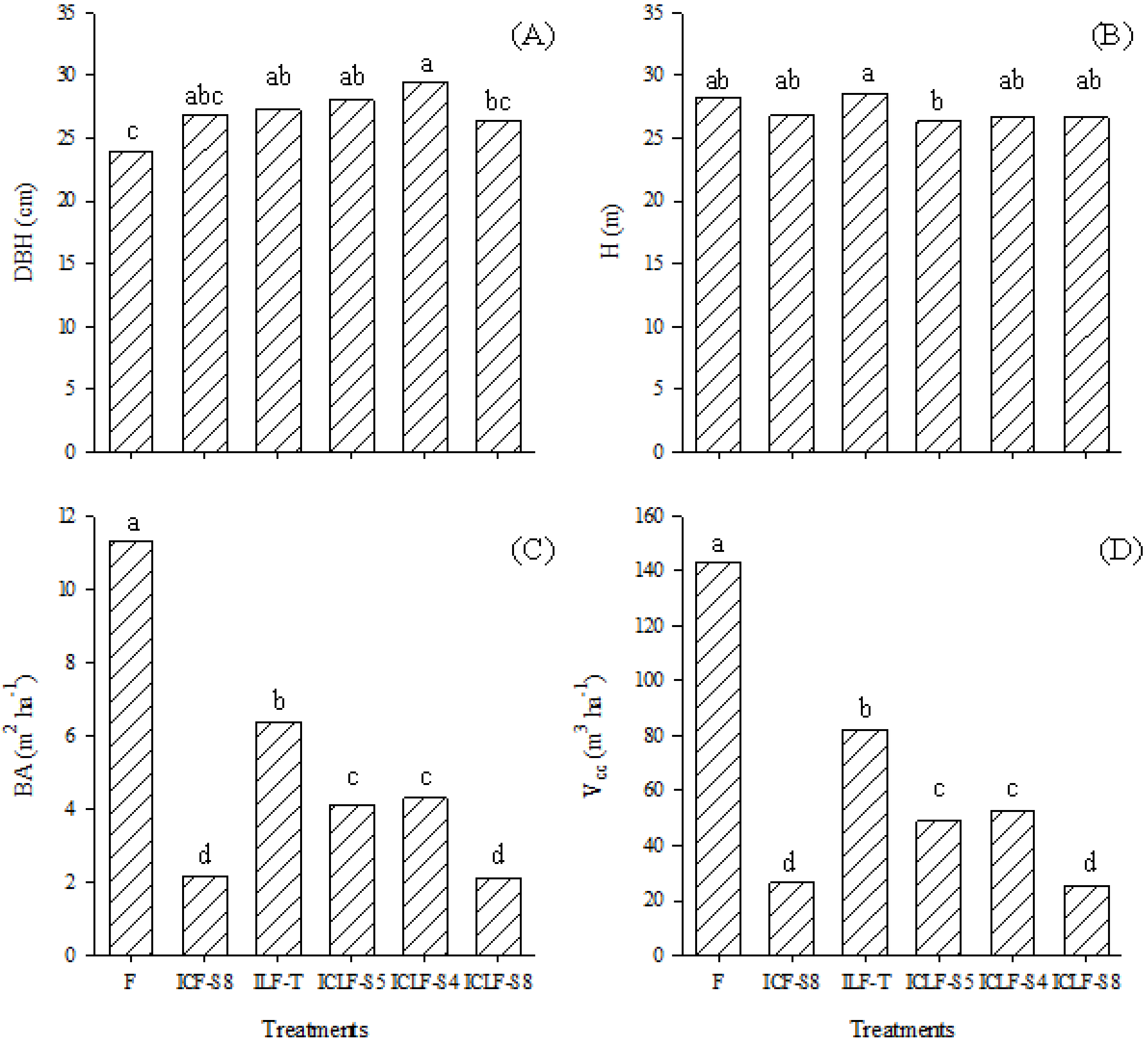

Figure 1. Diameter at breast height (DBH), total height (H), basal area (AB) and wood volume (clone H13) in production systems with eucalyptus, at nine years after planting. Columns with different letters indicate significant differences (Tukey's test, $p < 0.05$).

CONCLUSIONS

The ICLF provides greater growth and individual tree production.

Thinning management in ICLF system determines final wood production.

The ILF-T system, with higher trees density after thinning management present higher wood production, equal 57% of remnant wood in F.

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POD, STRAW AND ROOT MASS AFTER SOYBEAN PHYSIOLOGICAL MATURITY IN INTEGRATED SYSTEMS

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ABSTRACT

Soybean has a great economic impact for Brazil and with the growing search for sustainable systems the systems integration has gained increasingly space. Thus, the aim was to evaluate the effect of different integration systems on soybean grain mass, straw dry mass and root mass. The experiment it was carried out at the Brazilian Agricultural Research Corporation (Embrapa), Beef Cattle Unit, in Campo Grande – MS, Brazil. The experimental design used was a randomized block design with four repetitions. The treatments were agro-forestry-pasture system (ICL) in full sun; agro-forestry-pasture system with inter-row distance of 28 m ($ICLF_{28}$); agro-forestry-pasture system with inter-row distance of 22 m ($ICLF_{22}$). There was no significant effect for pod mass in the evaluated systems, however an effect was observed for straw and root mass in the systems, besides pod mass in the sampling sites of the ICLF systems. The pod mass is not affected by the integration system, but in the ICLF systems the distance from the row alters the mass. Straw and root mass are affected by the integration system.

Key words: Sustainable agriculture; *Glycine max*; shading

INTRODUCTION

Soybeans have presented, each year, an increase in its cultivation and yield area, and this has provided positive economic impact for Brazil that reached in the 2018/2019 harvest mean production of 3,359 kg ha^{-1} (CONAB, 2019).

However, the appeal of using sustainable production methods is growing every year. Integrated systems have gained increasing visibility, among them the Crop-Livestock-Forestry Integration (ICLF) system that stands out as a strategy for reducing greenhouse gas emissions (PEREIRA, 2019).

Crop yield in integrated systems with trees can increase or decrease depending on the spatial arrangement of the tree component, size and management of trees over time, crop species used (REIS et al., 2007; REYNOLDS et al., 2007).

This is due to the shading performed by the tree component. This shading is responsible for reducing the incidence of light, affecting the plants ability present in the field to perform photosynthesis, influencing the grains yield (VIANA et al., 2012). Thus, the aim was to evaluate the effect of different integration systems on soybean grain mass, straw dry mass and root mass.

MATERIAL AND METHODS

The experiment was conducted at the Brazilian Agricultural Research Corporation (Embrapa), Beef Cattle Unit, located in Campo Grande, MS, Brazil (latitude 20º 27' S; longitude 54º 37' W; 530 m altitude).

The climate is in the transition belt between Cfa (humid mesothermal without drought) and Aw (humid tropical), with an average annual rainfall of 1,560 mm, with rainfall during the hottest part of the year and drought during the coldest months. The average temperature observed during the period was 25 °C, with variations from 31.3 °C to 20.8 °C in maximum and minimum, respectively.

The experimental area has been used in succession cycle since 2008, using pasture in the winter period since the beginning and occurring crop variation in the summer, where in 2008 soybeans and sorghum were grown and in the following year eucalyptus was introduced in the area. In the years 2012 and 2018 soybeans were grown in the area and in the years 2010, 2011, 2013, 2014, 2015, 2017 and 2019 the pasture was the crop used in the summer, in addition in the years 2016 and 2017 a pruning and thinning was performed, respectively of eucalyptus.

The experimental design used was in randomized block design in a banded scheme with four repetitions. The treatments were arranged in subdivided plots, being agroforestry (ICL) with full sun cultivation; agroforestry-pasture system with distance between eucalyptus rows of 28 m ($ICLF_{28}$); agroforestry-pasture system with distances between eucalyptus rows of 22 m ($ICLF_{22}$). The subplots were composed of the sampling sites, being five sites between rows of eucalyptus trees (ICLF). These sites were demarcated on a transect perpendicular to the tree rows (east-west direction).

The sampling sites (north-south direction) were identified by the letters A; B; C; D and E, with the following distances from the nearest tree row: for $ICLF_{28}$, 7 m (A), 10 m (B), 11 m (C), 9 m (D) and 4 m (E). In the $ICLF_{22}$ system, the sampling sites were 3 m (A), 7 m (B), 10 m (C), 7 m (D) and 3 m (E). In both systems, 1 m distance between the rows of eucalyptus and the annual crop was respected.

The soil in the experimental area was classified as Red Dystrophic Latosol. Soil was collected from 0 to 20 cm deep for chemical analysis. In the full sun area the analysis revealed the following values: pH (CaCl2) = 5.36; P (Melich) = 4.91 mg dm^{-3}; K (Melich) = 8.52 mg dm^{-3}; Ca = 2.33 $cmol_c$ dm^{-3}; Mg = 1.49 $cmol_c$ dm^{-3}; Al = 0.01 $cmol_c$ dm^{-3}; S = 4.05 $cmol_c$ dm^{-3}; V = 46.46%. The following values were found in the understory: pH (CaCl2) = 5.08; P (Melich) = 11.03 mg dm^{-3}; K (Melich) = 148.68 mg dm^{-3}; Ca = 2.05 $cmol_c$ dm^{-3}; Mg = 1.19 $cmol_c$ dm^{-3}; Al = 0.07 $cmol_c$ dm^{-3}; S = 3.72 $cmol_c$ dm^{-3}; V = 41.69%.

The soybean crop management in the experimental area was initiated by desiccation of the total area with the use of non-selective herbicides of systemic and contact action known as glyphosate (Roundup®) and paraquat (Gramoxone®) in quantities of 1,225 g and 440 g of a.i. per hectare, respectively.

Sowing was performed on straw mulch in November 2017 with the soybean cultivar TEC7849 iPRO from Bayer. The cultivar's cycle is characterized as late, 7.8 maturity group, medium/high plant stature of indeterminate growth. The seeding rate used was 14.7 seeds per linear meter. Seeds were treated with biological peat inoculant Adhere® 60 - 1.5g m^{-1} (5x109 CFU g^{-1}), liquid inoculant Masterfix® - 4.5mL kg^{-1} seed (1.4 million bacteria per seed) and insecticide Standak Top® at a concentration of 2 mL kg^{-1} seed.

Fertilization was performed in installments using the formulation 00:20:20 in two applications, the first of 100 kg ha^{-1} in the field at the end of October and the second of 150 kg ha^{-1} in the sowing furrow, according to soil analysis. During the crop development applications of insecticides to control pests and fungicides to control diseases were made.

When the soybean crop reached physiological maturity (R8), the plants present in the two 2.0 m rows at a spacing of 0.50 m were harvested by hand. The pod mass was obtained by weighing and the values were corrected to 13% moisture. At the same time the root mass was obtained. After harvest, the straw mass was collected.

The results obtained were submitted to variance analysis by means of SISVAR 5.7 software and when the F test was significant the Tukey test was applied, adopting a probability level of 5%.

RESULTS AND DISCUSSIONS

There was no significant effect for the mass of pods in the three systems evaluated, however there was an effect for the soybeans straw and root mass (Table 1). The ICL system presented the highest straw and root masses among the systems with an increase of 22.72% and 51.96% in comparison to the ICLF, respectively.

Table 1. Productive characteristics of pod mass, straw dry mass and root mass after soybean physiological maturity in integrated systems.

Systems	**Pods** (g plant^{-1})	**Straw** (kg ha^{-1})	**Root** (g plant^{-1})
ICL	262.14 a	7,450.8 a	1.93 a
ICLF$_{28}$	279.82 a	6,204.9 b	1.39 b
ICLF$_{22}$	248.56 a	5,937.4 b	1.15 b
[1]CV (%)	9.73	4.3	4.33

ICL: Integration Crop-Livestock; ICLF$_{28}$: Integration Crop-Livestock-Forest com espaçamento de 28 m; ICLF$_{22}$: Integration Crop-Livestock-Forest com espaçamento de 22 m. [1]CV: Coefficient of variation. Means followed by the same lowercase letter in the column do not differ by the Tukey test (P>0.05).

Although root mass was lower in the ICLF$_{28}$ and ICLF$_{22}$ systems, this did not affect soybean pod mass. The systems with the tree component, soybean suffered from overgrowth affecting root mass production and consequently reducing the roots nutrient uptake capacity (FARIAS NETO et al., 2019).

In contrast, the lower straw mass in the ICLF systems demonstrate that the plant probably reduced its mass, which affected the straw due to the stress caused by shading (VIANA et al., 2012).

The sampling sites affected the pod mass in the ICLF$_{28}$ and ICLF$_{22}$ systems (Table 2). In both ICLF systems, it was possible to observe that the sampling sites closer to the rows showed the lowest pod mass production. This reinforces that the trees presence in the system are responsible for shading the crop, reducing the plant photosynthetic capacity (FARIAS NETO et al., 2019).

This reduction in photosynthetic capacity has a direct effect on the plant, directly affecting the mass of pods, straw and nutrient absorption capacity due to lower root mass, thus harming the yield of the system as a whole (ANDRADE et al., 2004).

Table 2. Pod mass (g) at different sampling locations in ICLF systems after physiological maturity.

Systems	Sampling Locations					[1]CV (%)
	A	B	C	D	E	
ICL	278.3 a	255.7 a	261.6 a	257.2 a	257.9 a	10.37
$ICLF_{28}$	240.5 c	303.8 ab	333.0 a	270.4 bc	251.4 c	8.37
$ICLF_{22}$	227.6 b	268.0 a	270.3 a	248.7 ab	228.2 b	7.38

ICL: Integration Crop-Livestock; $ICLF_{28}$: Integration Crop-Livestock-Forest com espaçamento de 28 m; $ICLF_{22}$: Integration Crop-Livestock-Forest com espaçamento de 22 m. [1]CV: Coefficient of variation. Means followed by the same letter in the row do not differ by Tukey test (P>0.05).

CONCLUSIONS

Straw and root mass are lower in systems with the tree component presence.

Sampling sites closer to the rows in the $ICLF_{28}$ and $ICLF_{22}$ systems reduce pod mass, reinforcing the idea that shading reduces the yield.

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GASTROINTESTINAL NEMATODE EGG COUNTS IN NELLORE HEIFERS RAISED ON INTEGRATED SYSTEMS, MATO GROSSO, BRAZIL

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ABSTRACT

Among the strategies integrating crops, livestock, and forestry, silvopastoral systems must be highlighted due to the particular microclimatic conditions, mainly in tropical countries such as Brazil, where cattle are frequently submitted to unfavorable thermal conditions. However, according to some authors shading can potentially worsen parasitism in herds due to the more favorable conditions. This study aimed to assess fecal egg count in Nellore heifers reared in two silvopastoral arrangements, crop-livestock system and in an open pasture. In silvopastoral composed by triple rows, we found lesser means, with a peak of infection on February/March and October. Regarding the effect of seasons over the year, there was an environmental influence on the egg counts, with higher averages during the late rainy season, and when the dry season starts. Based on our results, it can be concluded that both silvopastoral systems were not a risk factor for nematode egg counts in Nellore heifers, indeed, the shaded system promoted inferior egg counts.

Key words: parasitic burden; helminths; livestock

INTRODUCTION

Gastrointestinal nematodes cause serious injuries such as severe gastroenteritis and acute anemia in livestock. Predominantly, control has been based on chemicals. Despite some technical protocols are available to farmers, treatments without any criteria still a reality in some Brazilian regions, as in the Amazon Biome. The lack of information and inappropriate health management cooperates for drug resistance and economic losses in many farms. Moreover, nematode larvae (L3) have a close relation to the local environmental conditions, concerning pasture composition, and climate features for instance. Regarding performance and animal welfare, many farmers have been adopting integrated systems, as silvopastoral arrangement based on more favorable microclimatic conditions. However, in spite of several benefits of the consortium, afforestation may be a risk factor for parasitosis occurrence according to previous research. The reasons are quite clear; the survival of free-living stages is mainly affected by radiation, temperature and moisture, which directly influences the larval development rate. The present study aimed to assess fecal egg count in Nellore heifers in an Open Pasture (OP), Crop-Livestock system (CL) and two silvopastoral systems (SPS) based on *Brachiaria brizantha* cv. Marandu pastures and eucalyptus (*Eucalyptus urograndis*, H13 clone) trees.

MATERIAL AND METHODS

Location

It was carried out at Embrapa Agrosilvopastoral, Sinop, MT, Brazil (11º 51´ S, 55º 35´ W, 370 m a.s.l.). The soil is a Rhodic Hapludox (Soil Survey Staff, 2014), and the climate was classified according to Köppen criteria as Tropical wet and dry (Aw), with rainfall concentrated in the summer/autumn and the dry season in winter/spring (Stape et al. 2014). The average annual temperature is 25.5 ºC, with 20.2 ºC minimum and 33.0 ºC maximum average temperatures. The mean annual relative air humidity is 70%, with annual precipitation of 2,250 mm.

Production systems and experimental design

A long-term experiment was established in 2011 as described by Magalhães et al. (2019). The experimental design was set in a completely randomized block, containing four systems and four replicates on each (blocks). Randomized blocks were adopted to reduce unexplained variability of some data due heterogeneity in local conditions due to other simultaneous agronomic studies conducted in the same area (see Magalhães et al. 2019). Ninety-six Nellore heifers were distributed into the four systems: (a) livestock in open pasture (OP) with *Brachiaria (syn. Urochloa) brizantha* (Hochst. Ex A. Rich.) Stapf. (palisade grass) cv Marandu; (b) silvopastoral system (single | SPSs), with eucalyptus trees (*Eucalyptus urograndis*, H13 clone) disposed into a single row (east-west direction with 3 meters intra-row spacing trees) spaced 37 meters apart, mixed with pasture Marandu, and overall density of 90 trees ha^{-1}; (c) silvopastoral system (triple | SPSt), also with eucalyptus trees (H13 clone) but disposed into triple rows (east-west direction, 3.0 m intra-row and 3.5 m inter-row spacing) spaced 30 meters apart, mixed with pasture Marandu, with an overall density of 135 trees ha^{-1} . This density was achieved after selective thinning removal of 50% of trees in 2016; (d) crop-livestock system (CL), where both components were rotated every two years. Before livestock started, from October 2018 to February 2019, soybean [*Glycine max* (L.) Merr.] was cultivated and then harvested. All systems were installed and evaluated in experimental plots of two hectares (100 x 200m) each. Palisade grass was adopted in all systems due to its abundance as a monoculture pasture within the region (CARVALHO et al., 2019).

The herd was composed of Nellore heifers (*Bos indicus indicus*) with an initial mean weight of 270 ± 36 kg (add here if SD or SE) and 14 to 16 months of age. In each system, weight gain was recorded every 28 days on 12 tracer animals (i.e., replicates), three heifers per block. Three extra pastures were used as a reserved area, where animals (regulators) used only for adjustments in the stocking rate were kept throughout the experiment, no data was recorded from them. The individual weighing was performed after 16h of fasting, including liquids, and the average daily weight gain was expressed in g day^{-1}.

The experiment was carried out from May to November 2019 (210 days) whit animals in continuous stoked with variable stocking rate, maintaining the canopy height at 30 cm (GOMES et al., 2020), assuming a variation of up to 15%. In February 2019, 50 kg N ha^{-1}, 50 kg K_2O and 40 kg ha^{-1} P_2O_5 ha^{-1} in the form of urea, potassium chloride and superphosphate, respectively, were applied to all pastures. The animals had free access to water (*ad libitum*) and mineral supplements, set at 0.2% of body weight (mix for the dry season: NDT (min.) 530g kg^{-1}; protein min. 300g kg^{-1} | mix for the rainy season: NDT min. 720g kg^{-1}; protein min. 200g kg^{-1}); both formulas used were from Fortuna Nutrição Animal™. During the dry season, starting in June, corn silage was provided at an amount of 15 kg of animal^{-1} day^{-1}, terminating the offer on the first week of October.

Fecal egg count | EPG

The fecal samples were collected directly from the rectum of the animals and taken to the laboratory to further analysis. The technique of Gordon and Whitlock, modified by Ueno and Gonçalves (1998), was used to calculate the number of EPG. In total, 12 samplings of fecal material were gathered between February 2019/2020, covering a dry and rainy season.

Statistical analysis

The data were analyzed with general linear mixed models (PROC MIXED | SAS™ version 9.4 | Institute Inc., Cary, NC, USA) with a parametric structure. The treatments (OP, CL, SPSs, SPSt), cycles (repeated measures) and their interaction were considered fixed effects. The repetition (block) was considered a random effect.

RESULTS AND DISCUSSIONS

There were differences in the parasitic burden for the EPG mean counts among SPSt and the other three systems (Table 1). Regarding the effect of seasons over the year, it is possible to clearly check the environmental influence on the egg counts, and as expected, higher averages of EPG were obtained during the dry season. In SPSt and OP, greater fecal egg counts were found in February/March and October of 2019. Similarly, greater fecal egg counts were found in February/March in SPSs, but the second pick occurred earlier, in May of 2019. On the other hand, in CL system greater egg counts were found in February/March of 2019, but there was no second peak over the year.

Table 1. Egg counts (EPG) over 12 months.

System	EPG	Standard Error
OP	137.95^{A}	15.8571
SPSs	133.86^{AB}	15.8571
SPSt	85.85^{B}	16.1176
CL	169.43^{A}	15.8571

Lower case letters compare systems (p < .05).

CONCLUSIONS

We concluded that the silvopastoral system was not able to influence the parasitic burden according to egg counts of gastrointestinal nematodes in Nellore heifers. Moreover, February/March and October are the most critical months, in which there is a greater parasitic infestation. In summary, silvopastoral systems are an interesting option for cattle ranchers without the need for a differentiated sanitary procedure based on the helminth's strategic control protocol.

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DEVELOPMENT OF THREE SORGHUM CULTIVARS IN CONSORTIUM WITH UROCLHOA BRIZANTHA CV. PAIAGUÁS AND DWARF PIGEON PEA

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ABSTRACT

The sorghum (*Sorghum bicolor* Moench.) Intercropped with grass and dwarf pigeon can enable the production of forage and enable of pastures in the cerrado. The objective of this research was to verify the development of sorghum plants in a triple consortium in an upland area. Sorghum cultivars were evaluated: graniferous, A9902 (SG); Volumax (FS), Rancheiro (SDA), with *Urochloa brizantha* cv. Paiaguás with dwarf pigeon in the densities of 0, 6, 12, 18, 24 seeds m-1, between the lines. In the sowing, 350 kg ha-1 of the formula 08-28-16 (NPK) was applied, and 120 kg ha-1 ammonium sulfate in the cover at 30 days. The experimental design was randomized blocks in a factorial scheme (3 x 5), with 04 repetitions. Plant height, stem diameter and sorghum plant population were evaluated, and in dry grass and pigeon pea the dry matter productivity was evaluated during the consortium harvest. The SDA cultivar showed the highest AP, while the highest DC was observed in the SG, in the two years of evaluation. The cultivar PP decreased to the second. In SG and FS, better conditions for the development of grass-paiaguás were observed, favoring the establishment of pasture.
Key words: *Sorghum bicolor* Moench; Fodder production; Cultivation in the cerrado

INTRODUCTION

The consortium of forage grasses such as those of the genera *Urochloa* sp. with sorghum (*Sorghum bicolor* L. Moench), interspersed with legumes between the sowing lines, can enable the production of better-quality forage in the off-season for the months of greatest food scarcity (dry season), and lead to improvements in productive capacity. of soil in pasture areas. Sorghum cultivation is an excellent option for the cerrado region and can be grown both in summer crops and in second crops (safrinha), in rotation with soybeans. Since its expansion is favored in this region, it can be inserted in succession or rotation with summer crops (COELHO et al., 2002), in situations where low rainfall and soil fertility offer greater risks for the corn crop. The interaction between cultures for the conditions of establishment of a consortium, require development assessments regarding the agronomic potential, so that one can better understand the growth and development of each of the species used, in order to make the cultivation feasible and continue the pastures. improved, making the areas suitable for agricultural production. The objective of this work was to evaluate the development of three sorghum cultivars intercropped with *Uroclhoa brizantha* cv. Paiaguás, subjected to five dwarf pigeon pea sowing densities in autumn cultivation for two years, harvests 2016 and 2017.

MATERIAL AND METHODS

The experimental area is located at the Teaching, Research and Extension Farm (FEPE) - Vegetable Production Sector, Faculty of Engineering - UNESP, Ilha Solteira Campus, located in the Cerrado Biome, Selvíria municipality, State of Mato Grosso do Sul. geographic coordinates of latitude 20°20'36.95” S, longitude 51°24'5.96” W and altitude of 356m. The preparation of the area before the sowing of the cultures was carried out with desiccation of the weed with Glyphosate herbicide

(1,560 g ha^{-1} of a.i.), and later harvesting of vegetable residues (Triton). Dolomitic limestone (PRNT 85%) was applied on the surface, without incorporation, at the dose of 2.0 t ha^{-1}, in September 2015.

The sorghum sowing took place at a depth of 0.03 m, with 6 seeds per meter, using a 7-row sowing-fertilizer tractor with a furrow-like mechanism (stem), in no-tillage system (NTS), with a spacing of 0.45m, on 04/04/2016 and 04/04/2017, respectively, for the 2017 and 2018 autumn crops. 350 kg ha^{-1} of the formula 08-28-16 (N-P_2O_5- K_2O) were used in the sowing. The cultivars used were grain Sorghum, cultivar A 9902 (SG); Forage sorghum, cultivar Volumax (FS) and, Sorghum double aptitude, cultivar Rancheiro (SDA), recommended for the region. The cover fertilization was carried out manually on 05/05/2016 and 05/03/2017, in the sorghum sowing line, when the sorghum plants had 6 fully developed leaves. 120 kg ha^{-1} of N (ammonium sulfate with 20% N) were applied, 30 days after sowing, according to the recommendations of Cantarella, Raij and Camargo (1997). The seeds of *Urochloa brizantha* cv. Paiaguás were mixed with the fertilizer, moments before the operation, and placed in the fertilizer compartment of the seeder-fertilizer used for the sorghum, and sown simultaneously with the sorghum culture, in the same implement. Being deposited at a depth of 0.06m, using approximately 10 kg ha^{-1} of pure viable seeds. The seeds of the dwarf pigeon (Caqui cultivar) were deposited at a depth of 0.05 m, just after sowing the sorghum, at densities of 0, 6, 12, 18, 24 seeds m^{-1}, at a spacing of 0.45 m, on the other, a tractor-seeder-fertilizer set with a double disc-type furrower mechanism found for NTS, aligning the seeding devices between the lines of the sorghum seeding. The experimental design used for the two years of conducting the experiment was that of Randomized Blocks in a factorial scheme (3 x 5). Formed by 03 (three) sorghum cultivars (graniferous, forage and double aptitude) cultivated with the paiaguás grass in the sowing line and intercropped between 05 (five) dwarf pigeon sowing densities (0, 6, 12, 18 and 24 seeds m^{-1}), with 04 (four) repetitions, totaling 60 plots. The experimental plots in the field were arranged in sowing strips, formed by 14 lines of sorghum spaced at 0.45 m with paiaguás grass and pigeon pea between the lines spaced at 0.45 m. The dimension of the area of each plot was 6.30 x 8.50 m, totaling 53.55 m^2 per plot.

The height of sorghum plants (HP) was evaluated, with the aid of a graduated ruler, and stem diameter (SD) using a 0.1 mm precision caliper, with the measurement carried out in the second internode from the base on 10 plants arranged in the same line in the useful area of the plot. The determination of plant populations (PP) was obtained by counting the number of plants contained in the three central lines with 3 m in length in each plot, converted to the number of plants per hectare.

RESULTS AND DISCUSSIONS

Significant differences were observed between treatments for PP, with a further reduction in the PP attributed due to the significant influence of dwarf pigeon pea sowing densities for the second year of cultivation (Table 1). This reduction in PP from the first to the second year of cultivation, can be attributed to the use of the same species in consortium for two consecutive years. Another condition is the fact that the consortium provides a greater amount of straw, making it difficult to sow with a shank mechanism in the seeder. According to Silva et al. (2015) evaluating sorghum consortia with. *U. brizantha* cv. Marandu and *U. decumbens,* this effect can be described due to competition with the grass. Reporting a reduction in the plant stand, which may also influence grain yield. Mateus et al. (2011) also highlighted the influence of grass, evaluating sorghum intercrops with grasses in the formation of forage during the dry season.

Table 1. Height of plants (HP), stem diameter (SD) and plant population (PP) of sorghum cultivars intercropped with paiaguás grass and with different densities of pigeonpea sowing between rows, in second crop crops, Selvíria - MS, 2016 and 2017.

	HP (cm)		**SD (mm)**		**PP (plant ha^{-1})**	
Treat.	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
SG	118 b	134 c	18.9 a	12.1 a	196,296	147,220 b
FS	187 a	186 b	18.5 a	10.1 b	185,240	169,998 a
SDA	191 a	195 a	15.7 b	10.1 b	201,944	166,109 a
			Dens.			
0	167	170	18.5	10.0	205,247	162,961[1]
6	163	173	17.4	9.9	188,734	157,405
12	164	175	18.1	10.7	188,364	179,164
18	167	173	16.7	11.4	209,876	164,813
24	166	168	18.1	11.8	180,246	141,202
M.S.D.	4.57	8.85	1.31	1.54	26,568	18,856
S.V.			*F test*			
Treat.	9.58**	162.97**	20.13**	6.57**	1.20^{ns}	4.90*
Dens.	1.32^{ns}	0.71^{ns}	2.06^{ns}	2.23^{ns}	1.57^{ns}	3.73*
Treat x Dens.	1.78^{ns}	1.81^{ns}	1.4^{ns}	1.26^{ns}	0.61^{ns}	0.15^{ns}
Mean	166.0	172.0	17.8	10.8	194,493	161,109
C.V.	3.60	6.72	9.66	18.66	17.77	15.27

Averages followed by the same letter, lower case in the column, do not differ statistically from each other, by the Tukey test at 5%. SG: consortium of graniferous sorghum / grass-paiaguás and dwarf pigeon; FS: consortium of forage sorghum / paiaguás grass and dwarf pigeon pea; Dens. = dwarf pigeon pea sowing density; SDA: consortium of double-capacity sorghum / paiaguás grass and dwarf pigeon. S.V.: sources of variation; Treat.: Treatment; Dens.: Density of sowing if dwarf pigeon. **, *, ns: (P <0.01), (P <0.05) and (P> 0.05), respectively; [1]$y = 158014.29 + 2837.27x - 143.29x^2$ (R^2 = 66.78%).

The cultivars of FS and SDA showed higher HP than GS (Table 1). Assessing the development of the sorghum consortium with forage grasses, Miranda and Pereira (2001), reported plant height as maximum 170 cm for SG, with height variations between 200 to 220 cm for SDA and above 270 cm for FS. These differences occur due to the morphology of the plants used in the experiment, and are attributed to the characteristics of the sorghum cultivars, in producing grains, compared to the plant specialized in producing more vegetable mass, these results being expected, due to the sorghum with grain production characteristics. present a smaller size. The opposite behavior occurred for the HP and the SC, where the cultivar of GS, with smaller size presented higher values of DC. The sowing took place almost on the same date for the 2016 and 2017 harvests. Even though the FS was the highest among the three cultivars evaluated, its growth maintained the same height in both crops, possibly not having expressed its full potential due to the cultivation in 2nd crop (photoperiod effect). Thus, the increase in SD in the first year of cultivation for this cultivar can be a strategy to compensate for the shorter height. The characteristics of sorghum plants vary with climatic conditions, soil and temperature, and the fact of being in conditions of triple intercropping may have an aggravating factor related to the possible competition between intercropped species.

The water reduction in the second year of cultivation (2017) occurred during the growth stage 2, between 30 to 60 days after germination, seems to have affected the SD more in all evaluated cultivars. This period coincides with that of the application of N in coverage, and the availability of water assumes extreme importance. As for AP, it is observed that the cultivar of SDA was similar to the FS for the first year of cultivation, and stood out differing significantly during the evaluation for the second year. In the present study, regardless of the cultivar evaluated, the lower values presented for the evaluated cultivars, can be attributed to the cultivation in second crop (autumn). No significant differences were observed for the total dry mass of pigeon pea between treatments in the consortium for both harvests (Table 2). However, higher values were observed in the form of consortium with SG depending on the years of cultivation. In general, the values reported for all treatments in the second year exceeded those obtained for the first year of cultivation.

Tabel 2. Total dry matter of paiaguás grass (DM Paiaguás) and total dry matter of pigeon pea (DM Pigeon pea) in the consortium with different sorghum varieties. Selvíria-MS, 2nd harvest 2016 and 2017.

	DM Paiaguás		**DM pigeon pea**	
Treat.	**kg ha^{-1}**			
	2016	**2017**	**2016**	**2017**
SG	2,268 a	2,502 a	685	1,323
FS	1,895 ab	2,274 a	250	1,279
SDA	1,151 b	354 b	401	1,039
		Dens.		
0	3,135(1)	2,778(2)	0(3)	0(4)
6	3,395	1,841	0	1,561
12	3,910	1,726	150	1,545
18	1,356	1,066	603	1,983
24	578	1,138	1,476	979
M.S.D.	2,132	1,012	545	893
S.V.		*F test*		
Treat.	4.20*	15.97**	1.93^{ns}	0.34^{ns}
Dens.	15.58**	3.26*	9.35**	5.19**
Treat x Dens.	0.89^{ns}	1.52^{ns}	0.97^{ns}	1.91^{ns}
Mean	1,771	1,710	446	1,214
C.V.	25.8	77.2	85.9	95.9

Averages followed by the same letter, lower case in the column, do not differ statistically from each other, by the Tukey test at 5%. SG: consortium of graniferous sorghum / grass-paiaguás and dwarf pigeon; FS: consortium of forage sorghum / paiaguás grass and dwarf pigeon pea; Dens. = dwarf pigeon pea sowing density; SDA: consortium of double-capacity sorghum / paiaguás grass and dwarf pigeon. S.V.: sources of variation; Treat.: Treatment; Dens.: Density of sowing of dwarf pigeonpea. **, *, ns: (P <0.01), (P <0.05) and (P> 0.05), respectively: $^{1}y = 3202.15 - 199.21x$ ($R^2 = 63.98\%$); 2 ** $y = 2520.92 - 67.54x$ ($R^2 = 86.55\%$); $^{3}y = -265.26 + 59.2795x$; $^{4}y = 69.66 + 262.44x - 9.28x^2$ ($R^2 = 90.56\%$).

The dry matter productivity of paiaguás grass was higher when intercropped with SG cultivars for the two years of cultivation (Table 2). This behavior probably occurred due to less competition from the GS cultivar in relation to the shading occurred on the grass, due to its lower height. However, the productivity values of the paiaguás grass obtained in the consortium with GS in the autumn harvest 2016 was 2,268 kg ha^{-1} and in the autumn harvest 2017 with 2,502 kg ha^{-1}, respectively. Silva et al. (2013) obtained values varying between 1,250 and 1,540 kg ha^{-1} in crops of *Urochloa brizantha* intercropped with graniferous sorghum. Oliveira et al. (2005) also reported dry matter values of grass around 1,550 kg ha^{-1}, in consortium with corn in the production of silage, quantified shortly after harvest, and after 60 days, 12,577 kg ha^{-1} were reached of green matter. Crusciol et al. (2011) highlighted yields above 5,000 kg ha^{-1}, evaluating marandú grass intercropped with grain sorghum, obtained right after the consortium, even with restricted conditions of development, where the low size of grain sorghum, allowed that the grass presented a better development within the studied conditions (spring/summer).

The sowing densities of pigeon pea had significant effects on the total dry matter productivity of the Paiaguás grass in both harvests, causing reductions in the development of the grass with the increase in the sowing density of the legume (Table 2). It is also observed a greater interference in the second year of cultivation of the consortium (2017), where reductions in productivity may be related to the increase in sorghum PA associated with the increase in pigeon pea populations. However, the productivity of paiaguás grass and pigeon pea in combination with sorghum cultivars showed a reduction in their productive potential within the conditions observed in this study. The aspects related to the architecture and height of the sorghum plants in the consortium become a significant factor in the competition to guarantee their establishment in the area, compared to other crops, also associated with a greater water and photoperiod limitation, caused by seasonality due to the second crop (autumn).

CONCLUSIONS

The SDA cultivar showed higher values for PH, while the highest SD was observed in the GS cultivar, for the two years of evaluation.

The PP for all cultivars evaluated showed a reduction in relation to the second year of cultivation.

GS or FS cultivars provided better conditions for the development of grass-paiaguás, favoring the establishment of pasture.

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PRELIMINARY RESULTS ON AGRONOMIC PERFORMANCE OF CASSAVA-UROCHLOA BRIZANTHA INTERCROPPING

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ABSTRACT

This study aimed to evaluate agronomic traits of a cassava (*Manihot esculenta*) intercropping system with *Urochloa brizantha* (Syn. *Brachiaria brizantha*). The experiment was carried out at Paranavaí, Brazil, in the 2020-2021 agricultural season. Six treatments were studied with different establishment times of cassava-*Urochloa brizantha* intercropping and grass management: T1: cassava in double rows-DR (13,888 pl ha^{-1}) planted simultaneously with *U. brizantha* + mowing; T2: cassava DR and *U. brizantha* simultaneously + herbicide underdose; T3: cassava DR + *U. brizantha* sown 6 months after cassava + mowing; T4: cassava DR + *U. brizantha* sown 6 months after cassava + herbicide underdose; T5: single-row cassava monoculture with 13,520 pl ha^{-1}; T6: single row cassava monoculture with 18,168 pl ha^{-1}. *Urochloa brizantha* reduced the growth in height and stem diameter of cassava plants up to 180 days after planting (DAP) in T1 and T2, but not significantly ($p < 0.05$) in T2 when herbicide was used. The dry matter (DM) yield of pasture increased monthly from 90 (356 kg ha^{-1}) to 150 DAP (950 kg ha^{-1}), but it reduced 50% at 180 DAP (406 kg ha^{-1}).

Key words: BRS 429; double row arrangement; brachiaria

INTRODUCTION

Cassava (*Manihot esculenta* Crantz), originally from South America, is the main source of carbohydrate in the diet of poor populations in Africa, Asia and Tropical America. It is an easily cultivated food crop adapted to low fertility and acidity soil, to drought, little affected by pests, and requires minimal inputs (CEBALLOS et al., 2010). However, the successive cultivation of cassava can cause the depletion of soil nutrients and erosion, in addition to increasing losses due to competition with weeds, at levels above those observed in other crops under the same conditions. (SUYAMTO & HOWELER, 1997). Brazil is the fifth largest world cassava producer, with an annual production of 17.6 million tons of fresh roots from 1.2 million ha. Nigeria and Thailand are the two largest producers, with 59.5 and 31.7 million tons, respectively (FAO, 2019). Cassava cultivation in the center-south Brazil has expanded over sandy soils originating from sandstones, with emphasis on northwestern Paraná state, where the “Caiuá” formation predominates, occupying 3.2 million ha and covering 107 municipalities. The cassava root produced in these municipalities is used for industrial processing, mainly for starch production, which supplies the national market and represents more than 50% of Brazilian production (DERAL, 2020). The degree of technification is the highest in Brazil, with the use of mechanization, inputs, and genetics. However, these soils have a low organic matter content, low water retention capacity and high susceptibility to erosion, which, associated with the physiological characteristics and management practices, have caused a decline in the average root yield in the last decade at Paranavaí geographic microregion (IBGE, 2020). Another important agricultural activity in northwestern Paraná is beef cattle. Despite research and technology transfer efforts to expand the integrated crop-livestock-forest (ICLF) systems, high summer air temperatures and low soil water storage capacity raise climatic risks for crops of corn and soybeans, which has limited the full and widespread adoption of ICLF systems (FRANCHINI et al., 2016). The cassava’s crop is traditionally used in the renewal of pastures in areas under lease, which provides some economic advantage for cattle ranchers and farmers, but has contributed little to the improvement of soil attributes and the sustainability of activities. In the view of the challenges posed for cassava cultivation in the "Caiuá" sandstone and the need to develop a more sustainable livestock based on ICLF system, several technologies were sought to establish and evaluate a prototype of a cassava-brachiaria intercropping with purposes like those of the corn-brachiaria intercropping.

MATERIAL AND METHODS

The work was carried out in the Experimental Farm of the University Center Unifatecie, Paranavaí (PR), located at 23°00'52.0"S and 52°31'17.0"W; 467 meters of altitude. The soil is Typic Haplustox with sandy texture. The soil preparation was mechanized with plowing and two leveling harrows. The soil correction was carried out with the application of calcitic limestone at a dosage of 1,000 kg ha^{-1} and incorporation with disc plows when tilling the soil. The experiment was planted on August 7, 2020. The experimental design was completely randomized blocks, with six treatments and four replications. The treatments were combinations of cassava planting arrangements in consortium with *U. brizantha* cv. Marandu and ways of managing the grass during the cassava cycle. T1: cassava in double rows-DR (2.7 x 0.5 x 0.45 m, 13,888 pl ha^{-1}) planted simultaneously with *U. brizantha* + mowing; T2: cassava DR and *U. brizantha* simultaneously + herbicide underdose (Fluazifop-p-butyl, 55 g i.a. ha^{-1}); T3: DR cassava + *U. brizantha* sown 6 months after cassava + mowing; T4: Cassava DR + *U. brizantha* sown 6 months after cassava + herbicide underdose; T5: single-row cassava monoculture with 13,520 pl ha^{-1}(0.86 x 0.86 m); T6: single row cassava monoculture with 18,168 pl ha^{-1} (0.86 x 0.64 m). The plots of T1, T2, T3 and T4 consisted of three double rows of cassava, 4.05 m long and a total area of 36.85 m^2. The plots of T5 and T6 consisted of nine simple rows of 5.16 m and 3.84 m and total areas of 39.96 m^2 and 29.72 m^2, respectively. For the evaluation of the agronomic characteristics, a sample of 14 central plants of the plot was used, and for the double row's arrangement, the sampling was carried out in the double row located in the center of plot and, for the planting arrangement in single rows, the sampling was in the five central rows. The first and last plants of the central rows were not sampled. The industrial cassava cultivar was BRS 420. The propagation material was obtained from healthy plants at 12 months old and stem cuttings were cut with sharp machete and prepared with 5 to 7 buds and a diameter greater than 2 cm. The planting furrows were opened 10 cm deep with a tractor furrow. Planting fertilization was performed with the application of 40 kg P_2O_5 ha^{-1} at the bottom of the planting furrow. The fertilizer was covered with a thin layer of soil and the cuttings were manually placed in a horizontal position. The planting was finished with the closing of the furrows and leveling the land with a hoe. The cassava covering fertilization was 60 kg of K_2O and 40 kg of N ha^{-1}, the K being split in two periods, at 60 days after planting (DAP) together with all N, and at 90 DAP. The distribution was manual in lateral bands to the plant rows. The *U. brizantha* was sown manually, at a dose of 4 kg of pure viable seeds ha^{-1}, in furrows 3 cm deep and spaced 20 cm apart. In T1 and T2 treatments, 35 cm was initially left between the first row of grass and the first row of cassava, this distance being extended to 60 cm at 120 days after sowing. In T3 and T4, showing on February 26, 2021, the first row of grass maintained the distance of 60 cm to the row of cassava. The planting fertilization of *U. brizantha* was carried out in the sowing line with the same dosage and fertilizer applied for cassava. After planting cassava and grass, pre-emergent herbicides were applied, being Clomazone (1,000 g ai ha^{-1}) and *S*- metolachlor (1,920 g ai ha^{-1}), in mixture, in the area with cassava, and Flumioxazin (45 g ai ha^{-1}) in the area with *U. brizantha*. At 45 DAP, weed control of cassava was carried out with mechanical weeding. The chemical management of grass with underdoses of 55 g ai ha^{-1} of the herbicide Fluazifop-p-butyl was started at 35 days after sowing and was repeated whenever the pasture reached a height of 20 cm, with three applications in the T2 treatment. The applications were performed with a CO_2 pressurized backpack sprayer, an application bar with 2.5 meters, six flat fan nozzles (110 02 BD) spaced 0.5 m apart, with a spraying rate of 150 L ha^{-1}. The applications were performed on days when weather conditions were favorable to spraying. The mechanical management of the grass was initiated at 90 days after cassava planting and repeated at 90, 120, 150 and 180 DAP. The cuts were performed with a weed cutter with lowering up to 10 cm in height. The height and stem diameter evaluations were carried out in two seasons, at 100 and 180 DAP. The plant height was considered the vertical distance between the ground level and the highest point of the plant, measured with a ruler. The stem diameter was measured at 5 cm from the ground level, using a caliper. For plants that had more than one stem, the taller stem was considered for both measures. The dry matter yield of *U. brizantha* was done at the time of mowing. The pasture dry matter harvested on inter double rows in plots was considered for the extrapolation of the yield in kg ha^{-1}. For this determination, the fresh weight of the plot and the dry matter content of the grass were considered. The average dry matter content was calculated at each cutting season by taking a sample composed of four simple subsamples, one from each repetition. The average dry matter content was calculated at each cutting season by taking a sample composed of four subsamples, one from each repetition. The dry matter content was calculated by fresh and dry weight of *U. brizantha* samples, the first being measured immediately after cutting and the second after drying in an oven at 65 ºC for 72 hours. An analytical balance with a precision of 0.1 g was used. The height and diameter data were subjected to analysis of variance and the means were compared using the Tukey test at 5%. The dry grass yield data were treated statistically with the determination of the mean, the standard error, and the coefficient of variation of the mean.

RESULTS AND DISCUSSIONS

Figure 1 shows the results of plant height (1A) and stem diameter (1B) of cassava plants, cv BRS 420, with evaluations performed at 100 and 180 DAP. In the first evaluation, there was no significant difference ($p<0.05$) between the treatment means for both height and stem diameter, however there is a tendency for lower means for treatment T1. At 180 DAP, T1 stands out with the lowest average of characteristics and differs significantly from treatments T3 and T4 in plant height and from all treatments, except T2, in stem diameter (Figure 1, A and B). These preliminary results indicate that the consortium cassava with *U. brizantha*, in simultaneous sowing (T1), had a negative influence on the vegetative growth of cassava under double rows. However, management with underdoses of the herbicide Fluazifop-p-butyl (T2) induced mean height and diameter that did not differ from other treatments in double row arrangement (T3 e T4), that were sown with grass after the last agronomic evaluation. According to Albuquerque et al. (2008), the *U. brizantha* is considered a cassava weed of great occurrence in Brazil and surpasses the majority of weed plants in accumulation of fresh mass. Ferreira et al. (2015) supports the potential for interference of *U. brizantha* on cassava growth when they concluded that this species reduced the height and stem diameter of cassava plants in increasing levels with rise plant density at 50 days after emergence, under pot cultivation. These authors observed a reduction in height of up to 80% in relation to the control and found that the negative interference in the growth of cassava is greater than that caused by blackjack (*Bidens pilosa L.*), in the same study conditions. The treatments with arrangement in double rows T3 and T4 stimulated the growth in height of the cassava plants when compared to the treatments with plant arrangement in single rows T5 and T6, although the stem diameter is practically maintained unchanged among the treatments mentioned (Figure 1, A and B). The increase in plant density in single row arrangements from 13,500 (T5) to 18,000 pl ha^{-1} (T6) did not affect the growth of the above ground of the cv. BRS 420 to 180 DAP (Figure 1, A and B). Table 1 shows the average dry matter yield of *U. brizantha* in four mows. The low yields obtained in the first two mows (90 and 120 DAP) can be attributed in part to the drought occurred in the months of September, October, November of 2020 in the northwestern region of Paraná, which made it difficult to grass establishment. As of December, weather conditions were favorable to growth, producing a high dry matter yield in the 3rd mow (150 DAP), measured in January 2021. The 4th mow (180 DAP) registered a drop of more than 50% in the pasture dry matter yield in relation to the 3rd mow. A possible cause is the greater competitiveness of cassava at 180 DAP, when the crop has its maximum leaf area index (LAI) and, therefore, the lowest transmittance of sunlight to the layers closest to the soil (BACKER et al., 1989). Biffe et al. (2010) determined that the critical period of weed interference (CPWI) for cassava crop in northwest Paraná is from 18 to 100 DAP. These and other studies of weed interference periods in the cassava crop were carried out in a single row arrangement, so there may be variation in the period for the arrangement of double rows. The dry matter yields of *U. brizantha* cv. Marandu observed in this work are like those obtained by Kichel (2018) at the times when brachiaria was intercropped with corn, at 50 and 90 days after emergence (DAE), and under the effect of chemical suppression, but are lower in relation to the yields observed by the authors after the corn harvest (135 and 180 DAE).

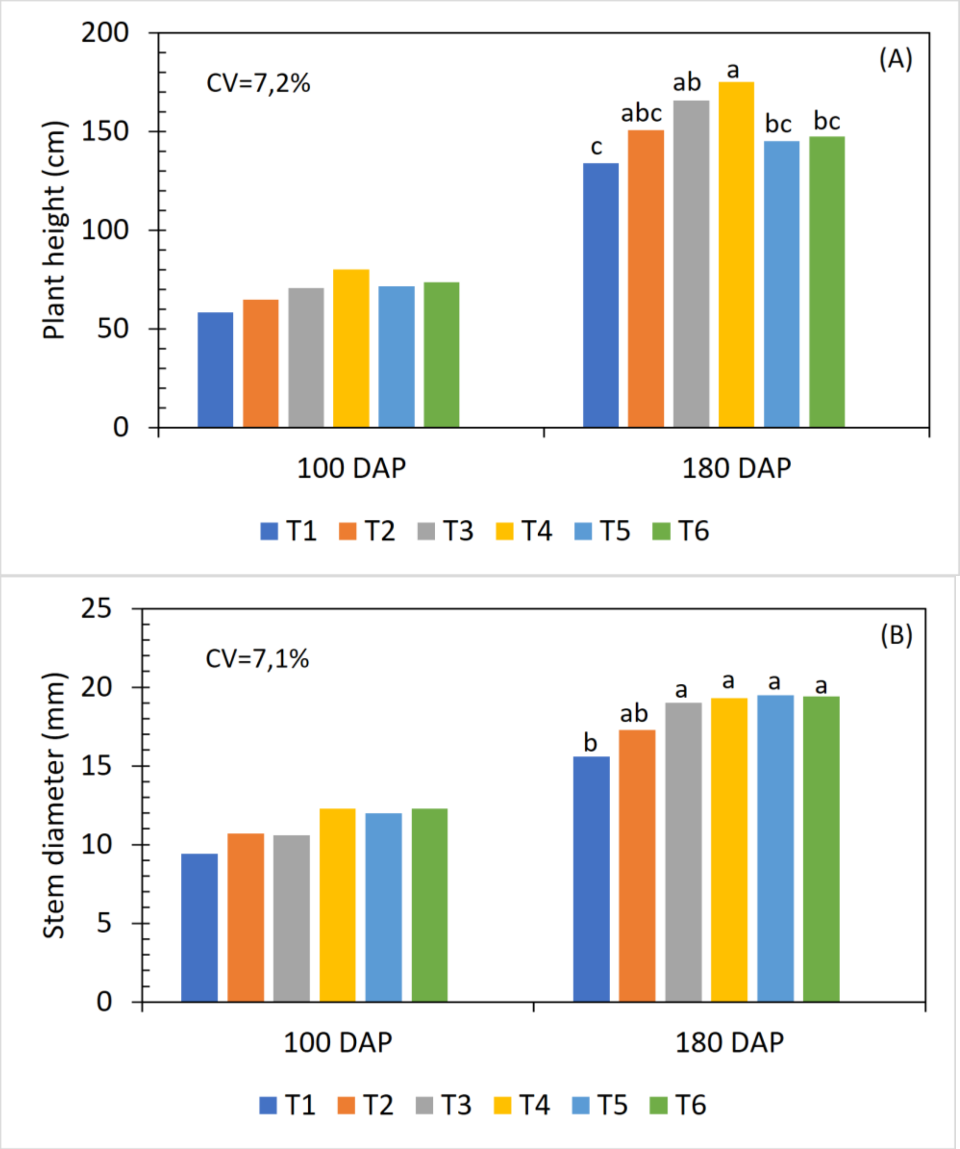

Figure 1. Height, in cm (A) and stem diameter, in mm (B) of cassava plants cv. BRS 420 at 100 and 180 days after planting (DAP), under different establishment times of cassava-*Urochloa brizantha* intercropping and 'Marandu' grass management. Paranavaí, Brazil. 2020/2021. Means followed by the same letter do not differ by Tukey's test, at 5% probability: T1: cassava in double rows-DR (13,888 pl ha^{-1}) planted simultaneously with *U. brizantha* + mowing; T2: cassava DR and *U. brizantha* simultaneously + herbicide underdose; T3: cassava DR + *U. brizantha* sown 6 months after cassava + mowing; T4: cassava DR + *U. brizantha* sown 6 months after cassava + herbicide underdose; T5: single-row cassava monoculture with 13,520 pl ha^{-1}; T6: single row cassava monoculture with 18,168 pl ha^{-1}.

Table 1. Above ground dry matter yield, kg ha^{-1}, standard error, and coefficient of variation of *Urochloa brizantha*, cv. Marandu, intercropped with cassava cv. BRS 420, with evaluations performed at 90, 120, 150 and 180 days after planting (DAP) cassava. Paranavaí, Brazil, 2020/2021.

Mow date (DAP)	Dry Matter (kg/ha)	CV (%)
90	364.9 (75.7)	41.5
120	459.3 (52.5)	22.9
150	944.5 (122.1)	25.8
180	406.4 (98.1)	48.3

CONCLUSIONS

Urochloa brizantha cv. Marandu, reduced the growth of cassava *Manihot esculenta* cv. BRS 420 when sowed simultaneously with the planting of cassava in the arrangement of double rows.

The growth management of Marandu grass with underdoses of the herbicide Fluazifop-p-butyl (55 g ia ha^{-1}) reduced their ability to compete with cassava until 180 days after planting.

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HIGHLIGHTING THE PASTURE COMPONENT OF A LONG-TERM CROP-LIVESTOCK SYSTEM IN THE CERRADO BIOME, BRAZIL

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ABSTRACT

In the tropical region central of Minas Gerais State, integrated crop-livestock systems are characterized by annual rotation or succession of crops and pastures in a no-till system in which the pasture is used to produce either milk or meat. In this paper the system focus on integration of maize and sorghum in consortium with *Urochloa* and *Megathyrsus maximus*, respectively, for silage, followed by pasture were Nellore and 1/2 Nellore: Angus calves remain for one year, and then soybean is cultivated in no-till system. The green and dry biomass production, in t/ha, of grass forage cultivar 'Tanzânia-1' or 'Mombaça' are presented in annually data before and after stocking in rotated management during wet and transition seasons. The calves body weight gains recorded in these years of integrated crop-livestock system are above the average of Brazilian productivity. In average, the annual animal productivity was of 1,281 kg of live weight per hectare. In conclusion, the integrated systems in region provide the opportunity for intensification with sustainability.

Key words: Cerrado; Forage analysis; Guinea grass

INTRODUCTION

The Brazilian Cerrado is one of the most important region for agriculture and livestock production. This region presents a wide variation in rainfall rate and, invariably the rains are concentrated during spring and summer, with dry autumn and winter. As climate changes, these areas are being affected by water shortage and longer water stress periods, and this poses major challenges not only for inner but worldwide food supply. Integrated systems are one way to enhance the resilience of crop and livestock production (SZYMCZAK et al., 2020). The strong performance of integrated crop-livestock systems has showed relevant and presented positive impact in land productivity and in diversifying production and of itself for global sustainable development (REIS et al., 2021). This system allows the land sustainable use and its intensification by introducing no-till technology in synergy with crops and livestock activities with a minimal interface between them. While it increases productivity, the system also reduces costs and risks, improves the efficiency of machinery use, increases diversity, promotes gas mitigation, reduces weed incidence, and increases profitability and incomes to farmers (MORAES et al., 2014).

In the central region of Minas Gerais, with great aptitude for beef and dairy cattle, periods of water restriction are evidenced annually even during the summer as well as a scarcity of food supply for animals during the drought period, which makes it suitable for the use of integrated crop-livestock systems. A cyclic combination of no-till crop production – crop-forage consortium for silage – livestock pasture feed –feedlot has been evaluated in the last 15 years in Sete Lagoas, MG.

Data of pasture management and productivity in integrated crop-livestock systems represent an important component in the sustainability of the system. However, information about this component is scarce in literature, and it certainly cannot be relegated to a secondary plan because all risks evidenced in extensive pastures can be extended to integrated systems such as pasture degradation, low animal body weight gain, and low straw formation for the subsequent no-tillage crop cultivation.

This study was evaluated the animal body weight gain and biomass production of forage grass *Megathyrsus maximus* grazed in an integrated crop-livestock system using intermittent grazing with high stocking rate of calves per hectare, during the last six years.

MATERIAL AND METHODS

The study was conducted in an integrated crop-livestock system (CLS) installed in the Embrapa Maize and Sorghum experimental field, located at the geographical coordinates 19°29'4.37"S and 44°10'25.66"W, at 755 m altitude. The local and predominant climate in almost the entire Cerrado region is classified, according to the Köppen classification, as Aw - Type A: megathermic (tropical humid) - with average temperature of the coldest month above 18 °C and subtype w, dry winter and maximum summer rainfall (Macena et al., 2008). The average annual coverage is 1350 mm, distributed between the months of October and March. The soil is a Oxisol, dystrophic Red Latosol according to the Brazilian Soil Classification System (SANTOS et al., 2013), clayey and smooth wavy relief.

The total area of the integrated system was 22 ha divided in four areas of 5.5 ha, in which annually the treatment crops were rotated: corn + *Urochloa* cultivar, sorghum + *Megathyrsus maximus* (Guinea grass) cultivar, *M. maximus* pasture area for one year followed by soybean seeded on no-tillage area. *M. maximus* pastures formed after the sorghum harvest for silage were based on ‘Tanzânia-1’ in 2013-2014, and ‘Mombaça’ in 2015-2016, 2016-2017, 2017-2018, and 2018-2019. The pasture in this system benefits itself from the residual fertilization remaining from the annual crops in the three years of previous crops and was also fertilized every year with cover fertilization and corrections according to soil analysis. Nitrogen fertilization was always used as a strategic tool modulating pasture growth in order to supply the demand of the herd during the water period. Nitrogen fertilization used urea in quantities varying from 465 kg/ha, in the first years, to 200 kg/ha from 2015-2016 on, always divided in three applications during summer.

Pasture area was subdivided in five paddocks of 1.1 hectare each and the rotated management was adopted, mostly during the water surplus season. During the dry season all 22 ha area was used as pasture. Green (t/ha) and dry biomass yield (t/ha) was determined by clipping at ground level in ten randomly located 1 x 1m quadrats per paddock in pre- and post-stocking conditions. Samples were dried at 65°C for 72 hours and then weighed. Green and dry biomass yield was averaged in transition, wet and dry water seasons from 2013 to 2019.

The animals, from two blood groups of specialized breeds for meat production (Nellore and 1/2 Nellore: Angus), entered annually in the system in May/June live weighing on average 172.5 kg and remained around one year under grazing, when they entered the feedlot and a new batch of calves entered the pastures. Stocking rate of 1 AU/ha were used during winter, and achieved 7-8 AU/ha during summer when animals stayed exclusively in the 5.5 ha Guinea grass paddocks.

The data of biomass and animal production were organized by season and will be presented in the form of media with their respective standard deviations.

RESULTS AND DISCUSSIONS

Table 1 shows the biomass production characteristics of ‘Tanzânia-1’ and ‘Mombaça’ cultivars pasture evaluated in 2013/2014 and from 2015/2016 to 2018/2019, respectively. The average availability values for each period are demonstrated. The wet season presented the highest average availability, followed by the transition and dry season, as expected for this species. These results present grasses biomass production stability over the years and corroborate the feasibility and planning of integrated systems for the region, in order to ensure animal production. In addition, the system keeps the pasture and soil in adequate conditions for sowing the crop under no-tillage, allowing a sustainable intensification.

Table 1. Season means and standard deviations of the green and dry biomass available (t/ha) and consumed by animals in *Megathyrsus maximus* 'Tânzania-1', in 2013/2014, and 'Mombaça' pasture, in two seasons, years from 2015 to 2019.

Characteristic	**Wet season**	**Transition**
	2013/2014	
Green biomass availability– before stocking	27.82±13.27	16.14±6.76
Dry biomass availability– before stocking	5.56±2.65	3.23±1.35
	2015/2016	
Green biomass availability– before stocking	19.45±3.68	10.80±1.8
Dry biomass availability– before stocking	4.12±0.78	2.92±0.49
	2016/2017	
Green biomass availability– before stocking	19.48±3.84	9.38±0.48
Dry biomass availability– before stocking	4.24±0.83	3.06±0.16
	2017/2018	
Green biomass availability – before stocking	28.05±9.46	15.01±3.14
Dry biomass availability - before stocking	5.57±2.11	5.09±1.16
Green biomass – after stocking	14.38±6.15	12.9±2.4
Dry biomass - after stocking	3.05±1.22	4.75±0.97
	2018/2019	
Green biomass availability – before stocking	26.43±7.35	23.15±6.35
Dry biomass availability - before stocking	5.03±1.32	4.18±0.60
Green biomass – after stocking	14.70±4.98	16.45±5.70
Dry biomass - after stocking	2.80±0.48	3.10±0.28

In Table 1, the organization of the data allows the visualization of the average forage availability of Mombaça grass paddocks in pre- and post-stocking conditions. The data show that the average values of available forage (pre-stocking) were very close for the water period and transition within each agricultural year. However, the nutritive value of forage in the water period is almost double that observed for the transition period (data not shown). This fact reinforces the importance of having an area with postharvest forage (corn, sorghum, soybean), in order to balance this amount of forage still available in Mombaça grass pasture with the initial quality of forage of a *Urochloa* pasture, for this transition and dry period, and of course, together with strategic use of supplementation.

Considerable are also the average masses of forage available in post-stocking. This indicates that even under the criterion of fixed days of occupation and rest adopted in the system, it was possible to maintain sufficient amount of residue to stimulate the regrowth of pastures.

The average body weight gains (Table 2) in the six agricultural years evaluated ranged from 350 to 800 g/animal/day; 700 to 900 g/animal/day and 300 to 800 g/animal/day in the dry, wet and transition period, respectively (data not shown). The variations in gain are mainly due to the amount and quality of pasture in each of the seasons of the respective agricultural year, as well as the type of pasture supplementation, since the animals received supplementation with mineral and protein supplement of low consumption (0.1 to 0.2% of BW) in the wet and dry periods, respectively.

Table 2. Live body weight gain (LBWG), and grazing days (GD) per season (dry, wet and transition), over the years of conducting the integration crop-livestock system at Embrapa Maize and Sorghum, Sete Lagoas, MG, Brazil.

	Dry	**Wet**	**Transition**	**Total of Period**
		2013-2014 – 32 animal units		
LBWG (kg/ha)	64.65	619.18	351.81	1035.00
GD	109	167	81	357
		2014-2015 – 42 animal units		
LBWG (kg/ha)	71.14	699.90	401.00	1172.04
GD	96	114	79	289
		2015-2016 – 40 animal units		
LBWG (kg/ha)	157.14	549.36	628.45	1334.90
GD	65	167	63	295
		2016-2017 – 60 animal units		
LBWG (kg/ha)	74.09	1117.36	578.45	1769.90
GD	89	177	82	348
		2017-2018 – 45 animal units		
LBWG (kg/ha)	96.86	483.86	216.11	796.83
GD	145	142	56	343
		2018-2019 – 47 animal units		
LBWG (kg/ha)	192.09	1030.54	357.54	1580.17
GD	103	165	59	327

Using pasture fertilization, supplementation and pasture management it was possible to guarantee high production of body weight per unit area. Moreover, the productivity values recorded in these years of integrated crop-livestock system are above the average of Brazilian productivity (ABIEC, 2020; BARBOSA et al., 2015).

CONCLUSIONS

The animal gains recorded in the pasture phase over the years reflect the potential of pastures associated with the proper management, and group animal evaluated. Therefore, the integrated crop-livestock system in region provides the opportunity for intensification with sustainability.

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VOLUMETRIC QUANTIFICATION OF EUCALYPTUS WOOD IN SIMPLE LINES AND TRIPLE LINES FOR USE IN THE ICLF SYSTEM

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ABSTRACT

This study aims to quantify the volume of Eucalyptus in a system of single and triple lines, for use in Integration Technical Agriculture-Forest. For that, the genetic material COP 1277 (*Eucalyptus grandis* x *Eucalyptus camaldulensis*) was selected in two different spacing. The total and commercial height of three individuals that represented the minimum, medium and maximum diameter at breast height (DBH) was measured, as well as the diameters of the stem, including the bark, at the height of the base, of the DBH, and of 25%, 50%, 75% and 100% of commercial height. The data obtained followed the Smalian cubing methodology. In the end, planting in multiple strips obtained the highest density (1,190 ind./ha), despite having the lowest volume per individual (0.162 m^3) and per hectare (192.78 m^3). On the other hand, planting in simple strips showed lower density (641 ind./ha), but with the advantage of obtaining greater volume per individual (0.425 m^3) and per hectare (272.43 m^3), therefore, more suitable for the ICLF system for presenting greater profitability to the rural entrepreneur.

Key words: energy use; firewood; sawmill

INTRODUCTION

The practice of agriculture in a sustainable way has become a challenge for humanity. This has been instigated by the existing demand, not only for the production of food, but also of other inputs and products that use natural resources as raw material, as well the pressure for the recovery of these areas already used (RANGEL et al., 2020). The removal of vegetation for agriculture, the development of monocultures and other inappropriate crops have had a negative impact when adequate management techniques are not developed, such as increased erosion, reduced soil quality, low productivity, degradation and pressure on natural resources (BALBINO et al., 2012; CORDEIRO; BALBINO, 2019).

Sustainable agriculture can be characterized as a type of exploration that provides benefits to production and economy without placing a burden on the environment and to society (KICHEL et al., 2019). Therefore, the use of production systems in an integrated way, can be associated as an aid in the search for sustainability. The integration between integrated crop-livestock-forestry systems can favor the more complete use of an area, providing the opportunity to apply several activities at once, generating more products (REIS et al., 2020). They must be designed to complement each other, bringing balance to the production system, reducing environmental impacts and assisting in the recovery and reuse of the achieved area. Which will contribute to the reduction of the implantation of new spaces containing native vegetation for multiple uses (SILVA et al., 2020).

The planting of forest species aiming at their multiple use, provides entrepreneurs greater income from obtaining different products, such as sawmill wood, fence posts, firewood and charcoal, as well as decrease in the residue left in the field. Therefore, the spacing used between individuals during planting influences their growth rate and, consequently, the volume per individual and per hectare.

The spacing for forest growth, is often determined in na empirical way, the decision being due to common practices and local culture, this observation can be observed when the spacing fator is still not used correctly in relation to the objective for which planting is intended in terms of adaptations to local conditions (LIMA, 2013). For Siqueira (2017), the correct forest management is an essential tool for the viability of silvopastoral system projects. These systems correspond to sustainable development because they reduce the negative impacts of the productive activity on the environment, reduce the costs of recovering degraded areas, diversify production and increase the financial income of rural properties.

Thus, this study aims at the volumetric quantification of *Eucalyptus* wood, in a single and triple line system for use in the crop-livestock-forestry integration technique.

MATERIAL AND METHODS

The study was carried out in the experimental area implemented in 2013 at the Unidade Acadêmica Especializada em Ciências Agrárias (UAECIA), at the Universidade Federal do Rio Grande do Norte (UFRN), in the municipality of Macaíba, Rio Grande do Norte, Brazil, through the cooperative program "Tolerance of *Eucalyptus* Clones to Water and Thermal Stresses" (TECHS).

The municipality of Macaíba (Figure 1), according to the Superintendência do Desenvolvimento do Nordeste (SUDENE) through the Working Group established by Decree n. 196, of May 27, 2014, was defined as semi-arid, the Secretaria de Estado do Planejamento e das Finanças - SEPLAN - SEPLAN (2014), considering Koppen's classification, categorized the municipality it as a dry sub-humid climate, a transition between Typical Tropical (Aw) and the Semi-arid (Bs).

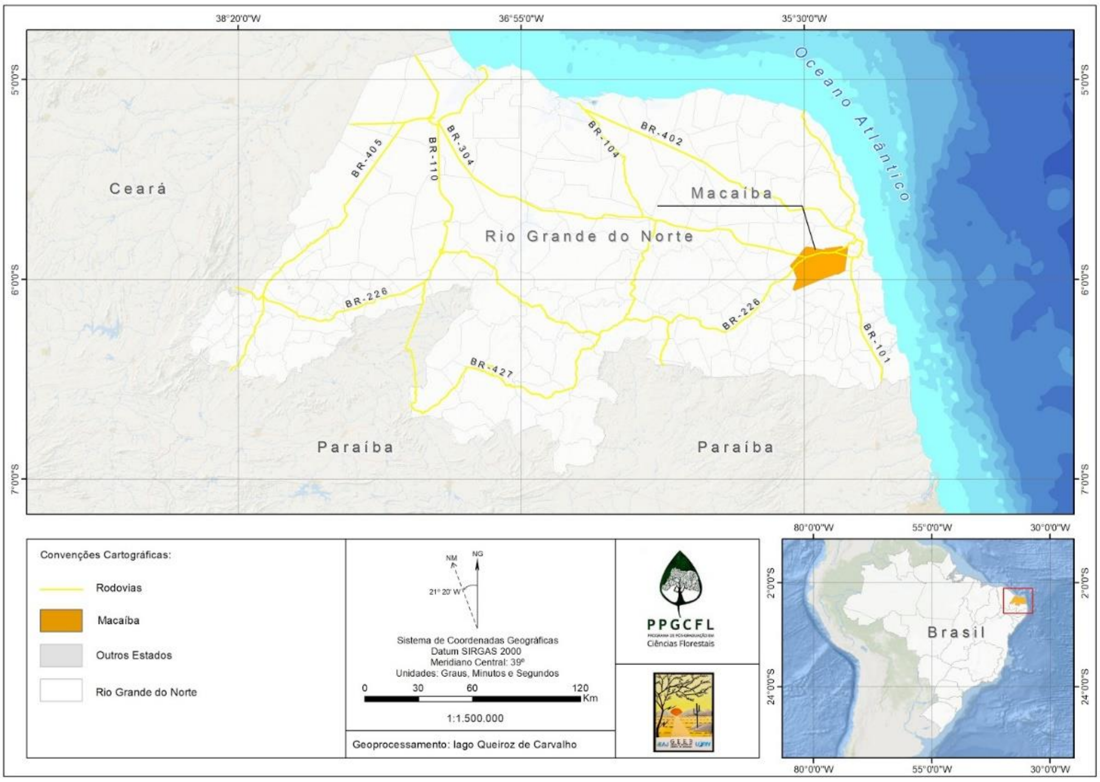

Figure 1. Location map of the municipality of Macaíba, in Rio Grande do Norte, Brazil.

Data collect

In the study area, ten different genetic materials were implanted, at a constant value between the lines of 3 meters and with a gradual increase between individuals, totaling 21 spacings. Of those, a genetic material cop 1277 (*Eucalyptus grandis* x *Eucalyptus camaldulensis*) were selected based on quality and low mortality rate, in two spacings: 4.8 m^2/individual and 15.60 m^2/individual. In the composition of the ICLF system, single and triple bands were used, the value between individuals of the largest spacing (5.2 meters) was defined as distance between rows, as observed in the sketch below (Figure 2).

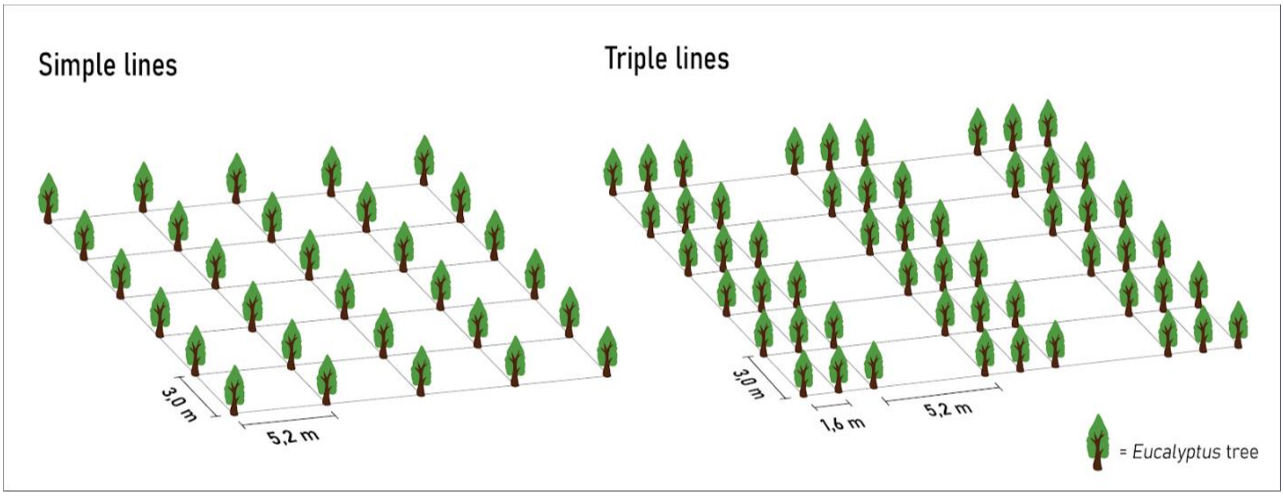

Figure 2. Schematic arrangement of plantings in single and triple lines for the composition of the Crop-Livestock-Forest Integration system.

It carried out measurement of the total height (Ht) and commercial height (Hc) of three subjects per spacings that represent the Diameter at breast height (DBH) minimum, average and maximum and subsequently by Hc, the measurement of the stem diameter, with bark, in heights: base (0.10 m), DBH, 25%, 50%, 75% and 100%. Then, the data obtained followed the Smalian cubing methodology.

Data analysis

The analyzes were processed with Excel® software.

RESULTS AND DISCUSSIONS

The ICLF system with planting in multiple strips showed a higher density (1,190 ind./ha), however a smaller volume per individual (0.162 m^3) and per hectare (192.78 m^3), while planting in simple strips showed less density (641 ind./ha) but a higher volume per individual (0.425 m^3) and per hectare (272.43 m^3).

The volumes found per individual are similar to the study by Oliveira et al. (2009), that at 27 months of age, the wider spacing showed greater results. Effect also observed by Santos et al. (2017), who evaluated 16 different spacings, at 72 months of age, from 9 m²/ind. the volume production per tree was higher.

A higher volume per hectare is associated with the denser planting, due to the high number of trees in these arrangements, however, it is noteworthy that, in an ICLF system, the spacing between rows influences this result. According to Cipriani et al. (2018), the densification causes a higher density of thin individuals, however, it is not as a rule to be rewarded by a higher productivity per area.

Systems aimed at the multiple use of an area are reality in Rio Grande do Norte, Brazil. However, the use of forest species is not so common, thus, the sectors that use wood for energy production buy, mostly, fruit pruning, native or algarobas (*Prosopis juliflora* (Sw) DC); for the furniture industry that uses *Eucalyptus* in its production, they commonly need to buy from other states, which results in a increases your expenses.

In environments with water deficit, the COP 1277 clone performs well and a wood compatible with energy use, sawmills, cellulose production, among others (REIS et al., 2014). Regarding the purpose, Ferreira et al. (2019) highlight that *Eucalyptus* has different possibilities of use, however, in ICLF systems, the highest profitability results from the more noble use of its wood, such as for sawmills and furniture industries. Therefore, in integration systems, less dense plantations, which allow greater volumetric increase per individual, should be prioritized, considering, however, the regional demands of the buying market.

CONCLUSIONS

The study shows that within an ICLF system, eucalyptus planted in simple tree lines leads to a greater volume per individual and per hectare, while planting more dense triple tree lines does not determine greater productivity per area. This information contributes to the decision-making of producers who aim for a greater volumetric production of wood while in an ICLF.

In addition, the possibility of using eucalyptus under the dry sub-humid climate in Rio Grande do Norte, Brazil is clear. This provides entrepreneurs who use this wood as a raw material a reduced transport radius, which generates lower expenses with freight and thus a more economically viable product.

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PRODUCTIVITY OF CASSAVA UNDER TWO TILLAGE METHODS IN AN INTEGRATED CROP-LIVESTOCK SYSTEM

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ABSTRACT

This study aimed to assess cassava productivity, under conventional tillage and no-tillage, in an integrated crop-livestock system with marandu grass. The determinations obtained from the cassava crop harvest were number of plants, number of tuberous roots per plant; fresh mass and dry mass of the tuberous roots, dry mass of the roots and percentage of plants with rotten roots. We also evaluated the marandu grass straw decomposition through of packaging of litter bags made in naylon, containing the dry matter proportional to grass production per area. The number of cassava plants was the same in conventional tillage and no-tillage. Regarding the number of roots per plant, conventional tillage showed significant higher values than no-tillage. No-tillage showed the lowest fresh and dry masses of cassava roots as compared to conventional tillage. The average marandu herbage mass accumulated before planting cassava in no-tillage plots was 7969 kg DM ha^{-1}. At 448 days after cassava planting, the straw decomposition reached 76.23%, leaving 1894 kg of residual straw in the no-tillage cassava plots. It took 164 days for 50% of the marandu grass straw to be decomposed in the no-tillage cassava treatment.

Key words: conventional tillage; decomposition; Marandu grass

INTRODUCTION

Traditional cassava cultivation involves mechanical manipulation of the soil with one plowing and two harrowings, a practice that may generate problems such as soil erosion, compaction and nutrient loss (GABRIEL FILHO et al., 2000). These issues may be even bigger in sandy soils such as those in northwestern Paraná, derived from the Caiuá Sandstone Formation. Some research has already been carried out to evaluate the cultivation of cassava in no-tillage systems (OTSUBO et al., 2008; FIGUEIREDO et al., 2017), reporting advantages such as low costs and soil conservation. However, the yield variability of cassava, observed in different soil types, leads to a non-adoption of no-tillage systems (FASINMIRIN and REICHERT, 2011). This study aimed to assess cassava productivity (cultivar IPR B 36), under conventional tillage and no-tillage, in an integrated crop-livestock system with Marandu grass.

MATERIAL AND METHODS

The experiment was conducted at the experimental station of the IAPAR - Agronomic Institute of Parana, located in the city of Paranavaí, from June 2016 to January 2018. The predominant climate type in the region is *Cfa* - subtropical climate (mesothermal) according to Köppen classification, with hot summers, infrequent frost, and rainfall tending to be concentrated in the summer months. During the experiment, minimum and maximum monthly temperatures ranges were 18.21 and 28.05 ºC and total rainfall was 1327 mm. Evaluation was carried out in an area of crop-livestock system with cassava (*Manihot esculenta* Crantz, cultivar IPR B 36) and marandu grass (*Brachiaria brizantha* cv. Marandu; syn. *Urochloa brizantha* cv. Marandu). The soil of the experimental area is classified as

Typical Paleudult (ARGISSOLO VERMELHO dystrophic latosol), containing 890 g kg^{-1} of sand, 20 g kg^{-1} of silt, and 90 g kg^{-1} of clay in the layer found 0-20 cm deep (MERTEN et al., 2016). The experiment was installed in a randomized complete block design, with four replicates and two treatments: conventional tillage cassava and no-tillage cassava. The experimental units consisted of eight paddocks (900 m^2) cultivated with marandu grass for two years before cassava planting. Marandu grass was grazed under a rotational stocking with crossbred young bulls (Purunã x Nelore and Purunã x Red Angus). For pasture management, in the two years before cassava planting, we used the canopy heights recommended for marandu grass of pre-grazing height of 30 cm and post grazing of 15 cm. The stocking rate varied according to the herbage allowance, being around 7.6 AU (Animal unit: 450 kg of body weight) ha^{-1} in the summer and 3.2 AU ha^{-1} in winter period. The animals were removed from the paddocks in March 2016, allowing the herbage accumulation of marandu grass. In all treatments, the herbage mass of marandu grass was burn down using 1.44 kg ha^{-1} of glyphosate as active ingredient. In the conventional tillage plots, the soil was prepared with heavy disk harrow, moldboard plow and leveling disk harrow. In the no-tillage plots cassava was planted directly on the marandu grass straw. Cassava stems with 0.13 m were planted horizontally and mechanically at a depth of 5-10 cm, on June 20, 2016, using a two-row planter composed of a cutting disc, furrow rod, two discs for opening furrows, press wheel, and cover disk, in a spacing of 0.90 m in between rows, and 0.60 m in between plants. Fertilization was done with 28.1 kg ha^{-1} of P_2O_5 as simple superphosphate at the planting and 132 kg ha^{-1} of K_2O as potassium chloride 78 days after planting. The herbage accumulation of marandu grass was measured before desiccation with glyphosate in May 2016. The grass dry matter production was assessed in the paddocks, using a sampling frame measuring of 1m^2. Four samples were taken from each paddock. The samples were weighed and dried in an oven at 65 °C for 72 h. The dry samples were put inside nylon bags (30 x 30 cm) with a 2 mm mesh. The amount of sample in the bag was proportional to the pasture dry mass produced per area. The bags were distributed into the plots on July 21, 2016, right after cassava was planted. Eight collection periods were assessed (7, 14, 28, 56, 112, 224, 336, 448 days after distribution in the field). After each collection, the bags were dried in an oven at 65 °C so that the remnant straw was weighed. Straw decomposition was determined by weight difference, calculating the percentage of the remaining material in the bag, based on the initial total amount. The decomposition constant (k) was determined from this first order equation: $At = A0\ e^{-kt}$, in which A_t is the concentration of remnant substrate at any t time; the half-life time ($t_{1/2}$) of the straw was calculated through the following equation: $\ln [(A_{0/2})/A_0] = - Kt_{1/2}$, in which $t_{1/2} = 0.693\ k^{-1}$ (PAUL and CLARK, 1989). The determinations obtained from the cassava crop harvest were number of plants, number of tuberous roots per plant (total number of roots divided by total number of plants in the plot); fresh mass and dry mass of the tuberous roots, dry mass of the roots (oven at 65 ^{o}C until constant weight) and percentage of plants with rotten roots. The dry mass of the roots was obtained by correcting the fresh mass of the roots based on their dry matter percentage. The same industrial performance evaluation was made through de specific weight of the 5 kg sample dipped into the water. The data found were subjected to analyses of variance and mean comparison tests by the "F" test at 5% probability, using SAS Software (SAS INSTITUTE, 1999).

RESULTS AND DISCUSSIONS

The number of cassava plants was the same in conventional tillage and no-tillage (Table 1) and showed that the planting executed well. Regarding the number of roots per plant, conventional tillage showed significant higher values than no-tillage. No-tillage showed the significant lowest fresh and dry masses of cassava roots as compared to conventional tillage. These results were similar obtained by Watanabe et al. (2002) and Pequeno et al. (2007) in similar soil where they obtained higher cassava productivity in conventional tillage system. The number of roots per plant directly correlated with root fresh mass (0.92 P<0.01) and root dry mass (0.92 P<0.01). The specific weight showed no differences in both tillages. The rotten roots in the plants did not influence by the tillages, mainly due to the higher variation coefficient. However, there was correlation between the percentage of plants with rotten roots and root fresh mass (-0.77 $P<0.05$) and root dry mass (-0.75 $P<0.05$). The average marandu herbage mass accumulated before planting cassava in no-tillage plots was 7969 kg DM ha^{-1} (Table 2). According to Cruz et al. (2002), an efficient implementation and management of a no-tillage system requires the minimum amount of straw to be permanently kept at around 6000 kg ha^{-1} of dry mass to cover the soil. Thus, the amount of straw accumulated in the present study was higher than that recommended for the good establishment of crops in no-tillage systems.

Table 1. Cassava root yield components in conventional tillage and no-tillage.

Variables	**Treatment**		**CV (%)**
	Conventional tillage	**No-tillage**	
Number of plants (%)	091.25a*	091.25a	06.29
Number of roots/plant	005.02a	003.41b	08.05
Root fresh mass (Mg ha^{-1})	063.29a	047.85b	07.25
Root dry mass (Mg ha^{-1})	023.59a	017.58b	07.89
Specific weight (g)	636.00a	616.84a	02.80
Plants with rotten roots (%)	031.75a	053.76a	33.02

*Means followed by the same letters do not differ for the F test at $P<0.05$.

Table 2. Marandu grass straw decomposition (%) and straw residual mass, in eight collection periods, for no-tillage (NT) cassava treatment.

Collection periods (days)	**Decomposition (%)**	**Straw residual mass (kg DM*/ha)**
0	0.00	7969.28
7	6.07	7485.54
14	6,94	7416.21
28	11.73	7034.48
56	29.35	5630.29
112	39.55	4817.43
224	61.41	3075.34
336	74.48	1910.31
448	76.23	1894.30

*DM: dry matter.

For the cassava crop, which is planted in winter, the marandu grass straw decomposition in the early periods (7, 14, 28 and 56 days), is generally less than that observed for the same period of time in the summer. Higher temperatures and rainfalls contribute to raising the decomposition rates of vegetal residues (HAAG, 1985). In this study the decomposition rate of 29.35% observed at 56 days after cassava planting was slightly smaller than that observed by Gobbi et al. (2017). These authors reported an average percentage of Marandu grass straw decomposition (perennial pasture) of 31% after 56 days, in an integrated crop-livestock system with soybean, in the Northwest of Paraná. In this case, the collection at 56 days was carried out in December, summer period. On the other hand, in the present study the collection at 56 days was carried out in September, winter period. The high decomposition of straw observed even in the winter period may be related to the greater precipitation observed particularly in August, which was 100 mm above the historical average (NITSCHE et al., 2019). Because cassava is a long-cycle crop, residue decomposition increases with time and may vary as a function of the chemical-bromatological composition of the straw. At 448 days after cassava planting, the straw decomposition reached 76.23%, leaving 1894 kg of residual straw in the no-tillage cassava plots. After the decomposition constant (k) of the Marandu grass residual straw was determined, the half-life time ($t_{1/2}$) of that straw was calculated, which is the time required for 50% of the biomass to be decomposed. A total of 164 days were necessary for 50% of the marandu grass straw to be decomposed in the no-tillage cassava treatment.

CONCLUSIONS

Straw was maintained during the crop cycle in no-tillage, but it provided less tuberous root production compared to conventional planting. More studies are being conducted to determine the effect of grass straw on the physical and chemical properties of the soil in integrated crop-livestock systems with cassava and beef cattle.

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FERMENTATIVE PATTERN OF SILAGES OF MAIZE IN SINGLE CROP AND INTERCROPPED WITH RUZIZIENSIS GRASS IN INTEGRATED SYSTEMS

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ABSTRACT

Maize silage has a high nutritional value in the feeding of ruminants, having desirable characteristics for silage. The aim was to evaluate the fermentative pattern of maize silages in single crop and intercropped with ruziziensis grass in integrated systems in the municipality of Colorado do Oeste – RO, Brazil. The randomized block design was adopted, with five repetitions. The treatments were arranged in 2x4 factorial scheme, being: two crop modalities (single, intercropped) and four maize plant parts (whole plant, half plant, plant without ear and ear with straw). The forage and silage pH values did not change. Higher values of buffering capacity (BC) were observed for the forages of whole maize plant in single crop, plant without ear in single crop and whole maize plant intercropped with ruziziensis grass. The NH_3-N contents were higher for whole plant silages in single crop, half plant in single crop and snaplage in intercropped crop. The forage has low BC with values ranging from 7.70 to 13.30 eq.mg HCl/100 $g^{-1}$of DM. The silage has adequate pH and ammonia nitrogen values indicating a good fermentative pattern in the silage produced with different maize plant parts intercropped with ruziziensis grass.

Key words: Crop-livestock integration; Silage; *Urochloa ruziziensis*

INTRODUCTION

Most ruminant production systems in Brazil are based on the use of tropical forages (MOREIRA et al., 2015). In order to overcome critical periods of forage scarcity as occurs in the dry season of the year, some forage conservation techniques, such as silage (SANTOS et al., 2017), become important tools for animal origin products competitive in the current scenario of growing and constant demand for food.

Maize is considered a standard plant for ensiling, due to its fermentative characteristics (FERREIRA, 2001). Thus, it is important to evaluate the silage produced from maize intercropped with grasses in crop-livestock integration systems, given that the silage harvester platform does not harvest only the maize, also harvesting the grass that is above the harvest height (BORGHI et al., 2006).

With this, the aim was to evaluate the fermentative pattern of maize silages in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*) in integrated systems.

MATERIAL AND METHODS

The experiment was carried out in the rural property Nossa Senhora Aparecida, located in the municipality of Colorado do Oeste – RO, Brazil (13° 07’ latitude S; 60° 31’ longitude W). The region climate, according to the Köppen-Geiger classification, is of the Awa type, with two well-defined climatic seasons: summer (May to September) and winter (October to April).

The randomized block design was adopted, with five repetitions. The treatments were arranged in 2x4 factorial scheme, being: two crop modalities (single maize and maize intercropped with ruziziensis grass) and four maize plant parts (whole plant, half plant, plant without ear and ear with straw).

The grass was sown manually by hauling prior to the maize sowing, which occurred mechanically. Seeding fertilization was administered at doses of 25 kg ha^{-1} of N, 45 kg ha^{-1} of P_2O_5, using ammonium monophosphate and simple superphosphate, respectively. For covering fertilization, 196.6 kg ha^{-1} of N were used, divided into two applications (at 15 and 30 days after the emergence of maize plants) and 58 kg ha^{-1} of K_2O, using urea and potassium chloride, respectively. The maize plants were harvested manually at the floury stage, at a height of 0.2 m and 1.0 m above the soil surface.

The experimental silos were filled with forage by manual compaction, obtaining the density of green mass of 556.68 kg m^{-3} and were sealed with polyvinyl chloride film (PVC) at the edges of the lid in order to keep the environment in anaerobiosis. The opening of the silos occurred 135 days after silage. The forage and silage samples were analyzed to determine the buffering capacity (forages); nitrogen ammonia (NH_3-N) and pH (silages).

To evaluate the buffering capacity (BC), 20 g of silage were weighed and 250 mL of distilled water were added. The titration was carried out to pH 3.0 with HCl (0.1 N) and, subsequently, it was titrated with NaOH (0.1 N) to pH 6.0. With the silage sample, an aqueous extract was made, from the liquefaction for one minute, of 50 g of the silage and 100 mL of distilled water (Kung Jr. et al., 1996). Subsequently, the material was filtered through filter paper and subjected to pH determination with the aid of a digital potentiometer.

The NH_3-N content was determined by the colorimetric reaction method catalyzed by indophenol (Method INCET-CA N-006/1; Detmann et al., 2012), in which we proceeded with the preparation of aliquots to adjust the standard curve, pipetting 0; 5; 10; 15; 20; 25 µL of standard solution in eppendorf tubes and adding 1.5 mL of phenol solution and 1.5 mL of sodium hypochlorite solution, followed by vortexing.

The data were subjected to analysis of variance and Tukey's range test, at 5% probability.

RESULTS AND DISCUSSIONS

An interaction effect ($P<0.05$) was observed for the BC (forage) and for (NH_3-N) (silage). The pH values of the forages did not change due to the crop modality and/or maize parts, presenting a mean value of 5.65 (Table 1).

Relating these contents to the BC that the forage has, the pH will go down to adequate values, once the fermentation intensity is sufficient, configuring a forage with low resistance to lowering the pH. The greater the BC, the greater the amount of acid necessary to reduce the silage pH, the longer the fermentation process, the greater the consumption of soluble carbohydrates and the greater the losses. In general, the BC values ranged from 7,70 to 13,30 eq.mg HCl/100 g^{-1}of DM and did not constitute an obstacle to the rapid reduction of pH, with values ideally below 20 eq.mg HCl/100 g^{-1}of DM (FERRARI JUNIOR & LAVEZZO, 2001).

Table 1. Analysis of variance for the forage and silage characteristics of the maize plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

	Forage		**Silage**	
Variable	**BC**	**pH**	**NH_3-N**	**pH**
Modality (M)	ns	ns	ns	ns
Plant parts (P)	*	ns	*	ns
M x P	*	ns	*	ns
Block	ns	ns	ns	ns
CV (%)	31.69	14.92	12.77	2.12
Mean	9.61	5.65	5.70	3.85

BC: Buffering capacity (eq. mg HCl 100 $g^{-1}$of DM). pH: hydrogen potential, NH_3-N: Ammonia Nitrogen (% total N). *: Significant to 5% probability of error. ns: Not significant. CV: Coefficient of variation.

Although higher BC values were observed for the forages of whole maize plant in single crop, plant without ear in single crop and whole maize plant intercropped with ruziziensis grass forrages (Table 2), it is verified that all the values are adequate (MCDONALD et al., 1991), making it possible to reduce the forage pH from the fermenta- tion processes inside the silo. Such an increase may be related to the reduction in the soluble carbohydrates content due to the different plant parts and the consequent organic acids production, such as lactic and acetic acids, which may have occurred.

For the silage characteristics, although there was a difference in the NH_3-N values (Table 2), with higher contents for the silages of whole plant in single crop, half plant in single crop and ear with straw (snaplage) in intercropped silages, such superiority in the values it did not reach that content that would be harmful to the fermentation process. According to Van Soest (1994), NH_3-N values below 10% are an indication of high quality of silage.

Table 2. Buffering capacity (BC) of forage and ammoniacal nitrogen content (NH_3-N) of the silage maize plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

Modality	**Maize plant parts**				**Mean**
	Whole plant	**Half plant**	**Plant without ear**	**Ear with straw**	
		BC (eq. mg HCl 100 g^{-1} of DM)			
Single	13.30 aA	9.77 aAB	12.19 aA	5.03 aB	10.07
Intercropped	8.19 bB	7.70 aB	13.45 aA	7.21 aB	9.14
Mean	10.75	8.74	12.82	6.12	
		NH_3-N (%TN)			
Single	6.17 aA	6.57 aA	4.77 aB	5.84 aAB	5.84
Intercropped	5.40 aAB	4.74 bB	5.53 aAB	6.58 aA	5.56
Mean	5.78	5.66	5.15	6.21	

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ statistically from each other by the Tukey test at 5% probability.

The mean pH value was lower than 4.2, indicating that good fermentation occurred inside the silo, with an adequate reduction in the pH of ensiled forage (influenced by low BC) and low undesirable microorganisms' activity. Taking into account that in a good quality silage the pH should vary from

3.8 to 4.2, and in this research, it was found that the mean pH value of the 3.85 silage is within the recommended values of a good quality silage (MONTEIRO et al., 2011). Quaresma et al. (2010), also stated that pH with a maximum value of 4.2 indicates good quality silages.

CONCLUSIONS

The forage has low buffering capacity with values ranging from 7.70 to 13.30 eq.mg HCl/100 $g^{-1}$of DM. The silage has adequate pH and ammonia nitrogen values indicating a good fermentative pattern in the silage produced with different maize plant parts intercropped with ruziziensis grass.

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CORN GRAIN QUALITY IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS: HOW DISTANCE OF TREE LINES AFFECTS DAMAGE AND BULK DENSITY OF GRAINS

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ABSTRACT

The objective of this study is to evaluate how the distance between the corn planting rows intercropped with *Urochloa* cultivars and the tree stand line (eucalyptus) affects grain bulk density and percentage of damaged grains. The treatments consisted of the corn in two cropping systems, i.e., between eucalyptus stands (integrated crop-livestock-forestry-ICLF) and in full sun intercropped with the *Urochloa*, in the planting line three years after the establishment of eucalyptus trees (2013/2014 harvest). Corn samples in two cropping systems were submitted to the physical classification according to the methodology described in the Technical Regulation of Corn, volumetric weight (bulk density) of grains (kg m^{-3}) and moisture content. In the ICLF system, grain bulk density was negatively affected by tree growth, and this parameter increased with greater distance to the tree stand line, and on the other hand, the total damaged grains show the opposite tendency, with a reduction in the total percentage of damaged grains with the increase in the distance from the tree stand lines. The growth of trees in the harvests after the third year of the establishment of the ICLF system increases losses in grain bulk density and total damage of corn grains.

Key words: *Zea mays*; grain damage; intercropping system

INTRODUCTION

Intensive production systems such as integrated crop-livestock-forestry (ICLF) seek to improve the conditions of degraded areas by including different species, in a synergistic manner, to recover and maintain productivity (BALBINO et al., 2011). They offer an alternative for regions where the use of pasture predominates as a way of producing meat and milk and which are suffering from degradation of pastures, for example, the Brazilian Cerrado region. This system has other advantages, such as more rational use of inputs, machines, and labor on farms, in addition to diversification of production and the cash flow of producers (MACEDO, 2009).

The ICLF system with intercropping of corn and *Urochloa* cultivars is recommended for regions with agroclimatic aptitude for corn culture, and specific financing incentives should be provided by government programs, such as the ABC Plan (Low Carbon Agriculture) (GONTIJO NETO et al., 2014). The intercropping of eucalyptus, corn, and *Urochloa* has become one of the strategies to maximize the sustainability of livestock in different regions, including the Brazilian Cerrado, where livestock activity predominates as the main source of income for producers. This intercropping has been studied in long-term experimental areas, such as in the experimental field of Embrapa Maize & Sorghum, in Sete Lagoas/MG, with a focus on evaluations grain, forage and wood production and their sustainability (CAMPANHA et al., 2020; MOREIRA et al., 2018; SIMÃO et al., 2018; WENDLING et al., 2014).

The quality evaluations of grains produced in the ICLF systems are still little explored, especially when it comes to assessing the influence of the impact of trees, for example eucalyptus with 3 years of planting, on the shade and of the plants of the annual crops grown between the tree lines. Studies evaluating the presence of fungi in soybean grains, in ICLF systems, point out that these systems did not negatively affect the quality of soybean grains (WRUCK; MAGALHÃES; HENNING, 2019). Initial quality measurements of corn grains produced in the ICLF system compared to grains produced in the conventional system (monocultures) point out qualitative parameters compatible with the tolerance limits established in the current quality and identity standards established for corn (BRASIL, 2011; PIMENTEL et al., 2012), without damage to the quality of grains produced in this system.

However, in field observations, there was a certain influence of the tree line on the closest plants, whether owing to shading or even competition (SIMÃO et al., 2018), which can directly reflect on the quality of the grains produced, and negatively impacts producers, especially nowadays with comparatively higher prices of grains such as corn (CEPEA/ESALQ/USP, 2021). These work tests the hypothesis that the tree stand line impacts grain bulk density and percentage of total damage; thus, the objective of this study is to evaluate how the distance between the corn planting rows intercropped with *Urochloa* and the tree stand line (eucalyptus) affects grain bulk density and percentage of damaged grains.

MATERIAL AND METHODS

The experiment was conducted in the experimental area of Embrapa Maize & Sorghum, in Sete Lagoas/MG (19° 29’106’’S, 44° 10’773’’W, at an altitude of 708 m). The climate of the region is of the Aw type, according to Köppen’s classification, with dry season from May to October and wet season from November to April. The soil is classified as a typical dystrophic Red Latosol (LVd), with clayey texture, according to the Brazilian Soil Classification System (SANTOS et al., 2013), with smooth undulating relief, under Cerrado vegetation. The chemical attributes soil of the experimental area were described by Moreira et al. (2018).

On October 24, 2011, the cultivar GG100 of eucalyptus (*Eucalyptus urophylla* S.T. Blake) was planted in six rows, with a length of 100 m, in the spatial arrangement of 15x2 m, totaling 333.3 trees per hectare. Clonal seedlings were sown in the furrow and fertilized with 200 kg ha^{-1} single superphosphate, plus 120 g N-P_2O_5-K_2O (06-30-06) per plant, with 0.5% B and 1.5% Zn, half applied on each side of the hole, at 15 to 20 cm from the seedling. Cover fertilization was performed within the crown projection area with 120 g N-P_2O_5-K_2O (20-00-20) per plant one week after planting and with 200 g per plant in November 2012. Then, in February 2013, 15 g boric acid was applied per plant within the crown projection area of each tree. In September 2013, the trees were stripped to 1/3 of their height. In November 2013, the eucalyptus stands presented mean heights of 10.3 m.

A no-tillage seeder-fertilizer was used to sow AG 8088VT PRO corn seeds simultaneously with 4 kg ha^{-1} viable pure seeds of forage grass in the same planting row, both between the eucalyptus stands and in the area with full sun. To this end, three rows were spaced 0.70 m apart, keeping 1 m between the first row of corn and forage and the eucalyptus tree stand (tree component), up to a final stand of 68,000 plants per hectare. The area planted with corn intercropped with forage and eucalyptus was of 0.867 ha. The corn seeds were treated with 135 g ha^{-1} imidacloprid + 186 g ha^{-1} thiodicarb. Fertilization at the time of sowing consisted of 400 kg ha^{-1} N-P_2O_5-K_2O (08-28-16), and, when corn reached the V6–V7 phenological stage, the cover crop was fertilized with 250 kg ha^{-1} urea (Souza & Lobato, 2004). The seeds of the grasses were treated with 5 g ha^{-1} fipronil.

The control of invasive plants was carried out between 15 and 21 days after sowing with the application of 1.5 kg ha^{-1} atrazine and 10 g ha^{-1} nicossulfuron to slow down the development of the forage. The experimental design was completely randomized, in 2x5, with four replicates. The treatments consisted of the hierarchical factors: corn in two cropping systems (plot), i.e., between eucalyptus stands (ICLF) and in full sun intercropped with the forage grasses *U. brizantha* 'Marandu', *U. brizantha* 'Xaraés', *U. brizantha* 'Piatã', *U. ruziziensis*, and *U. decumbens* 'Basilisk' in the planting row (subplot) three years after the establishment of eucalyptus trees (2013/2014 harvest). Samplings were performed at 2013/2014 harvest when corn grains reached around 14% moisture. The useful experimental plot in the ICLF system consisted of 2.0x4.9-m (9.8 m^2) areas, perpendicular to the rows of tree, in which 2 linear meters were evaluated in the first (1.0 m), third (2.4 m), fifth (3.8 m), seventh (5.2 m) and ninth (6.6 m) corn rows.

In the full sun system, corn intercropping was evaluated in a useable area of 1.4 m^2 (2 m length x 0.7 m width), in the direction of the corn planting row. After mechanical threshing, homogenization and reduction of samples from each plot were performed, and grain bulk density (kg m^{-3}) was determined using a kit for determining the volumetric weight (bulk density) of grains (Gehaka®) with capacity of one liter of grains. Moisture content was also initially determined, following the recommendations of the Seed Analysis Rules (BRASIL, 2009).

The physical classification was performed according to the methodology described in the Technical Regulation of Corn (IN 60/2011), which defines the identity and quality for purposes of classification into group, class and type (BRASIL, 2011). The parameters analyzed in the classification process were (%): broken grains (5mm and 3mm sieves), foreign matter and impurities, insect damage, heat damage, immature grains, fermented (cob rot damage), germinated, plastered, mold damage and total of damaged grains, which represents the sum of the seven classes of defects described.

Grain bulk density and total of damaged grains (%) were submitted to analysis of variance. The relationships between grain bulk density and total of damaged grains and the distance to the tree stand line (m) were subjected to regression analysis, in addition to correlation analysis.

RESULTS AND DISCUSSIONS

The effect of distance to the tree stand line was significant in the variation of grain bulk density ($F_{4;16} = 39.44$; $P < 0.0001$), but non-significant between the five different stands ($F_{4;16} = 1.62$; $P < 0.1790$) and their interactions ($F_{4;16} = 0.69$; $P < 0.7916$) for the evaluated parameters. It was found that, in the ICLF system, grain bulk density was negatively affected by tree growth, and this parameter increased with greater distance to the tree stand line (Figure 1).

Linear response between grain bulk density and the distance to the tree stand line was significant ($F_{1,24} = 65.76$; $P < 0.0001$) (Figure 1). Simão et al. (2018) also found an effect on the distance between the tree stand line and corn grain yield, with up to 30.2% reduction. These authors reported a reduction in the incidence of photosynthetically active radiation among the ranks, directly reducing forage and maize grains yields in the intercropping system with *U. brizantha*. The arboreal component in the Integrated Crop-Livestock-Forest system, especially in 3-year-old eucalyptus trees (above 10.3 m in height), alters the environment in the sub-forest, reducing the incidence of radiation in corn plants, which are highly dependent on solar radiation for their full development.

The distance to the tree stands lines had a significant effect on the variation of total damaged grains ($F_{4;16} = 28.86$; $P < 0.0001$), but it was not significant between the five different stands ($F_{4;16} = 5.23$; $P < 0.0100$) and their interactions ($F_{4;16} = 1.42$; $P < 0.1579$) for the evaluated parameters. The ICLF system affected the total damaged grains near the tree lines, with a reduction of the damaged grains with increased distance from the tree stand line (Figure 2). The total percentage of damaged grains is represented by the sum of the main defects identified in the samples, being the sum of insect damage, heat damage, immature grains, fermented (cob rot damage), germinated, plastered and mold damage. The predominant damages observed in the samples were heat damage, fermented, mold damage and immature grains, respectively.

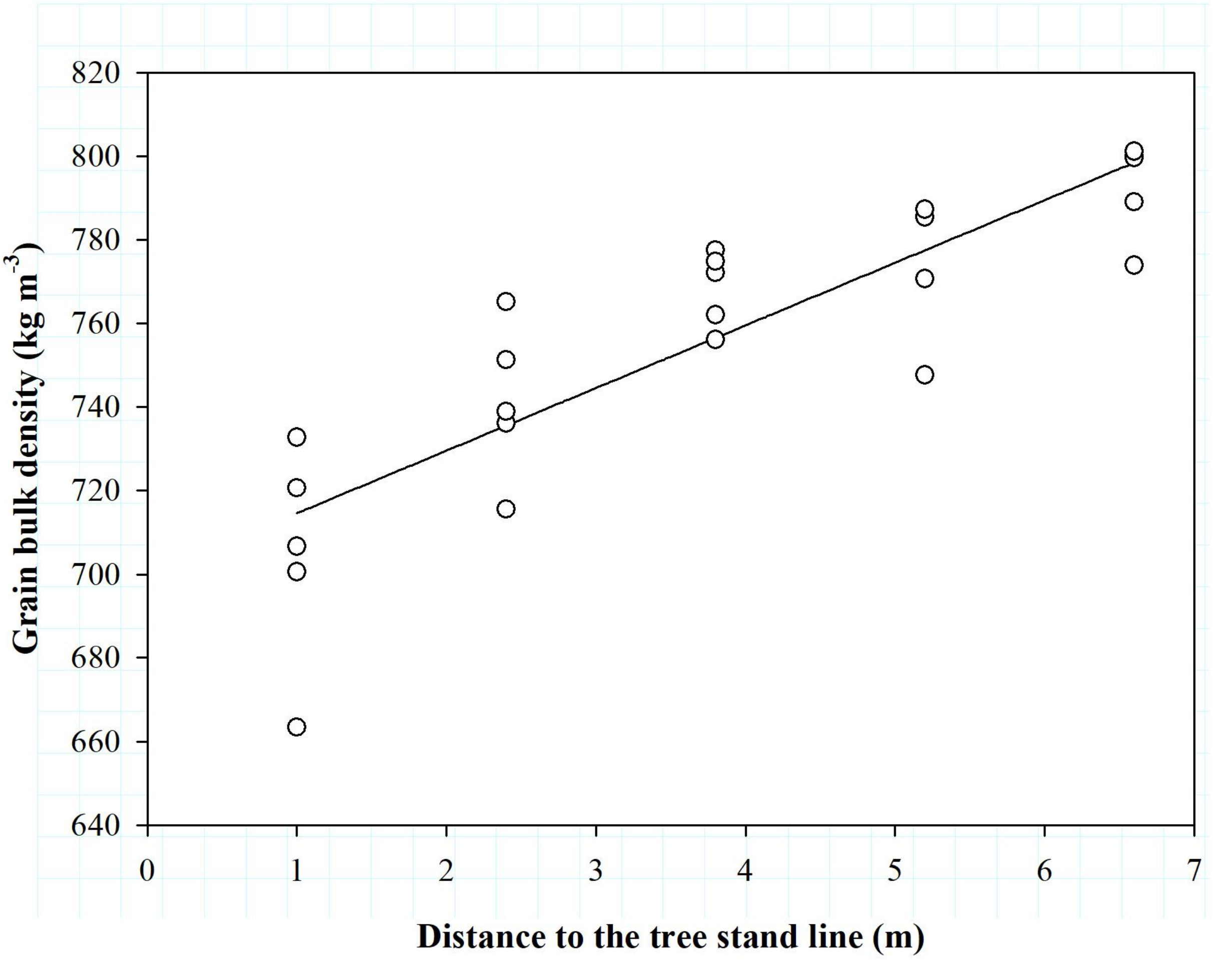

Figure 1. Influence of distance to the tree stand line (m) on bulk density of corn grains (kg m^{-3}). Curve was fit using regression analyses ($y = 699.59 + 14.99x$; $r^2 = 0.86$).

There was a significant linear response between total amount of damaged grains and distance to the tree stand line ($F_{1,24} = 54.47$; $P < 0.0001$) (Figure 2). This finding suggests that the total amount of damaged grains was reduced when the distance to the tree stand line was increased; total damage ranged between 1.5 to 3.0% in the first line after the tree stand line, and less than 1.0% in the furthest lines (Figure 2).

There was a reduction in grain bulk density in the ICLF system compared with full sun in the first two rows, with a mean reduction of 11.4 and 6.78% in weight, respectively. For the total amount of damaged grains, there was an increase by 84.6 and 83.3% in the ICLF system compared with full sun in the first two lines, respectively. It was found that grain bulk density increased with increasing distance to the tree stand line, and there was a positive and significant correlation (Table 1). The total damaged grains decrease with increasing distance to the tree stand line, and there was a negative and significant correlation (Table 1). The relationship between grain bulk density and total damaged grains was a negative and significant correlation (Table 1). Our results with positive and significant correlation between grain bulk density and distance to the tree stand line were corroborate in the work of Simão et al. (2018), who found significant positive correlations between corn grain yield and solar radiation level.

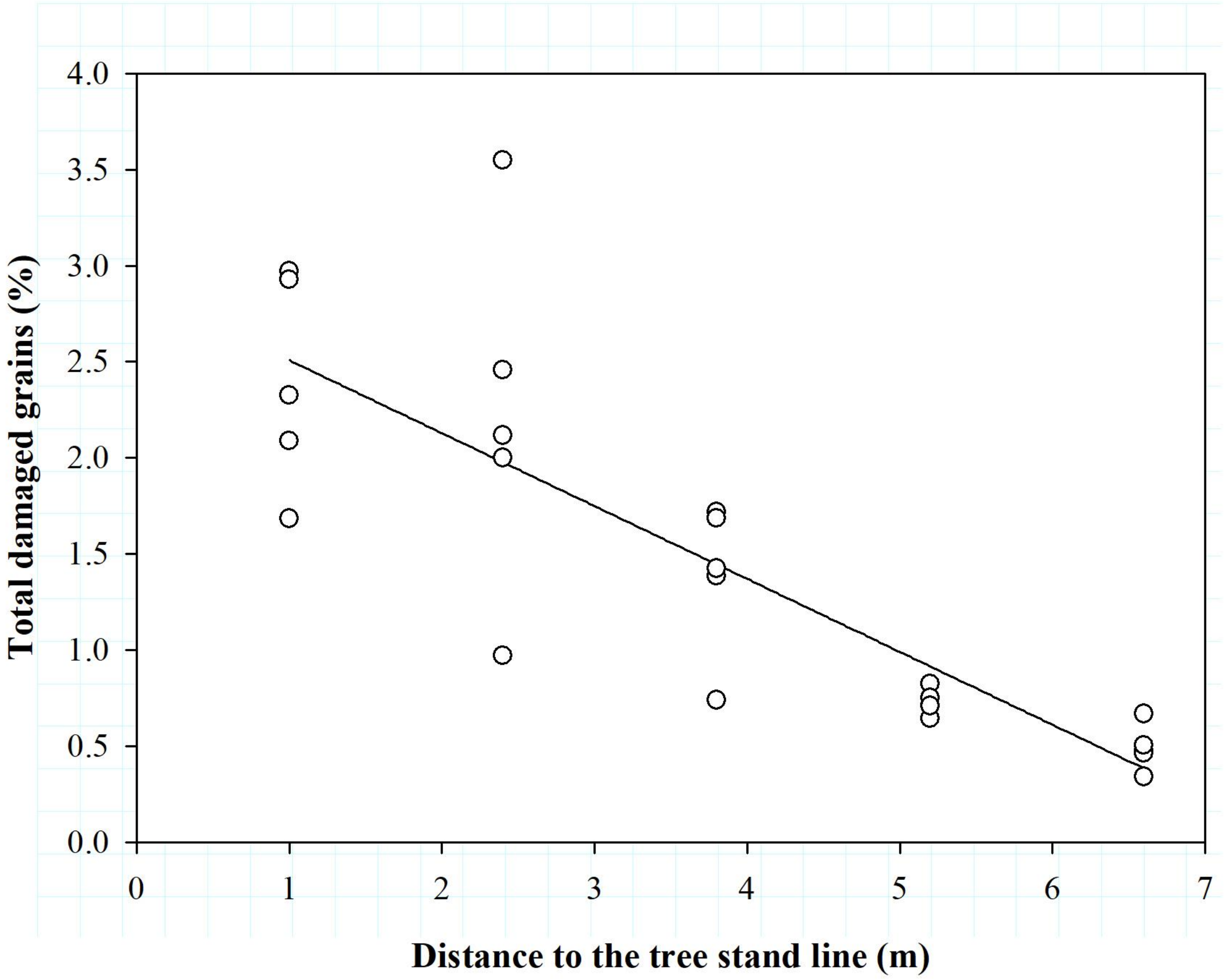

Figure 2. Influence of distance from trees (m) on total damage corn grains (%). Curve was fit using regression analyses ($y = 2.89 - 0,38x$; $r^2 = 0.84$).

Considering the Normative Instruction that establishes the qualitative parameters for classification of corn into types (BRASIL, 2011), the ICLF system presents a quality of grains similar to the one presented in the full sun system (monoculture), with percentages of damaged ones that allow framing in Type 1. Grains harvested in the rows closest to the tree stand showed percentages of damaged ones that fit the grains into Type 2 or 3. Thus, the producer must be attentive to the cultivation of corn in ICLF systems with larger trees, as in this experiment where the eucalyptus reached 10.3 meters in height, on average.

Table 1. Pearson's correlation coefficients between grain bulk density, total damaged grains and distance to the tree stand line.

	Grain bulk density	**Total damaged grains**	**Distance to the tree stand line**
Grain bulk density	1.00	-0.68888*	0.86073*
Total damaged grains		1.00	-0.83886*
Distance to the tree stand line			1.00

*Significant (p <0.01) by the Pearson test.

CONCLUSIONS

The tree stand line negatively impacts grain bulk density and increases the percentage of total damage, on the rows close to the stand tree line. The growth of trees in the harvests after the third year of the establishment of the ICLF system increases losses in grain bulk density and total damage of corn grains.

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GRAIN YIELD, DRY MATTER AND EFFICIENT LAND USE IN CORN CONSORTIUM WITH UROCHLOA RUZIZIENSIS IN EASTERN MARANHAO

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ABSTRACT

Integrated agricultural systems require technical, economic and administrative knowledge that guarantees better results and competitiveness. The objective of this work was to evaluate corn grain yield, *Urochloa ruziziensis* dry mass and land use efficiency in these crops consortium in response to different planting densities of brachiaria grass. Experiment was conducted in Brejo, MA, in 2016/2017 agricultural year and treatments arranged in a randomized block design, in factorial scheme, two corn genotypes (conventional simple hybrids - 30 F 35 and Truk VIP3 simple hybrid transgenic); four *U. ruziziensis* planting density (2, 4, 6 and 8 kg ha^{-1}); and two additional treatments (monoculture of corn and brachiaria). Hybrid corn Truk VIP3 showed higher grain yield and better adaptability in consortium with *U. ruziziensis*. For both hybrids, the corn consortium with brachiaria proved to be efficient with higher values of efficient land use with Truk VIP3. Regarding grain and dry matter productivity, the best treatment was observed at planting densities of 4 and 6 kg ha^{-1}.

Key words: Plant arrangement; Integrated system; *Zea mays*

INTRODUCTION

Crop-livestock integration (CLI) is characterized by diversified exploration, rotation, intercropping or succession of agricultural and livestock activities within rural property in a harmonious way, constituting the same system, in such a way that there are benefits for both. Integrated systems allow soils to be better used and economically, throughout the year or in most of it, favoring an increase in grain, fibers, wool, meat, milk and biofuel supplies.

It also allows production at lower costs due to the synergism that arise between crops, pastures, livestock and soil. The technologies that make up the CLI are sustainable and competitive in the different edaphoclimatic conditions in the country, enabling the sustainability of Brazilian agribusiness. Adopting the system leads to a reduction in input costs, a greater supply of jobs, a better income distribution and a reduction in rural exodus. According to Balbino et al. (2011) Integrated Crop-Livestock or Agro pastoral systems are those in which production includes agricultural and livestock components in rotation, consortium or succession, in same area and in same agricultural year or for several years, in sequence or interspersed.

Yield and profitability are three times higher for beef cattle and 10 to 30% for grain crops compared to traditional production systems. Several studies have demonstrated technical feasibility of the consortium forages / cereals in ILP systems, with emphasis on corn (COSTA et al., 2012; BORGHI et al., 2007; BORGHI et al., 2013). Leonel et al. (2009) stated that forage / maize consortium efficiency in the recovery of degraded pastures for ruminant production, attributed to higher dry matter yield cultivation of two rows of grass *Urochloa* genus between corn lines.

Thus, the objective of this work was to evaluate performance of two simple hybrids maize in consortium with forage species of *Urochloa* genus, in different planting forage densities.

MATERIAL AND METHODS

Filed experiment was performed in 2016/2017 harvest, in Brejo, MA, located in micro-region named "Chapadinha" (03°42'44" S; 42°55'44" W, 55 m altitude), Western Maranhão State, on red-yellow clay soil (FERRÃO et al., 2018; SANTOS et al., 2018).

Soil samples were collected at a depth of 20 cm and analyzed by the Soil Fertility Laboratory at Embrapa Meio-Norte, with pH (H_2O 1: 2.5) = 5.3; phosphorus (mg dm^{-3}) = 5.4; potassium (cmolc dm^{-3}) = 0.11; calcium (cmolc dm^{-3}) = 2.0; magnesium (cmolc dm^{-3}) = 0.9; aluminum (cmolc dm^{-3}) = 0.3; organic matter (g kg^{-1}) = 20.1.

Treatments consisted of two simple corn hybrids, 30 F 35 (conventional) and Truk VIP3 (transgenic) in four planting density of brachiaria (*Urochloa ruziziensis*), whose densities were 2, 4, 6, and 8 kg ha^{-1} of seeds.

Treatments were arranged in a 2 x 4 factorial scheme in a randomized blocks experimental design and four replications with two additional treatments (corn and brachiaria monoculture). Spatial arrangement of plants was corn sown in a row and brachiaria grass by haul. In each experimental plot, six rows of eight-meter-long corn were used, with a distance of 0.50 m and within the row and 0.33 m between corn pits, with brachiaria planted in a haul between corn rows.

Agronomic characteristic observed and analyzed statistically for corn was grain yield at 14% moisture. Dry mass for brachiaria grass was evaluated in 0.25 m^2 (0.5 m x 0.5 m) where they were transformed into kg ha^{-1}.

Land use efficiency (EUT) was determined using the expression EUT = PGMC / PGMS + BBC / BBS (WILLEY, 1979; TRENBATH, 1979). Where PGMC = maize grain productivity in consortium with brachiaria; PGMS = productivity of corn grains in an exclusive system; BBC = dry biomass productivity in consortium with corn and BBS = dry biomass productivity in an exclusive system.

Regression was used in variance analysis with first and second degree models for plant densities following the methodology of Pimentel-Gomes (2009) and Zimmermann (2014). Due to t test, best model was obtained with aid of significance of each parameter, accepting a level of significance up to the limit of 15% of probability (CONARGIN; JORGE, 1982).

All analyzes were performed using the ExpDes package version 3.5.1, in the R® language (FERREIRA et al., 2014).

RESULTS AND DISCUSSIONS

There was an effect ($P < 0.05$) of hybrid interaction of corn versus planting density of brachiaria for grain yield. For both hybrids, effects were linear decreasing with increase in planting density of brachiaria grass (Figure 1), with highest grain yields observed in hybrid Truk VIP3. Linear decreases observed in grain yields indicate that, for each increase of one kilo of brachiaria seeds per hectare, there is a reduction of 533.65 kg ha^{-1} and 336.5 kg ha^{-1} of corn grains, respectively, in the hybrids 30 F 35 (Figure 1 top) and Truk VIP3 (Figure 1 bottom). Difference between hybrids may be related to biotechnology (VIP3) to control the main caterpillars that attack the corn present in the hybrid Truk VIP3 in relation to the hybrid 30 F 35 (Conventional). At 30 F 35, several events were observed with caterpillar incidence, with reduction of leaf area, requiring control.

Regarding dry mass yield of brachiaria, the response to planting density was linear with an increase, for each kilo of forage seeds added, by 467 kg ha^{-1} (in consortium with corn 30 F 35) and 548 kg ha^{-1} (in consortium with the Truk VIP3 hybrid). These results are related to height of forage, which was higher, on average, in Truk VIP3 corn compared to corn 30 F 35. Important information for animal feed during off-season, as higher dry matter yields of forage provide more food supply.

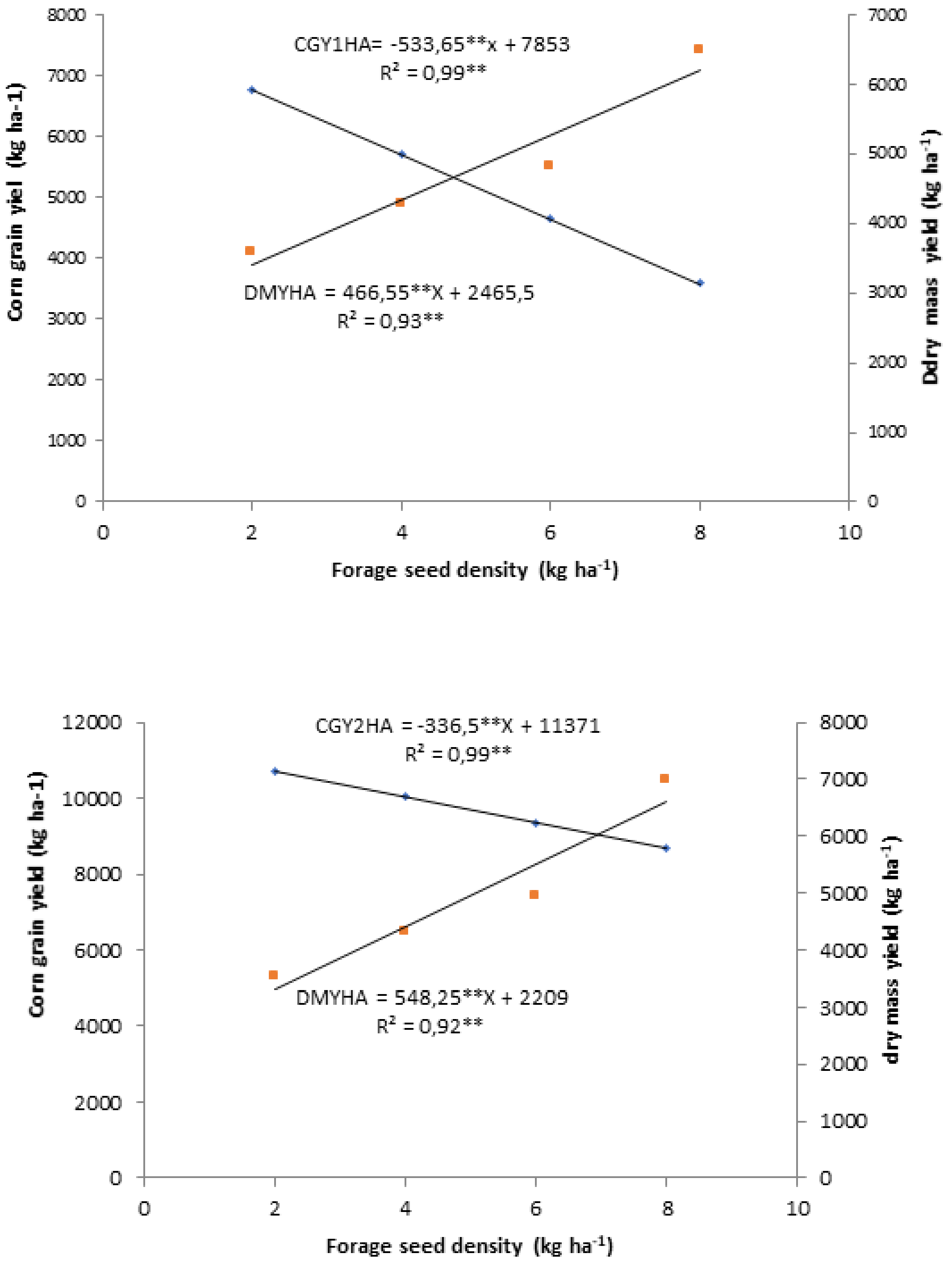

Figure 1. Relationship between grain yield of corn 30 F 35 (top Figure) and Truk VIP3 (bottom Figure) and dry matter yield of *U. ruziziensis* in relation to forage planting densities. Brejo, MA. Agricultural year, 2016/2017. ** (P <0.05) by t test.

Crops integrated has a higher grain yield than its respective monocultures when efficient land use (UET) reaches a value greater than 1 (LIEBMAN, 2012).

Both hybrids corn showed a greater efficient use of land in association with brachiaria whose best results were found when associated with hybrid Truk VIP3 (average 1.47) compared to hybrid 30 F 35 (average 1.32). There is a positive relationship in dry mass yield of brachiaria with an increase of its density and a negative relationship with grain yield of corn with better adjustment between 4 and 6 kg ha^{-1} of seeds of brachiaria ha^{-1}. Results with same trends have been observed in other studies (BORGHI; CRUSCIOL, 2007; BORGHI et al., 2013).

CONCLUSIONS

Integrated corn versus brachiaria system when compared to the exclusive system is 47% more efficient on average with Truk VIP3 corn and 32% with 30 F 35 maize. Best yields of corn grains and dry mass of brachiaria occur with planting density of 4 to 6 kg ha^{-1} of forage.

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ESTIMATES OF YIELD SAWN WOOD OF EUCALYPTUS AGED 15 YEARS IN CLFI SYSTEM

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ABSTRACT

Trees in the Crop-Livestock-Forest Integration (CLFI) systems represent an opportunity to increase income on the farm through the sale of wood. Sawn wood is the product with the highest value and highest rate of return for producers. The objective of this work was to evaluate the potential of production and yield of eucalyptus wood in CLFI system with growth projection for the age of 15 years, in the Brazilian Cerrado. In October 2011, 333 eucalyptus ha^{-1} trees were planted, arranged in simple rows at 15 x 2 m spacing, in an CLFI system. With the sampling of 40 trees, the growth was evaluated annually. After 97 months, the trees reached an average height of 27.8 meters, with an average diameter at breast height of 21.9 cm and an average volume of 153.6 m^3 ha^{-1} of wood. Wood production was projected for 15 years age, in which 220.34 m^3 ha^{-1} of wood would be produced, 50.64 m^3 ha^{-1} of which could be used as sawmill wood. The producer can view attractive markets for the commercialization of his product and plan its sale, when estimating the potential of wooden pieces that may be benefited from its tree population at any given time.

Key words: Crop Livestock Forest Integratio; wood splitting; projection

INTRODUCTION

Trees in Crop Livestock Forest Integration system (CLFI) provide important environmental and economic benefits to agricultural production in this system. Favoring the cycling of nutrients, contributing to the maintenance of soil fertility (SALTON et al., 2014) and presenting a great potential to carbon sequestration (ASSAD et al., 2019), the forestry component also adds wood production, as an opportunity to increase income on the property.

The market for planted forest products, including sawn wood, has been growing in recent years. According to the Brazilian Tree Industry, only 4% of the area planted with forests is destined for the solid wood products industry (IBA, 2019). Rural producers who have invested in the CLFI system, in addition to selling wood for coal to the energy sector, may also have the opportunity to offer wood to the sawn wood segment, enabling the formation of new regional poles that consume wood (DANIEL et al., 2019). The sawn timber market provides highest value and higher rates of return to producers (PAIXÃO et al., 2006; TONINI et al, 2019).

In CLFI systems, the forest component must remain long enough for large diameters logs to be obtained, of high quality can be obtained for noble purposes, such as the manufacture of furniture and lamination, since the number of plants per area is low (FRANCHINI et al., 2018). The influence of age is an extremely important factor, as it contributes to the formation of adult wood, with greater density and a higher percentage of heartwood (PLASTER et al., 2012; SERPA et al., 2013). Sette Jr. et al. (2012) report that the basic density of E. grandis trees increases with advancing age, forming the adult wood. And density is considered one of the basic indicators for most wood applications, for example, medium density wood may be suitable for furniture, cellulose and paper, etc. Higher density wood may be indicated for structural purposes, such as the manufacture of houses and bridges (CAIXETA et al., 2003).

In this sense, the objective of this work was to estimate the production potential and wood yield of an CLFI system after 15 years of its establishment, planted in the Brazilian Cerrado. For the purpose of this study, the age of 15 years was considered, when the eucalyptus reaches wood with reasonable maturity to obtain sawn pieces, due to the greater proportion of heartwood in relation to sapwood, based on information from sawmills in activities that operate with eucalyptus wood (oral communication).

MATERIAL AND METHODS

The CLFI system was established in Sete Lagoas city, in Brazil, at Embrapa Milho e Sorgo, in October 2011, composed of six simple lines of the GG100 clone, of Eucalyptus Grandis x urophylla, with 100 meters in length, in 15 x 2 meters spacing, forming a stand of 333 trees per hectare. The city is located in the central region of Minas Gerais state, at 708 m altitude, with a Cwa climate (dry in winter and hot in summer) (KÖPPEN, 1936 cited by ALVARES et al., 2013), and average annual rainfall of 1,335 mm. The soils were classified as typical dystrophic Red Latosols (LVd) are within the subcaducifolian Cerrado area.

One month before planting, 2 t ha^{-1} of dolomitic limestone were applied to the experimental area. The seedlings were planting with 200 kg ha-1 of simple superphosphate fertilizer. After seven days, 120 g plant^{-1} of NPK 06-30-06 + 0.5% B + 1.5% Zn were applied, with 60 days, 120 g plant^{-1} of NPK 20-00-20, to 13 months, 200 g plant^{-1} of 20-00-20 and, at 16 months, 15 g plant^{-1} of boric acid. At 24 months, the trees branches were removed up to 1/3 of their height.

During the 2011/2012, 2012/2013 and 2013/2014 crop growing season, the corn/ grass/ eucalyptus consortium was made. Corn (AG 8088 VT PRO) was sown between the eucalyptus rows in November, together *Urochloa brizantha* cv. Piatã. Fertilization of 400 kg ha^{-1} of NPK 08-28-16 were added to the soil at planting and 250 kg ha^{-1} of urea in the top dressing. The corn was harvested in May, and the pasture remained until the beginning of October, when the grass was desiccated for planting the new crop. After the initial three years, only the grass was kept between the eucalyptus lines, grazed by cattle, in the ICF system.

Eucalyptus growth was evaluated annually, with measures of diameter at breast height (DBH) measured with suta, and the total height (H) was measured with an electronic hypsometer, in 10% of the population. The volume (m^3 ha^{-1}) was estimated by an equation adjusted with the model by Schumacher and Hall (1933). The growth projection was carried out for the age of 15 years. The methodology used the Weibull distribution with three parameters, adjusted by the percentile method (WENDLING et al., 2011), and regression functions created from the relationship between the data for monitoring planting. Its implementation is part of the CalcMadeira software, still in its primitive version (COSTA et al., 2020).

RESULTS AND DISCUSSIONS

At 97 months of growth, the trees reached an average height of 27.8 meters, with an average diameter at breast height (DBH) of 21.9 cm. The estimated average volume of wood was 153.6 m^3 ha^{-1} (Figure 1).

A greater production of eucalyptus tree in CLFI in the Brazilian Cerrado is described in the literature (OLIVEIRA NETO et al., 2013; LEMOS JÚNIOR et al., 2016). The development of plants depends on intrinsic characteristics of the site, such as climatic and nutritional factors. In the region of Sete Lagoas, in the years 2013 to 2016, there was a predominance of water deficit (see CAMPANHA et al., 2017), which certainly compromised the growth of trees.

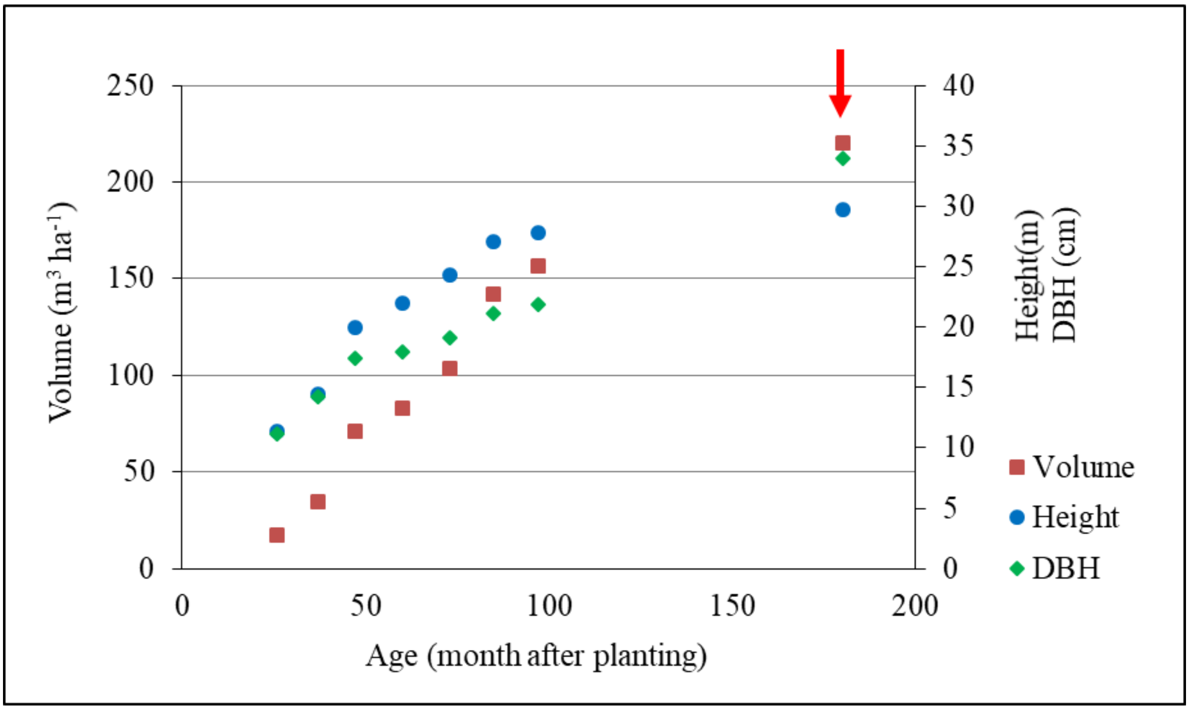

Figure 1. Average volume, height and diameter at breast height (DBH) per hectare, of eucalyptus trees at different ages, in CLFI system in the Brazilian Cerrado. The arrow indicates the projected values for 180 months.

As at the age of eight the eucalyptus is not yet suitable for cutting sawn wood, requiring diameters larger than 18 cm to delimit the commercial height, the production of wood was projected for the year 2026, a period in which 15 years of planting would be completed. The results of the split and the dimensions used for the pieces are shown in Table 1. The total volume was 220.34 m^3, with 50.64 m3 being used in sawn pieces with a 30% yield in relation to the volume of logs (171.01 m^3). The residue, referring to the wood that was not used in the sawmill, results in a surplus of 167.17 m^3 of wood that could be used for firewood, charcoal or wood chips.

With the possibility of estimating the quantity and volume of pieces of wood that may be benefited, the producer will be able to plan the appropriate moment for their sale, whether in the present or future. Although larger trees, in diameter and height and at an older age, can reach cut dimensions for products with higher added value, the cut intervention in a stand depends a lot on the need for financial resources and market opportunities seen by the producer.

Table 1. Projection of production and splitting of eucalyptus wood, for 180 months (15 years), planted in 1 ha in the CLFI system in the Brazilian Cerrado.

Use for swan wood	**Cutting priority**	**Width (cm)**	**Thickness (cm)**	**Pieces by use (quantity)**	**Volume used (m^3)**
batten	9	2 - 10	2 - 4		
big slat	8	5 - 7	2 - 2		
rafter	7	5 - 8	4 - 8		
prop	6	7 - 8	7 - 8		
slat	5	2 - 5	1 - 2	383	0.41
beam	4	8 - 16	4 - 8		
board	3	10 - 100	1 - 4	2,140	26.53
plank	2	16 - 100	4 - 7		
big plank	1	16 - 100	7 - 16	683	23.70
a) Volume of swan wood*				3,205	50.64
b) Volume of wooden tips (= d-c)					49.33
c) Wood logs volume					171.01
d) Total volume of pieces of wood					220.34
e) Sawdust residue (= d-a)					167.17

CONCLUSIONS

The integration of grain production with livestock, in CLFI systems, presents itself as potential in relation to the forestry component, as eucalyptus planted in this system have production conditions for the supply of sawn wood. Expectations for the production of wood with higher added value can be a better alternative for the rural producer who has the availability of permanence of his trees for long periods. In this sense, the work developed here provides subsidies so that the producer can visualize attractive markets for the commercialization of his product, being the estimate of the split of the wood an important tool for the planning of the cutting of the trees.

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DETERMINATION OF HORMONAL PARAMETERS OF COWS IN SHADOWED ENVIRONMENT IN INTEGRATED CROP LIVESTOCK FOREST SYSTEM AND FULL SUN

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ABSTRACT

The use of Integrated Crop-Livestock-Forestry (ICLF) systems provides more natural shade, improving the thermal comfort of the animals. In shaded environments the temperature and wind speed decrease, and humidity is higher even in the warmest months. Under heat stress, dairy cows decrease the intake of dry matter, and change the production of hormones via the hypothalamic-pituitary-adrenal axis (HHA) inhibiting the synthesis of thyroid hormones such as thyroxine (T4) and triiodothyronine (T3), responsible for metabolic heat production, oxygen demand by blood cells and energy output. The objective of this study was to evaluate hormonal parameters of dairy cows in an ICLF system in shade and full sun. The levels of thyroid hormones were collected through venipuncture blood samples from 64 Girolando cows, 31 in full sun and 33 in natural shade with *Eucalypitus grandis* species in the months of August to December. The climatic parameters (air temperature and humidity, wind speed and radiation) measured at the weather station did not change considerably during the evaluated months. Cows under shade presented higher levels of T3 (13%) and T4 (9%) proving the attempt to decrease metabolic heat production of unshaded animals with the ICLF system.

Key words: Energy and heat balance; thyroxine; triiodothyronine

INTRODUCTION

Crop-Livestock-Forestry integration systems have been adopted in several properties over the years as a source of degraded pastures recovery, reduction of GHG emissions, water and soil conservation, increase of organic matter in the soil and provides greater thermal comfort for animals raised in pastures through natural shading (ALVES, 2012). The Cerrado area, where the concentration of ICLF systems is prevalent, displays a well-defined dry and rainy season, with annual precipitation average around 1,500 mm, and an average annual temperature ranging from 21.3 to 27.2 °C, with low wind speed, indicating microclimatic conditions of thermal comfort for dairy cows (BALBINO et al., 2011).

In addition to the sustainability and responsibility concepts of the agribusiness, the use of shade trees, especially species of eucalyptus, reduces the incidence of solar radiation during the warmest periods of the year, when there is less amount of precipitation, and consequently reduces heat intake by the animals. Rodrigues et al. (2010) in a research with different types of shading for dairy cows, claim that the animal welfare conditions were increased compared to systems without shade exposure. The use of natural shade from trees reduces the incidence of radiation in dairy cattle grazing systems by at least 30% (FERREIRA et al., 2014).

Heat promotes physiological and behavioral alterations, as well as interferences in the endocrine system of dairy cows, modifying the hormone secretion through the activation of the hypothalamic-pituitary-adrenal (HHA) axis. This activation of the HHA axis initiates the production of hormones, such as, cortisol, insulin, and gonadotrophic (LH and FSH) and thyroid (T3 and T4) hormones (YAMADA, 2020).

Triiodothyronine (T3) and thyroxine (T4) hormones are susceptible to body temperature oscillations in dairy cattle, and according to Yamada (2020), T4, produced by the thyroid gland increases metabolic heat production capacity, oxygen intake by blood cells, and increases heart frequency. While T3 results from the enzymatic deionization of T4, jointly determining how every cell uses energy (MORAIS et al., 2008).

Alternatives to minimize heat stress in dairy cows through shading, either natural or artificial, are being adopted by producers in all regions of Brazil. It is expected that the Crop-Livestock Forest Integration (ICLF) systems, by facilitating the thermal comfort of animals, through shading, may influence variations in the production parameters of thyroid hormones in dairy cows during periods of higher heat levels.

In light of these considerations, the objective of this study was to evaluate the hormonal parameters of dairy cows in an ICLF system in shaded and full sun conditions.

MATERIAL AND METHODS

The experiment was conducted during the year 2018, in the Center for Technology Transfer of Zebu Breeds with Dairy Aptitude of Embrapa Cerrados (CTZL), located at 15º57'09" S, and 48º08'12" W, Gama, Federal District. The experimental area, covering 16 hectares, was equally divided in two treatments, full sun and shaded (ICLF) with Eucalyptus grandis species arranged in single rows, 1.5m distance between plants and 25 m spacing, totaling approximately 267 trees/ha. The rotational grazing system was divided into 12 pens for each environment (shade and sun) and the common area was in the center of the area, with drinking pans and salt lickers. The fodder species used was Panicum maximum cv. Mombaça, and the animals were fed with mineral salt and water *ad libidum*.

Thyroid hormone levels (T3 and T4) were measured periodically by ELISA (Pishtaz Teb Zaman kit ® for in vitro quantitative determination of the total amount of binding site available for the Thyroid hormones in serum or plasma. Tehran - Iran) method using serum collected by vein puncture from each animal. The samples were collected on the following dates: 24/08/2018; 14/09/2018; 10/10/2018; 28/11/2018 and 13/12/2018, after milking in the morning period of the day.

The data were collected from 64 Girolando cows (½ Gir, ½ Holstein and 3/8 Gir 5/8 Holstein), 31 of these subjected to the full sun environment and 33 in the shaded environment in the period from August to December. A repeated measures analysis was done using PROC MIXED procedure on SAS® (v 9.1, Cary, North Carolina) with fixed effect of treatment (shadow x full sun) and genetic group (½ Gir, ½ Holstein and 3/8 Gir 5/8 Holstein) and their interactions.

The climatic parameters (air temperature and humidity, wind speed and radiation) were obtained at the INMET weather station 4.0 from the experimental area (Ponte Alta station – data available on site www.inmet.gov.br). The THI was obtained by Thom's formula (1958) cited by Borghi et al. (2020): $THI = ta + (0.36 \times tpo) + 41.5$ where ta - air temperature, °C; and tpo - dew point temperature, °C.

Table 1. Mean values of air temperature, relative humidity, radiation, wind speed and THI of two environments (full sun and shaded ICLF) in a tropical Cerrado climate.

Month	TA (°C)	TA máx. (°C)	RH (%)	RH máx. (%)	R (MJ/m²/d)	WS (m/s)	THI	THI máx.
August	21.9±0.18	22.9±0.18	51±0.71	55±0.72	1597.3±55.4	2.5±0.06	67.0	68.2
September	23.7±0.19	24.7±0.19	46.2±0.83	49.9±0.85	1765.8±60.8	2.46±0.05	68.7	69.9
October	23.3±0.14	24.2±0.15	69.6±0.71	73.4±0.67	1279.6±55.3	1.94±0.04	70.8	71.9
November	21.8±0.10	22.4±0.11	79.3±0.49	83.2±0.43	1126.3±52.2	2.06±0.05	69.7	70.4
December	22.4±0.13	23.2±0.14	71.8±0.66	75.6±0.6	1426.6±56.7	2.1±0.04	69.8	70.8

TA: ambient temperature; TA máx: maximum ambient temperature; RH: relative humidity; RH máx: maximum relative humidity; R: radiation; WS: wind speed; THI: temperature and humidity index; THI máx: maximum temperature and humidity index.

RESULTS AND DISCUSSIONS

The average and maximum temperatures presented no major variations during the months September and October of 2018, ranging within 21 to 24 °C. The relative humidity average presented higher values in November, as a result of the higher rainfall average expected in that year. The solar radiation rates were higher in August and September, with daily maximum temperatures peaks of 30 °C only in the afternoon, smaller percentages of humidity, and consequently lower THI ranges, however, although the temperature and humidity values had small variations, the maximum THI index in October indicates that the animals were under heat stress in full sun conditions during the experiment period, suggesting that the animals although submitted in full sun conditions (Table 1).

Cows that were kept under shade had higher values of T3 and T4. T4 was 9% higher and T3 was 13% higher (Table 2). The increase in thyroxine concentrations in shaded conditions of ICLF systems indicates that even in mild temperature conditions (Table 1), animals exposed to full sun modify physiological behaviours, reducing the production of thyroid hormones in order to control metabolic heat production and maintain thermoregulation capacity.

Table 2. Triiodothyronine (T3, ng/mL), total thyroxine (total T4, µg/dL), and free T4 (ng/dL) levels of lactating cows under full sun and shade in ICLF in a tropical environment in the Cerrado

Hormone	Full Sun	Shade ICLF	P-value
T3 total (ng/mL)	4.02±0.20	4.55±0.17	0.0329
T4 total (µg/dL)	9.10±0.25	9.95±0.26	0.0216
T4 free (ng/dL)	1.25±0.09	1.43±0.09	0.0895*

* Significance of 0.05 at the level.

Morais et al. (2008) in an experiment with Holstein cows in a semi-arid climate in northern Brazil for a two-year period, concluded that during the second year of data collection, T3 concentrations were lower, while T4 concentrations were higher than in the first year of data collection, which indicates a decrease in the mobilization of T4 in the synthesis of T3, although the hypothalamic-pituitary-thyroid axis was more active during the warm season. Thyroid hormones are associated with endogenous energy regulation mechanisms, since they act by consuming oxygen through enzymatic action. Under high temperatures, during the height of heat stress, concentrations of thyroid hormones may decline to promote a lower rate of metabolic heat production.

In a more detailed study on the concentration of thyroid hormones per year in dairy cows, Façanha et al. (2013) have observed that the time of year with higher temperature and humidity rates promotes a reduction in the concentration of these thyroid hormones, indicating the susceptibility of the thyroid gland in heat-stressed animals. The reduction in the synthesis of these hormones affects the milk production, growth and reproduction, damaging the animals in both short and long term. The use of thyroid hormones as indicators of heat stress may facilitate further research on thermoregulatory processes related to physiological mechanisms, although the time of year and climatic variables on the collection of thyroid hormones may be further investigated in order to establish the immediate or delayed effect of physiological and production responses and mobility of T4 and T3 in dairy cows.

CONCLUSIONS

The concentrations of T3 and T4 in shaded environments with ICLF were higher, compared to the concentrations in full sun environments, evidencing attempts to mitigate thermal stress and subsequent endogenous heat production of these animals in high temperature conditions. It is suggested, therefore, the physiological benefit that shade provides for dairy cows on pasture ICLF systems in the tropical climate.

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SOIL CHEMICAL ATTRIBUTES IN CROP-LIVESTOCK-FOREST INTEGRATION SYSTEMS COMPARED TO DIFFERENT PRODUCTION SYSTEMS

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ABSTRACT

Integrated Crop-Livestock-Forest Systems (ICLFS) enable the use of the soil for sustainable food production and contribute to the better use of the land, rationalization in the use of insums and in the improvement of chemical, physical and biological attributes. The objective of this study was to evaluate the chemical characteristics in a Dystrophic Red Latosol under ICLFS and compare it with different areas in the southern region of Goiás. In January 2018, the ICLFS was implanted with the forest component the clone eucalyptus AEC 2034 (*Eucalyptus camaldulensis* x *Eucalyptus grandis*) x *Eucalyptus urophylla* in the arrangement of 10 meters of inter-rows and 4 meters from the row of eucalyptus trees. The experimental area was composed of four systems (pasture, corn monoculture, eucalyptus and native forest area). Soil fertility was evaluated, and samples were collected in ICLF three different distances from the row of trees and at two depths (0-0.10 and 0.10-0.20 m) and in the other areas random collections were performed. The experimental arrangement was in a completely randomized design with seven treatments and four replications in a split plot scheme. The integrated systems improved soil chemical attributes of the soil, showing a sustainable alternative.

Key words: Integrated agricultural production systems; quality indicators; sustainability

INTRODUCTION

The Integrated-Crop-Livestock-Forest Systems (ICLFS), or integrated agricultural production systems (SIPA), are known as the combination of different integrated systems that generally adopt principles of soil conservation, resembling natural ecosystems, improving soil-plant-animal synergistic effects (GROPPO et al., 2015; OLIVEIRA et al., 2018). These systems have advantages how to best use the soil, higher production and profitability by area, diversity of components, aid in the dynamics of nutrients and accumulation of plant residues on the soil surface (BALBINO et al., 2011; PISSINATI et al., 2018; BIELUCZYK et al., 2020). Excellent land use options are, contributing to better land use and improving chemical, physical and biological quality indicators (OLIVEIRA et al., 2016).

Soil quality can be conceptualized as the soil's ability to perform its activities within the limits of natural or agricultural ecosystems, to sustain or maintain plant and animal productivity, maintaining or increasing its quality (CAVALCANTE et al., 2021). The indicators can be classified as physical, chemical and biological, and the interaction between these attributes is a complex functional state (JIN et al., 2009), and it is necessary to define the soil functions related to each attribute, identifying and analyzing their sensitivity to changes and disturbances in the environment (BARBOSA et al., 2019).

Soil quality indicators refer to measurable attributes that influence capacity of the soil to carry out agricultural production, the most sensitive being the actions imposed by land use and management of the soil (NASCIMENTO et al., 2019; LAURENTIIS et al., 2019).

Thus, the present study aimed to evaluate the chemical characteristics in a Dystrophic Red Latosol under ICLF system compared with different soil use systems. The hypothesis evaluated was that ICLF systems contribute to a better soil quality and conservation.

MATERIAL AND METHODS

The study area is located in the municipality of Morrinhos, southern region of the state of Goiás, Brazil, in the Teaching, Research and Extension Unit (UEPE) in Integrated Systems of Agricultural Production (SIPA) of IF Goiano - Campus Morrinhos (17°49' S and 49°12'W) (Figure 1). According to the Köppen-Geiger classification system, the climate of the region corresponds to type Aw, tropical with dry winter, with an average temperature of 20 °C and average annual precipitation of 1,346 mm (Cardoso et al., 2014). The soil is classified as Dystrophic Red Latosol (Teixeira et al., 2017). In January 2018, the ICLF system was implemented in an area of 9.6 hectares. The forest component was the cloned eucalyptus AEC 2034 (*Eucalyptus camaldulensis* x *Eucalyptus grandis*) x *Eucalyptus urophylla* transplanted in the arrangement of 10 meters of inter-rows and 4 meters from the row of *eucalyptus* trees. The crop component began with sown of corn in consortium with the grass-zuri ((*Megathyrsus maximum* (Syn. *Panicum maximum*) cv. BRS Zuri). And in February 2019, was sowed sunflower in consortium with the piatã grass (*Urochloa brizantha* (Syn. *Brachiaria brizantha*) cv. BRS Piatã). From the silage of the sunflower component, in June 2019, the integration of grass-piatã with eucalyptus (silvipastoral system) remained in the area.

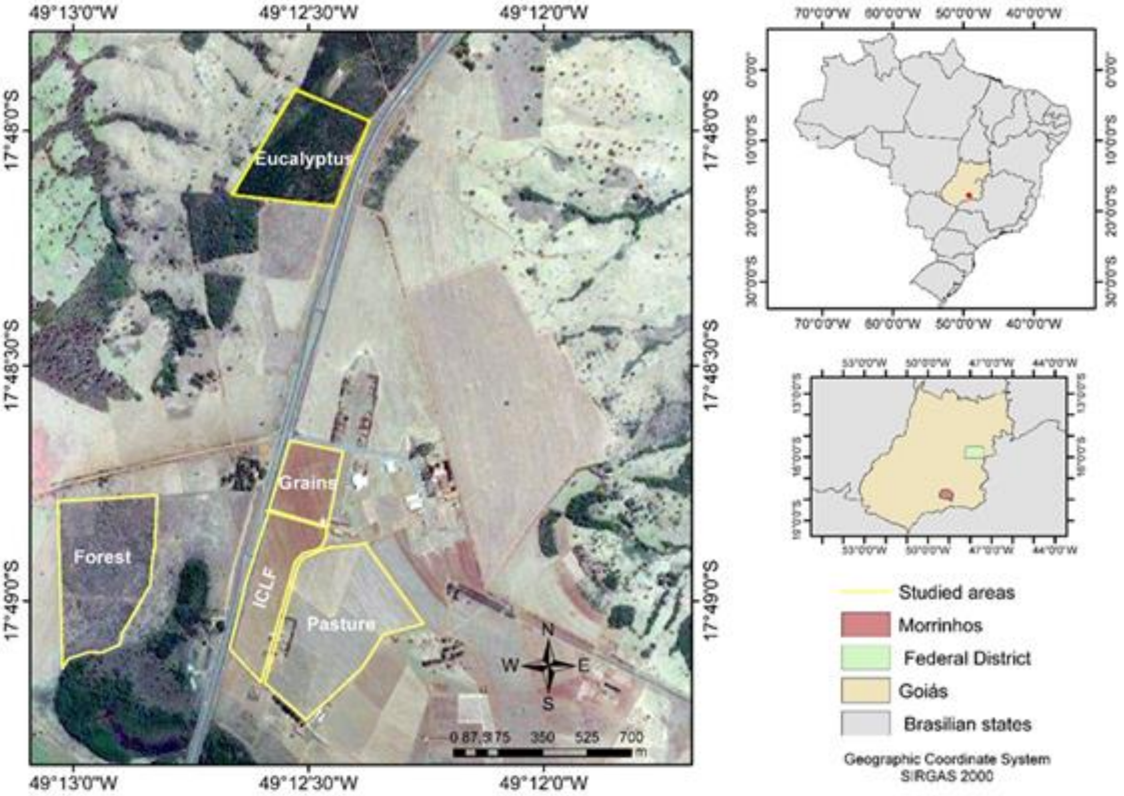

Figure 1**.** ICLF area, pasture, monoculture grain and native forest in IF Goiano Morrinhos campus.

The experimental area was composed of the treatments: I) ICLF evaluated in the trees planting line; II) ICLF assessment 2.5 meters from the row of *eucalyptus* trees; III) ICLF assessment at 5.0 meters from the row of trees. For comparison purposes, crops were used that are located adjacent to ICLF: IV) pure pasture of *U. brizantha* where there was no type of management and considered as degraded area; V) corn crop in monoculture; VI) *Eucalyptus* in monoculture with spacing of 3 meters between rows x 3 meters between plants and VII) native forest. The soils of the evaluated areas were classified as clay texture according to the Manual of Soil Analysis Methods (TEIXEIRA et al., 2017).

Soil sampling was carried out shortly after the beginning of the rainy season in December 2019. The areas were sampled by opening mini trenches and collecting soil samples at depths of 0-0.10 and 0.10-0.20 m. In all seven areas studied, four mini trenches considered as repetitions were used and were at least 30 meters distant from each other in order to guarantee randomness.

The statistical analysis was performed assuming a completely randomized design, with seven treatments and four replications in a split plot scheme, and the areas analyzed were the plots and the two layers of soil sampling in subplots (Faustino et al., 2020). The Assistat Version 7.7 software was used to perform the analyses, including the Kolmogorov-Smirnov and Lilliefors normality test (in which homoscedasticity and normal distribution of residues were found), the experimental variance. The comparison of means was performed by the Tukey test at 5% probability.

RESULTS AND DISCUSSIONS

The systems studied significantly affected the values of the variables pH, Ca, Mg, Al, P and K within each depth studied (Table 1). There was interaction between the analyzed systems and depths, with the exception of the variable H+Al (potential acidity). There was no variation in the pH attribute according to distance and depth in relation to the row of trees in treatments with ICLF and for the areas of monocultures and degraded pasture. However, for the area of native forest at the depth of 0-0.10 m this difference was observed in relation to the areas of ICLF of pH of the most acidic soil, pH 4.37 (Tabela 1). At the depth of 0.10-0.20 m the greatest differences were found in ICLF at 2.5 m away from the row, and in eucalyptus monoculture (pH 5.82 and 5.25, respectively). Among the depths, the pH in the native forest area showed the lowest pH values (4.37 and 4.85), characteristic of areas where there were no soil corrections and also of the region of more weathered soils (Stieven et al., 2018). Similar pH results from this study were observed in studies evaluating integrated systems in the Amazon and Latosols of the Cerrado with different soil cover crops (SANTOS et al., 2012, STIEVEN et al., 2018).

For the variable calcium (Ca) in the ICLF, there was no difference between the sampling distances from the soil along the rows of trees (Table 1). For the depths were found the best values of calcium in the 0-0.10 m layer (35.80, 34.75, 34.47 $mmol_c/dm^3$, *eucalyptus* monoculture, ICLF 5.0 m from the row and ICLF 2.5 m planting line), and at the depth of 0.10-0.20 m the monoculture area of corn was obtained the highest value for this variable (Ca 27.87 $mmol_c/dm^3$) due to the soil is always passing through corrections and fertilizations. These results corroborate with Costa et al. (2015) and Bonini et al. (2016), showing that soil chemical changes in integrated systems result from the greater supply of nutrients due to the accumulation of plant residues, mainly when eucalyptus shedding occurs generating greater deposition of organic matter in the soil, as Ca is present in large quantities in the leaves, woods and stems of the plant (STIEVEN et al., 2018). However, in the area of native forest, used as reference, the lowest Values of Ca (0.25 and 0.02 $mmol_c/dm^3$) were observed, because it is an area without anthropic interference.

Table 1. Chemical attributes of the soil under different areas, in the layers 0-0.10m and 0.10-0.20 m, in Morrinhos - GO.

Area	**pH**	**Ca**	**Mg**	**Al**	**H + Al[2]**	**P**	**K**
	(H_2O)	**-------------------- ($mmol_c/dm^3$)**			**----------------------**	**------ (mg/dm^3) -----**	
				0-0.10 m			
I[1]	6.17aA	30.72aA	11.85abA	0.00bA	14.75aA	16.42abA	177.25aA
II	6.07aA	34.47aA	18.60aA	0.00bA	16.00aA	23.77aA	203.25aA
III	5.97aA	34.75aA	17.50aA	0.00bA	17.75aA	15.62bA	178.25aA
IV	6.05aA	32.20aA	8.95bA	0.00bA	17.00aA	12.80bA	141.50abA
V	6.02aA	27.50aA	19.30aA	0.00bA	14.25aA	2.80cA	52.75bA
VI	5.65aA	35.80aA	17.10aA	0.50bB	21.00aA	2.20cA	41.75bA
VII	4.37bB	0.25bB	0.82cA	6.00aA	34.25aA	0.80cA	42.00bA
Average	5.76A	27.95a	13.44A	0.92A	19.28a	10.63A	119.53a
				0.10-0.20 m			
I	6.22A	19.17abB	6.82abB	0.00cA	13.25aA	2.80AB	109.50aB
II	5.82AB	16.67abB	6.32abB	0.25cA	16.00aA	3.77aB	61.00aB
III	6.00aA	20.30abB	8.30abB	0.00cA	16.00aA	2.97AB	58.50aB
IV	5.95aA	27.87aA	8.50A	0.00cA	17.00aA	5.47AB	37.50aB
V	6.07aA	17.40abB	6.77abB	0.00cA	13.75aA	1.40aA	27.00aA
VI	5.25bB	7.55bcB	4.30abB	2.25bA	19.50aA	1.12aA	17.75aA
VII	4.85bA	0.02cC	0.60bC	3.75aB	32.25aA	0.57aA	28.75aA
Average	5.73A	15.57b	5.94b	0.89A	18.25A	2.58b	48.57b
				0-0.20 m (layer averages)			
I	6.20 a	24.95 a	9.33 a	0.00 c	14.00 b	9.61 a	143.37 a
II	5.95 ab	25.57 a	12.46 a	0.12 c	16.00 b	13.77 a	132.12 ab
III	5.98 a	27.52 a	12.90 a	0.00 c	16.87 B	9.30 a	118.37 abc
IV	6.00 a	30.03 a	8.75 a	0.00 c	17.00 b	9.13 a	89.50 abc
V	6.05 a	22.45 a	13.03a	0.00 c	14.00 b	2.10 B	39.87 BC
VI	5.45 B	21.67 a	10.70 a	1.37 B	20.25 b	1.66 B	29.75 c
VII	4,61	0.13 b	0.71 B	4.87 a	33.25 a	0.68 b	35.37 c
Average	5,75	21,76	9,69	0,91	18,76	6,61	84,05
CV-a (%)	5.48	28.65	38.72	59.30	31.70	52.89	67.89
CV-b (%)	2.90	25.97	33.96	25.41	4.17	52.50	38.96

For each column, means followed by the same uppercase letter (which commins layers) or the same lowercase letter (which compared vegetation coverings), do not differ from each other by the Tukey test ($p \leq 0.05$). [1] I) ICLF evaluated in the planting line; II) ICLF 2.5 meters from the row of trees; III) ICLF at 5.0 meters from the row of trees, IV) degraded pasture of *U. brizantha*; V) corn in monoculture; VI) Eucalyptus in monoculture and VII) native forest. Note: CV-a and CV-b are, respectively, the coefficients of variation obtained in the analysis of variance for plot and subplot. [2] means that were not significant by f-test.

For the variable magnesium (Mg) at the depth of 0-0.10 m, there was a significant difference only in the area of native forest (0.82 $mmol_c/dm^3$) because it is an area that does not suffer from any type of anthropogenic charges (Table 1). However, for the depth of 0.10-0.20 m, the difference was observed between treatments, being observed the highest values of Mg in the degraded pasture area (8.50 $mmol_c/dm^3$) and the lowest values were found in the native forest area (0.60 $mmol_c/dm^3$). Regarding the depths, the highest values were found in the 0-0.10 m surface layer, due to the great mobilization of plants and vegetable materials that undergo some type of decomposition and recycling. It is observed that, in general, the chemical attributes varied significantly with the sampling depths showing more favorable conditions for the plants in the superficial layer and reduction of this condition as it deepened in the profile. Santos et al. (2021), evaluating the soil quality under different crop and soil tillage systems, observed that as the sampling deepens along the soil profile, the soil fertility tends to reduce from ideal conditions, which corroborates the results found in this research.

Therefore, for the variable aluminum (Al) the highest value found was in the native forest area at both depths (6.00 and 3.75 $mmol_c/dm^3$) (Tabela 1). As it is an area that does not undergo any type of corrections or anthropic actions and with acid soil with high levels of this element, in the surface layer the Al content is high and as the sampling deepened along the soil profile the concetration has decreased. In the other areas, there were no significant differences between the results, except for eucalyptus monoculture at the depth of 0.10-0.20 m, which also had a value of soils with a higher concentration of aluminum (Al 2.25 $mmol_c/dm^3$) in relation to the other treatments. These low levels of aluminum, in the integrated systems and cultivated areas, suggest that the presence and action of organic matter in the complexation of Al mainly through the carboxyl and hydroxyl groups, in which organic acids are stabilized by this ion, thus reducing them (ALLEONI & MELO, 2009).

For the variable phosphorus (P) at the depth of 0-0.10 m the highest values were found in the ICLF in the evaluated distances P (16.42, 23.77 and 15.62 mg/dm^3 respectively) and pasture areas P 12.80 mg/dm^3 (Table 1). Although this nutrient has a low cycling rate and low litter content, it has accumulated in the integrated system, contrary to what occurred in the other areas, where the dynamics are differents (SANTANA et al., 2002; STIEVEN et al., 2018). The lowest values found were in the areas of corn, eucalyptus monoculture and native forest (2.80, 2.20 and 0.80 mg/dm^3 respectively), these values in monoculture are due to the export of nutrients by eucalyptus trees and their low litter contents and the great demand of corn for phosphorus (STIEVEN et al., 2018). As for the native forest areas this low value may be due to the demand of the trees, low litter contents and the low availability of the nutrients in the soil (SANTANA et al., 2002). Among the depths, it is observed that the highest values were found in the superficial layer of the ICLF system in the tree lines, at 2.5 and 5.0 m in relation to the row of trees, in relation to the integrated system in the layer of 0.10-0.20 m, tree line at 2.5 and 5.0 m (16.42, 23.77, 15.62 mg/dm^3). However, for the depth of 0.10-0.20 m the lowest values were found in the areas of monocultures and the native forest, and as the soil sampling deepens, there tendency to decrease the supply of nutrients to the systems, results that corroborate with studies carried out by Bonini et al. (2016).

In relation to the Potassium (K) the highest values observed were in the ICLF system area in the tree lines at 2.5 and 5.0 m, in relation to the rows of trees at the depth of 0-0.10 m (177.25, 203.25, 178.25 mg/dm^3) and 0.10-0.20 m, tree lines at 2.5 and 5.0 m (109.50, 61.00, 58.50 mg/dm^3) (Table 1). These values can be observed due to the forage component that may have contributed to the increase of this nutrient in the soil, thus favoring the cycling of this nutrient (Assmann et al., 2017; Alves et al., 2019). This condition can be justified by the absorption of grasses in these areas, because they absorb k better than other vegetables (Costa et al., 2015). However, the lowest values found at depths of 0-0.10 m (52.75, 41.75 mg/dm^3), 0.10-0.20 m (27.00, 17.75 mg/dm^3 respectively) were in the monoculture corn, eucalyptus and native forest systems at a depth of 0-0.10 m (42.00 mg/dm^3) and 0.10-0.20 m 28.75 mg/dm^3). The important factor in this dynamic would be the high demand of plants for this nutrient and the lack of soil covered with grasses in these areas, which better absorb this nutrient (COSTA et al., 2015; STIEVEN et al., 2018).

CONCLUSIONS

The ICLF system contributed to the higher nutritional intake in the soil, which through the forage and forestry components resulted in higher nutrient contents compared to the other productive systems evaluated.

Potassium was one of the main nutrients observed in the ICLF system, which is largely due to the contribution of the forage component that has better potassium absorption and recycling.

Thus, integrated systems are great options for recovering degraded soils and improving soil quality indicators.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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ESTABLISHMENT OF DIVERSIFIED CROP-LIVESTOCK-FORESTRY SYSTEMS BY ARBOREAL FORAGE ASSOCIATION

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ABSTRACT

Integrated Crop-Livestock-Forest (ICLF) systems tend to be less sensitive to variations in their component prices and are more stable than exclusive crops. To confirm these advantages, however, more species options are needed, especially for those farms in which soybean cultivation may not be interesting. The present study aims to identify options of forage species (*Cajanus cajan*, *Leucaena leucocephala*, *Vigna unguiculata* and *Tithonia diversifolia*) to increase the diversification of herd food supply in ICLF systems. The ICLF Technological Reference Unit (TRU) Sítio Nelson Guerreiro (established in 2009) is located in Brotas, São Paulo State, Brazil. The establishment process of these four alternative forage species has been carried out in a mature ICLF system, and the difficulties and first conclusions are presented. The project's expectations are to advance in the recommendation of practices for ICLF diversification, to verify the cost-benefit ratio of its implementation and management, and to assess the resulting socio-environmental impacts, as to contribute with the public policies of the 'Low carbon agricultural Plan' (Plano ABC).

Key words: pigeon pea; legumes; alley crop

INTRODUCTION

The diversification of production systems is an important strategy for reducing the risks of agricultural activities, and one existing option is the implementation of integrated Crop-Livestock-Forest (ICLF) systems. The decrease in production costs with the maintenance of good productivity is a main goal for farmers, in order to maintain the activity's economic viability. This is even more decisive when production scales are not sufficient to favor negotiation of input purchase prices, nor the sale prices of the products. Hence, most of the available ICLF systems include crop rotations with high-value species, such as soybeans and maize. However, due to logistic difficulties, higher production costs, or commercial restrictions, intensive cropping is not always feasible or desired by the farmer, for whom alternatives must be offered. For example, forage plants with complementary nutritional characteristics can be introduced in arrangements aimed at improving soil fertility and increasing the diversification of livestock feeding resources. The adoption of the ICLF system at the Technological Reference Unit (TRU) Sítio Nelson Guerreiro arose from the need for productive diversification, given its almost exclusive economic dependence on orange cultivation, more than a decade ago. Although orange is an important source of income in the region, it has been recently submitted to constant losses, due to the instability of prices practiced by industries and the incidence of HLB or greening disease. The TRU consists of a total area of 88 ha, destined to beef cattle, grain crops (maize consortiated with palisade grass - *Urochloa brizantha* - in no tillage system, in some areas associated with pigeon pea and other legumes), both in ICLF; maize production associated with a mini maize sorter; silviculture in ICLF, with several species and varied clones of eucalyptus; mini sawmill for wood/firewood and fence posts for own use (from eucalyptus clearing and thinning); technological tourism, ICLF project consultancy, citriculture consultancy, partnership beekeeping and hibiscus planting. Even though there has been a great improvement in the commercialization conditions due to product diversification, the search for the reduction of production costs is a management permanent goal. In this context, animal supplementation with good quality forage, especially during the dry season, is still a challenge. The incorporation of woody forage species, nitrogen fixers, favors the balance of the diet, demands less quantity of external inputs, and adds advantages related to the production and recovery of ecosystem services. The diversification of species in an animal's diet enhances the use of diet components, by a more efficient metabolism, improves palatability and consumption, and may even reduce possible toxic effects of certain forages. The production and management of woody forages need, however, to be evaluated under the conditions of its use so that they can be more widely disseminated. The use of other forages, preferably legumes, in consortium with tropical grasses, in the present case *Brachiaria brizantha* cv. BRS Piatã, can be one of the main means of achieving good dry matter productivity, and consequently good animal productivity, with low cost, as also suggested by Paulino et. al. (2008). Consortium cultivation, as in the case of agroforestry systems is a traditional technology, but with the use of new species in different regions, it is important to describe fundamental steps to maximize their yield (CECCON et al., 2007). Of the four species evaluated, *Cajanus cajan* cv. BRS Mandarim, *Leucaena leucocephala*, *Vigna unguiculata* and *Tithonia diversifolia*, the first three are legumes, and their use in intercropped pasture can provide increase in the nutritional value of the diet, as they present high levels of crude protein and elevated digestibility. According to Broderick (2003), the increase in the available protein content of the diet supplies the limitation of rumen nitrogen, common in the dry season, with better utilization of dietary fiber by the animals. The choice of these species considered the demand defined by the farmer, the availability of reproductive material in the region, and the characteristics of the plants described in the literature (MOREIRA et al., 2003; SEIFFERT, 1988; COOK et al., 2005; NAS, 1977; COOK et al., 2005; MAIA, 2010; BEVILAQUA, 2008; COOK et al., 2005; MAHECHA and ROSALES, 2005; IBRAHIM et al., 2005; RUÍZ et al., 2014). That said, the project aims to identify options of forage species to diversify the food supply for the herd, by offering species with complementary characteristics and capable of exploring distinct ecological niches in the landscape. This work presents the implantation process of the four forage species in a mature ICLF system, the main difficulties, and the first conclusions.

MATERIAL AND METHODS

The ICLF Technological Reference Unit (TRU) “Sítio Nelson Guerreiro” is located in Brotas, São Paulo State, Brazil, at coordinates 22º10'58” S and 48º15'48” W, 550 meters altitude, and was established in 2009. At that time, eucalyptus (*Eucalyptus citriodora*) was planted following soil level lines so that the average distance between rows, called alleys 1, 2, 3 and 4, were 37 m, 30 m, 13 m and 43 m, respectively. The diversified ICLF system was installed in January 2020 on a pasture of 8.11 ha of total area and 7.68 ha of usable area. The distribution of the four species followed a 'cell arrangement' (Figure 1), considering the given spacing between the eucalyptus rows.

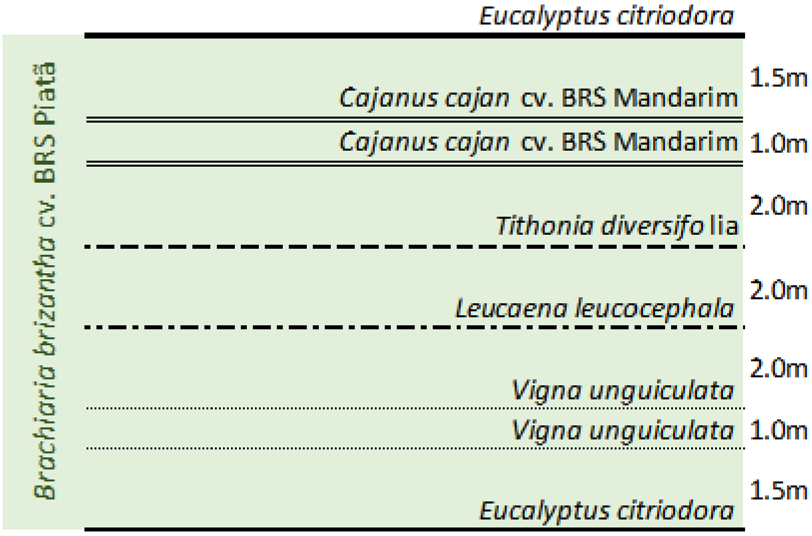

Figure 1. ‘Cell arrangement’ of the diversified Integrated Crop-Livestock-Forestry system deployed at the Technological Reference Unit at Brotas, State of São Paulo, Brazil

The forages were implanted on the existing palisade grass (*Brachiaria brizantha* cv. BRS Piatã), which was overgrazed and only mowed (not desiccated) in the rows, prior to sowing. An area of sole Piatã was kept to allow comparisons with the diversified systems (consisted of Piatã + four alternative species). Soil analyses showed satisfactory levels of nutrient contents, except phosphorus, which was supplemented. The control of ants was carried out from the beginning and according to recurrence. Cowpea sowing took place on 01/18/2020 and pigeon pea on 01/19/2020, both in double rows 0.9 m apart, and 4 seeds m^{-1}, with an Imasa PHS 63 seeder-fertilizer, from two lines (Massey Fergusson 65X tractor, reduced 3rd gear, at 5.3 km h^{-1}) and Imasa's own discs. Cuttings of tithonia (40 cm each) were planted on January 21 and 28 (2020) in a single line, with spacing of 0.7 m between cuttings. Leucena was sown on 02/12/2020, in a single row, by manual seeder, with a density of 5 to 7 seeds per hole, after several attempts of mechanized sowing. The determination of the availability of BRS Piatã happened on 02/12/2020, by the direct method with a 0.5 m x 0.5 m square, five samples in each plot and plants cut at ground level. Samples were weighted and dried in an oven with forced air circulation at 60 °C until constant mass and again weighted to obtain the dry matter mass. With the occurrence of the Covid-19 pandemic, only essential and non-extendable assessments were carried out, according to the guidelines of the institutions responsible for conducting the project. Plant density and height were measured in 10 m in each of the lines of each species, in all four eucalyptus alleys.

RESULTS AND DISCUSSIONS

The experience of planting with no desiccation had already been feasible on the property, even during midsummer, with high availability of light, water and high temperatures. In the present experience, this practice proved to be possible for both cowpea and pigeon pea whose sowing was mechanized. In the case of tithonia, which was furrowed, this does not apply, and in the case of leucena, this practice was not interesting, considering that sowing had to be manual with subsequent planting line weeding, so that it was possible to give them more advantage to grow, considering slow initial development. Until March 2020, the need to develop a mechanized sowing system for leucena was identified, as its implementation proved to be complex for the farmer, despite the technical material available for decades. For example, the seed dormancy breaking methods and the viability of the acquired leucena seeds posed difficulties, as in the present case 53% and 65% germinated, for the non-swollen and swollen ones, respectively, at 24 days after seeding (in sand). Additionally, seeds tended to overflow the sowing disc when not-swollen, while the swollen ones suffered damage in the sowing disc, even with the larger hole, a major problem given the high seed cost at R$ 75.00 kg^{-1}. A guideline adopted before and during the establishment of the diversified systems was to prioritize perennial forage species (leucena and tithonia) - and the most costly to implant, so that management considered the survival of species in the leucena > tithonia > pigeon pea > cowpea order. Another factor for this prioritization in management was the finding that pigeon pea BRS Mandarin emerged showed good growth and development, comparing to leucena and tithonia, although it also seemed to suffer some competition by BRS Piatã, which was also observed in cowpea until the beginning of winter. Even with the intensified control of ants during the implantation of forages, the control was not satisfactory, especially in alleys 3 and 4. This is attributed to faulty control of ants in the sugar cane of the neighboring area. It is recommended that when choosing for leucena, consider infestation by ants in the vicinity, once within the five available species, leucena was the most susceptible. Another aspect to be considered for a system with different forage species is the waiting time for cattle to enter the diversified pasture. In the present case, the project area was closed for eleven months, being considered as a deferred pasture within the whole property, to guarantee the establishment of the perennial species. This decision was considered the most interesting, considering the cost of its implantation and its permanence in the system, to the detriment of the forage quality of cowpea and pigeon pea. This may even be a possible practice to be recommended for the diversified ICLF system and may vary according to the seeding date. The availability of BRS Piatã after the emergence of the four forages tested was 7.492 kg ha^{-1} of dry matter. The plant counting (Table 1) showed that cowpea and pigeon pea, which were mechanically sown, varied less. The sowing density of these two species was 4 seeds m^{-1} and the average of emerged plants was 0.94 for cowpea and 1.98 for pigeon pea, a possible indication of competition by BRS Piatã. The average of 1.50 m^{-1} clusters of leucena revealed that the dynamics of manual seeding changing the predicted density in clumps spaced every 0.5 m. The tithonia showed an average of 0.29 plants per meter, indicating that the sprouting was much lower than the amount planted. In fact, we observed many rotting cuttings in the furrows. The average height of pigeon pea plants (46.52 cm) indicates that this species has suffered competition, once it gets from 1.80 m to 1.95 m when sole cultivated, while tithonia allows to suppose that the sprouted cuttings had an expected growth. In case of leucena, the average height of the clump was provided, and this species was the smallest one, much shorter than it is indicated to get before herd pasture it, e.g. 1.0 m, when consortiated with palisade grass species (Seiffert and Thiago, 1983). The slowest initial development of leucena is attributed to the delay in its seeding and the ant attack suffered.

Table 1. Number of plants per meter and plant height (cm) (10-meter line averages) of cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan* cv. BRS Mandarim), leucena (*Leucaena leucocephala*) and tithonia (*Tithonia diversifolia*), in the Integrated Crop-Livestock-Forestry Technological Reference Unit of Brotas, São Paulo State, Brazil, on 06/06/2020.

Alley[1]	**Cowpea**	**------- Pigeon pea -------**		**------- Tithonia -------**		**------- Leucena --------**	
	Plants m^{-1}	**Plants m^{-1}**	**Height (cm)**	**Plants m^{-1}**	**Height (cm)**	**Clump m^{-1}**	**Height (cm)**
1	1.26	1.92	56.84	0.33	83.20	1.73	18.49
2	1.02	2.28	51.49	0.20	73.94	1.13	15.63
3	0.55	0.40	33.07	0.50	78.40	1.50	-
4	0.93	2.11	44.69	0.15	47.00	1.63	-
Average	0.94	1.68	46.52	0.29	70.64	1.50	17.06

[1] Average distance between eucalyptus rows in alleys 1, 2, 3 and 4 are 37 m, 30 m, 13 m and 43 m, respectively.

CONCLUSIONS

The main conclusions of the process of introducing *Cajanus cajan* cv. BRS Mandarim, *Leucaena leucocephala*, *Vigna unguiculata*, and *Tithonia diversifolia* to diversify a consolidated Integrated Crop-Livestock-Forestry (ICLF) system of *Brachiaria brizantha* cv. BRS Piatã with *Eucalyptus* *citriodora* were (i) the forages suffered strong competition by BRS Piatã, and (ii) the diversification as tested is quite complex and unprecedented. Other consortia with fewer species are more common and therefore may be easier to manage in the day-to-day life at the farm. However, it is noteworthy, for now, that despite the difficulties faced for the proper establishment of perennial forages, this is a promising system, since practices are consistent with farmers' reality and their management have been used. The experience observed in the ICLF theme is clear regarding to the fact the main established arrangements have been screened by countless producers accompanied by scientific studies, which leads the team to maintain the arrangement initially outlined.

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GRASS FORAGE YIELD INTERCROPPED WITH CORN CULTURE IN ICLF SYSTEM IN “CERRADOS” BIOME OF MARANHÃO STATE

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ABSTRACT

For corn and forage consortium success, it is essential to choose a grass that expresses its maximum productive potential of forage and straw for no-tillage, without affecting corn grain productivity. This experiment sought to select forage grasses that present higher dry matter productivity in consortium with two commercial maize materials in an ILPF system, under “Cerrado” biome conditions in Maranhão State. Experiment was carried out from February to June 2019, municipality of Brejo-MA. Treatments were: T1 corn + *Megathyrsus maximus* cv. Massai, T2 corn + *M. maximus* cv. Tamani, T3 maize + *M. maximus* cv. Zuri, T4 maize + *M. maximus* cv. Tanzania, T5 maize + *Urochloa brizantha* cv. Marandu and T6 maize + *U. ruziziensis* grass. Forage grasses intercropped with maize reveal technical feasibility for roughage production in off-season period, when Zuri and Tanzania grass standing out as the most promising.

Key words: Integrated system; Corn-forage consortium; Dry mass production

INTRODUCTION

Crop - livestock - forest integration systems, as well as domestic animals with crops association, has been carried out by man since the beginning of agriculture, often, in conflict over divergent interests situations. These systems, with adequate management of crops and pastures associated with tree component, can provide substantial increases in production, especially when there is recovery of degraded or poorly productive areas (KICHEL et al., 2012). A sustainable system is understood to be “one that meets the needs of the present without compromising the possibility of future generations meeting their own needs” (STERN, 2010).

Adoption of ILPF systems (crop-livestock-forest integration) and their modalities have been gaining ground in Brazilian rural properties. However, scientific information about this technology is still scarce, which may result from the complexity of integrated systems period, combined with recent research starts and relatively small number of technicians working in this field (BERNARDINO and GARCIA, 2010). However, Macedo and Vale (2010) observed that the vast possibility of combinations that tropical biodiversity offers to work with integrated systems is clear with great possibilities to achieve sustainability.

In this context, the states of Piauí and Maranhão stand out as promising for the sectors in question, since they are considered one of the last agricultural frontiers in Brazil. In a consortium system, it is essential to choose a forage grass that expresses its forage and straw yield potential for no-till (FERREIRA et al., 2014).

The objective of the present work is to select forage grasses that present greater performance in dry matter production in consortium with corn culture, in ILPF system, under “Cerrado” Biome conditions in Maranhão State.

MATERIAL AND METHODS

Experiment was carried out in 2019 agriculture year in rainy season period (February to June), at Barbosa Farm, located in Brejo, Maranhão State. Geographical coordinates 30º42 '48.84" S and 42º 55'40.60" W, 106m altitude from sea level. The region's average annual rainfall is 1,600 mm, with highest rates in February and March. Soil classification is a typical Dystrophic Yellow Clay soil, sandy-loam texture, with cohesive horizon (RESENDE et al., 2014).

Maize seeds materials, as well as forage, occurred on same day (02/14/2019). Forages sowing was carried out by haul, manually and immediately before planting corn crop in a mechanized way. As recommended by soil analysis results, 300 kg ha^{-1} from 13-33-08 NPK formula applied at the planting time. At first cover fertilization, which occurred when corn plants had four well-defined leaves, 280 kg ha^{-1} of fertilized compound containing 10% N and 30% K_2O was applied. Second cover fertilization occurred out when plants had eight fully developed leaves, applying 44 kg ha^{-1} of N.

Sowing rate adopted for forages (Massai, Tamani and Zuri) of the species Megathyrsus maximus was 3 kg ha^{-1} of viable pure seeds, while for forages *Urochloa brizantha* cv. Marandu and *Urochloa ruziziensis* were 6 kg ha^{-1} of pure viable seeds. Sowing rates used, were determined by relation of desired cultural value ha^{-1} and cultural value of each forage lot (DIAS-FILHO, 2012). Corn materials planted at a spacing of 0.5 meters between rows and 6 to 7 seeds per linear meter.

The experimental area was arranged between eucalyptus tree rows with a total area of 100 x 26 meters, each plot being 8 x 13 meters. Experimental design was a randomized block in a split plot, with six treatments and four replications combined with two maize materials (M1 = Pioneer 30F53 and M2 = Syngenta Status Vipera 3). Treatments used were: T1 maize + Massai grass, T2 maize + Tamani grass, T3 maize + Zuri grass, T4 maize + Tanzania grass, T5 maize + *Urochloa brizantha* cv. Marandu and T6 maize + *Urochloa ruziziensis* grass.

Variables evaluated at corn harvest (130 days after planting), were: stand, height and dry matter production (DM) of each forage, within each plot with two samples for each parameter evaluated at random. Stand measurements of different forages in each plot were made by counting plants within a sample unit (iron square) with a dimension of 0.5 x 1.00 m (0.5 m^2).

To evaluate dry matter production, the 0.5 m^2 "iron square" was used where all material was cut into the square and weighed on an electronic field scale, taking a sample to bromatology Lab. at Embrapa Mid-North for DM determination and subsequent determination of forage productivity. Height parameter of each forage was made using a ruler with metric graduation.

Data obtained were submitted to the Shapiro-Wilk (normality of errors) and Cochran's T (homogeneity of variance) tests. Once basic requirements were satisfied, data were subjected to analysis of variance and test of comparison of means (Scott-Knott). Statistical analysis was performed using ExpDes.pt package of the R program (FERREIRA et al., 2014).

RESULTS AND DISCUSSIONS

Corn materials (M1 and M2) did not significantly influence ($p \geq 0.05$) evaluation parameters averages of the stand and height of the forages, but for the DM from grasses there was an interaction ($p \leq 0.05$), as shown in Table1.

Table 1. Stand parameters, height and dry matter from different consortium of forages with corn crop (M1 = Pioneer 30F53 and M2 = Syngenta Status Vipera 3. Brejo-MA, 2019.

Treatment	**[1] Stand** **(plants m^{-2})**	**[2] Height** **(cm)**	**[3] DM production in consortium with M1 (kg ha^{-1})**	**[4] DM production in consortium with M2 (kg ha^{-1})**
T1 corn + Massai	9.25^a	78.75^c	5,05^d	5,40^d
T2 corn + Tamani	8.25^a	76.37^c	5,97^c	6,15^c
T3 corn + Zuri	10.00^a	149.37^a	10,68^a	10,31^a
T4 corn + Tanzânia	8.50^a	153.12^a	9,44^b	9,40^b
T5 corn + *brizantha*	9.25^a	95.00^b	4,06^e	3,69^e
T6 corn + *ruziziensis*	8.25^a	86.87^b	4,03^e	2,80^f

[1] Averages followed by the same letter do not differ statistically from each other at the level of 5% by F test.
[2, 3 e 4] Averages in the same columns followed by the same letter do not differ statistically from each other at the level of 5% by Scott-Knott test (SK).

Regarding grass stand (Table 1), there was no significant difference between them, as well as interaction between M1 and M2 ($p \geq 0.05$), varying between 8.25 to 10.00 plants m^{-2}. Similar results have been reported by Colett et al. (2015), after researching maize intercropped with different forages in a hot and humid tropical climate, in a dystrophic red latosoil.

Forage height showed statistical difference ($p \leq 0.05$), when Tanzania and Zuri grasses were highest, 153.12 and 149.37 cm and the smallest Massai and Tamani grasses, with 78.75 and 76.37 cm, respectively, showing forage potential and growth within an integrated system. According to Gimenes et al. (2008), plant height is a factor that can directly influence DM production.

Zuri grass was the forage that obtained the highest average ($p < 0.05$), with 10,68 and 10,31 kg ha^{-1}, followed by Tanzania grass (9,44 and 9,40 kg ha^{-1}), Ruziziensis grass (4,03 and 2,80 kg ha^{-1}) and Brizantha (4,06 and 3,69 kg ha^{-1}) showed lower DM production. The Tamani (5,97 and 6,16 kg ha^{-1}) and Massai (5,05 and 5,40 kg ha^{-1}) grasses showed DM production per hectare with an intermediate value. Ferreira et al. (2014), evaluating forages *Urochloa brizantha* cv. Marandu and *Urochloa hibrida* cv. Mulato II in consortium with corn, in “Cerrado” Biome in Mato Grosso State obtained average productivity, varying from 6,404 to 4,375 kg ha^{-1} of DM, respectively.

Perennial forages from *Urochloa* and *Megathyrsus* genera can be used for straw or pasture production during the dry season in “Cerrado” Biome (Machado and Assis, 2010), being excellent alternatives for crop-livestock-forest (ILPF) integration systems. Work carried out at Embrapa Beef Cattle, with the planting of “safrinha” corn intercropped with several perennial tropical grasses, higher DM production was observed with Piatã, Marandu, Tanzania and Mombaça grasses, with an average of 8,764 kg ha^{-1} being Massai the least productive with 4,780 kg ha^{-1}, while Ruziziensis, Decumbens and Xaraés grasses had intermediate productivity, with an average of 7,969 kg ha^{-1} (Kichel et al., 2014).

CONCLUSIONS

Forage grasses intercropped with maize reveal technical feasibility for the production of roughage in the off-season, with Zuri and Tanzania grasses standing out as the most promising.

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GEOMETRIC ARRANGEMENT OF CORN+PALISADE GRASS IN CROP-LIVESTOCK INTEGRATION SYSTEM

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ABSTRACT

The production systems have been modified due to greater sustainability. The intercropped corn crops with *Urochloa ruziziensis* provide biomass that can be used as straw in sequential crops, favoring the intensification of productive areas. Investigating and proposing a phytotechnical arrangement between corn and brachiaria is important to favor the production of forage / grain, and consequently animal production, by minimizing the negative effects of forage shading and maximizing grain productivity. This study was conducted in Colinas do Tocantins, Brazil. The experimental design was in complete randomized blocks in a factorial scheme (2x2x2). The treatments consisted of three factors: 1- corn seeding spacing (0.45m and 0.90m); 2- planting orientation (north-south and east-west); 3- forage planting method (corn planting line and in between corn planting line). Corn grain yield, forage dry matter yield and grass height were evaluated on the day of the corn harvest. The yield of corn grains and dry mass of forage, does not depend on the spacing and orientation of the planting of corn. The height of the grass at the time of the corn harvest shows significant differences.

Key words: productivity; planting orientation; spacing

INTRODUCTION

Livestock farming is considered one of the main causes of environmental conflicts related to deforestation, compaction, soil erosion and the loss of biodiversity (IBRAHIM et al., 2003). Areas destined to agricultural monocultures are also criticized for the environmental impacts caused and the loss of biodiversity. However, from an environmental point of view, several studies show that it is possible to work with livestock and agriculture while conserving the environment with the use of multipurpose components in integrated systems (MURGUEITIO, 2003; ALONSO et al., 2007). The use of intercropped crops using grain cultivation with tropical forages favors the rural producer a financial compensation to cover the costs of recovering pastures (RODRIGUES, et al., 2015), in addition, the intercropped crops favor an increase in food production without the need to expand cultivation areas (BORGUI et al., 2008). According to EMBRAPA (2003), the behavior of intercropped crops needs to be known, as the competition for resources determines grain productivity and forage yield, in addition, nitrogen and potassium cycling is benefited in production systems of the corn with palisade grass (OLIVEIRA et al., 2019). Therefore, it is necessary to understand the relationships between components of the intercropped crops, in which the corn with the brachiaria in function of the spacing, orientation of the corn planting and the way of planting the forage, maximizes corn productivity and forage yield, as well as reduce the unfavorable effects of organizing these arrangements. The objective of this study was to evaluate different geometric arrangements of the components of intercropped corn cultivation with brachiaria for greater grain and forage productivity.

MATERIAL AND METHODS

The experiment was conducted, from February to June 2020, in the experimental area of the Federal Institute of Education, Science and Technology of Tocantins - IFTO, located at Latitude 8°05'24"S and Longitude 48°28'58" W, at an altitude of 221 meters, in the municipality of Colinas do Tocantins, TO. The climatic data of the place, during the period of the experiment, are presented in Figure 1.

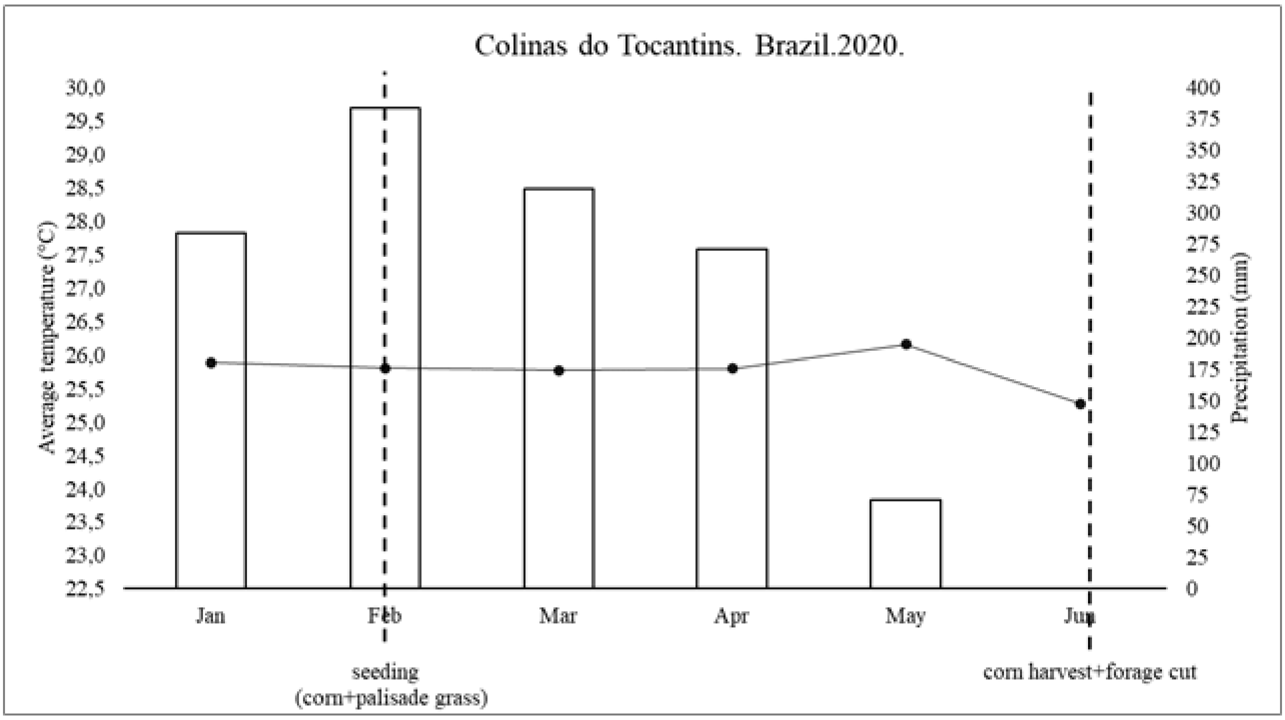

Figure 1. Climatic data of the study area.

The soil of the area is characterized as a Typic Quartzipisamment (USDA, 2014). Fertilization was carried out with 201 kg ha^{-1} of N, 153 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O. The experimental design used was in complete randomized blocks in a factorial scheme (2x2x2). The treatments consisted of three factors: 1- corn seeding spacing (0.45m and 0.90m); 2- planting orientation (north-south and east-west); 3- forage planting method (corn planting line and in between corn planting line). The plots had dimensions of 20.25 m² (4.5 m x 4.5 m). The maize used was the early hybrid 2B512PW® at a density of 66,600 plants ha^{-1}. The forage *Urochloa ruziziensis* (Syn. *Brachiaria ruziziensis*) was sown with 7.5 kg ha^{-1} (viable seeds 60%) with inlaid seeds in all treatments, planted simultaneously. At 25 days after sowing, 1000 g a.i. ha^{-1} of 6-chloro-N2-ethyl-N4-isopropyl-1,3,5-triazine-2,4-diamine (atrazine) 500 g l^{-1} was applied. It was evaluated (i) the corn yield by manual harvesting of ears on the central lines of each plot, weighing the grains, moisture correction to 13% moisture and extrapolation to kg ha^{-1}; (ii) forage dry matter yield by manually cutting the forage flush with the soil in a 1.2 m² frame, drying in a forced ventilation oven at 65ºC for 72 h, and weighing the dry material and extrapolating it to kg ha^{-1}; (iii) height of the forage canopy measured with a ruler graduated in centimeters at six central points of each plot.

The statistical model was adjusted using the PROC MIXED procedure of the SAS® (version SAS Studio; Copyright© 2012-2018, SAS Institute Inc., Cary, NC, USA), using the maximum likelihood (REML) as an estimation method. The treatments were compared using the Tukey test at 5% probability.

RESULTS AND DISCUSSIONS

For the variables corn yield and dry matter of forage there was no effect of treatments. Corn produced, on average, 5,212 kg ha^{-1} and grass 1,241.9 kg ha^{-1} (Figure 2). Demonstrating that the corn yield is not reduced by corn spacing and forage planting method. The orientation of the planting of corn and the spacing of the planting of corn influenced the height of the grass, however there was no effect of significant interaction between the factors. The grass showed greater growth when the system was implanted in the north-south orientation (32.8cm) in relation to the east-west orientation (29.5cm), such behavior can be explained due to the plant's stiolation, since the corn planting oriented in north-south direction, it promotes greater shading by reducing the amount of light that enters the canopy. The grass presented greater height in the spacing of 90cm (32.6cm), in relation to the spacing of 45cm (29.7cm), this is due to the decumbent behavior of this forage, this characteristic being intensified under spacing of 45 cm.

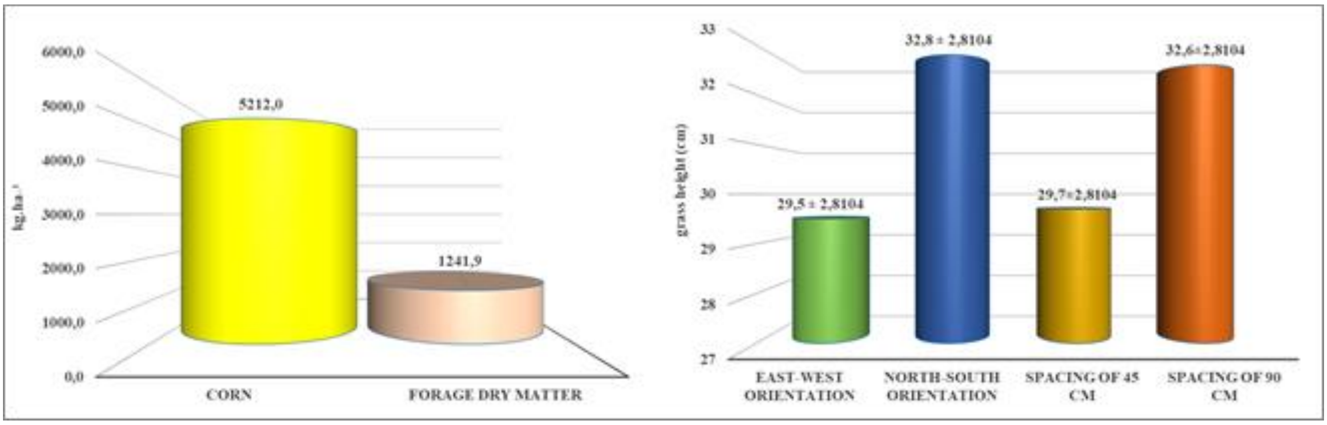

Figure 2. Maize yield, forage dry mass and grass height at corn harvest.

CONCLUSIONS

This study demonstrates that the geometry of organization of the intercropped components does not alter the corn yield and the dry mass of the forage. The height of the forage canopy is influenced by the planting orientation and spacing between lines.

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PHYSICAL ATTRIBUTES OF SOIL IN AN AGROFORESTRY SYSTEM WITH OIL PALM

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ABSTRACT

Currently, there is a lack of related studies on the impacts of management in diversified cultivation with oil palm, on the attributes of the soil. Thus, this work aimed to evaluate whether the management affects the physical attributes in different positions within an agroforestry system with oil palm. The research was carried out at an experimental site, in the county of Tomé-Açu, Brazil. The system is called the Biodiverse Agroforestry System (AFS-BIO), with oil palm as the species with the greatest economic value. We collected soil samples with preserved structure in the weeded circle oil palm (WED); harvest path (HAR); leaf pile (PIL) and diversified strip (DIV) in depths 0-5; 5-10; 10-20 and 20-30 cm from the soil, to determine aggregation and bulk density. In management zones without machine traffic, soil aggregation is greater and the density of the soil is lower compared to the harvest path. Machine traffic decreased aggregation and promoted values of bulk density above the ideal (1.4 g cm^{-3}), for sandy loam soils, in the harvest path. The organic management and the presence of mulch on the soil contributed to a higher physical quality, while the heavy machinery traffic in the harvest path causes soil compaction.

Key words: Management zones; Physical quality; Soil management

INTRODUCTION

Physical attributes (bulk density, aggregate, porosity and resistance to penetration) are considered the main indicators of physical soil quality in integrated agricultural production systems (POLANÍA-HINCAPIÉ et al., 2021). The management practices carried out in the systems with or without oil palm, can cause changes in the carbon content of the soil (CARVALHO et al., 2014; DLAPA et al., 2020), that influences physical components, such as bulk density, porosity and water storage (MACHADO et al., 2008; MORADI et al., 2015) and, consequently, can affect plant growth (MORAES et al., 2016).

Oil palm is considered the most economically valuable oilseed and has the highest productivity per harvested area (SEDAP, 2021). One of the characteristics of the production system of this agricultural commodity is the spatial variation of the soil due to management, which conditions the emergence of management zones (NELSON et al., 2015). The studies by Frazão et al. (2013) and Ramos et al. (2017) found spatial variation for soil carbon content in monoculture and agroforestry systems with oil palm, respectively, mainly due to the management carried out in these use systems.

Agroforestry systems with oil palm are land-use systems that can provide more ecosystem services compared to conventional farming systems (monoculture) (GOMES, 2019). In these production systems, the impacts of management on the physical components of the soil have not yet been reported. The most recent studies on physical attributes have been carried out in monoculture systems (FERREIRA et al., 2019; SATO et al., 2017; ZURAIDAH, 2019). However, related studies on diversified oil palm systems lacking.

Therefore, the objective of this work was to evaluate whether the management influences the physical attributes of soil in different positions (management zones) within an agroforestry system with oil palm, in the eastern Amazon.

MATERIAL AND METHODS

The research was carried out at an experimental site, which is located in the county of Tomé-Açu, eastern Amazon, Brazil. The soil in the area is characterized as a medium textured dystrophic yellow Oxisol with a predominance of the sand fraction (EMBRAPA, 2018). The study was conducted in an agroforestry system that occupies an area of 2.0 ha and has oil palm as the main crop of economic value.

The system, called the Biodiverse Agroforestry System (AFS-BIO), was implemented in 2008 and consists of double lines of oil palm (spacing of 7.5 m between lines and 9.0 m between plants) alternated by lines of herbaceous, shrub and tree species. In addition to oil palm (*Elaeis guineensis* Jacq) the predominant species were *Acacia mangium* (acácia), *Euterpe oleracea* (açaí), *Carapa guineenses* (andiroba), *Theobroma cacao* (cacau), *Lecythi spisonis* (castanha), *Theobroma grandiflorum* (cupuaçu), *Adenanthera pavonina* (falso pau-brasil), *Gliricidia sepium* (gliricídia), *Inga edulis* (ingá), *Artocarpu sheterophyllus* (jaqueira), *Mangifera indica* (manga), *Spondias lutea* (taperebá), *Bixa orellana* (urucum). The fertilization is organic and consists of the application of empty bunches of the oil palm (that is, those remaining after the oil has been extracted in the industry) in the crowning area of the plant.

Four plots measuring 30 m x 30 m were delimited and, in each plot, we collected samples in the following zones: weeded circle oil palm (WED); harvest path (HAR), machine traffic location; leaf pile (PIL), stacking location of oil palm leaves and diversified strip (DIV). In each management zone in the plots, we collected two samples (duplicates) of soil with preserved structure in volumetric cylinders and in the form of monoliths measuring 10 cm x 10 cm x 10 cm in layers 0-5; 5-10; 10-20 and 20-30 cm of soil.

We determined the stability of aggregates through wet sieving (YODER, 1936), using a set of seven sieves with decreasing mesh opening, namely: 4.0 mm; 2.0 mm; 1.0 mm; 0.5 mm; 0.25 mm; 0.106 mm and 0.053 mm. After wet sifting, we transfer the samples of aggregates of each class of sieve diameter, by means of a light jet of deionized water, to aluminum containers and then we dry the samples in a forced air circulation oven at 105 ºC for a period of 24 h (EMBRAPA, 2017). After this period, we determine the dry mass of the samples retained in each sieve. We calculated the mean weighted diameter of the aggregates (MWD) using the equation below:

$$MWD = \sum_{i=1}^{n} xi\ wi$$

xi: medium diameter of each class of aggregates;

wi: proportion of each class of aggregates in relation to the total aggregates.

We determined the density soil (Ds) following the methodology of Embrapa (2017), in which the samples were dried in greenhouses with forced air circulation at 105 ºC for 48 h. We calculate the density soil according to the equation below:

$$D_s = \frac{m_s}{V}$$

D_s: soil density, in g cm^{-3};

m_s: mass of dry soil in an oven at 105 ºC until constant weight, in g;

V: cylinder volume, in cm^3.

We used one-way analysis of variance (Anova, $p \leq 0.05$) to test the effect of management zones on variables, separately by soil layer. To compare the averages, we applied the Tukey test ($p \leq 0.05$). We performed statistical analysis with the AgroEstat software (BARBOSA; MALDONADO JÚNIOR, 2015).

RESULTS AND DISCUSSIONS

The management zones of the weeded circle oil palm, leaf pile and diversified strip in the 0-20 cm layer of the soil showed a higher weighted average diameter of the aggregates statistically, compared to harvest path. In the 20-30 cm depth, the average diameter of the aggregates was greater in WED than in DIV (Table 1). The larger diameter of the aggregates that we found in these management zones (WED, PIL and DIV) in the 0-20 cm profile compared to harvest path may be related to the greater presence of roots and continuous supply of organic matter, in addition to the absence of the passage of machines in these management zones. The roots of the plants release exudates and organic compounds that act as cementing and bonding agents between mineral particles, playing a fundamental role in the formation of soil aggregates (TISDALE; OADES, 1982; XIAO et al., 2020).

The higher organic matter content influences the average diameter of the aggregates in a positive way, through the links between organic polymers and inorganic surfaces of soil particles (CASTRO FILHO et al., 2002; SALTON et al., 2008). On the other hand, to harvest path, the constant passage of agricultural machines and implements causes negative impacts on the soil surface, since it leads to the breaking of the aggregates of larger diameter to their conversion into smaller aggregates, causing soil compaction (COLOMBI et al., 2018; ZURAIDAH, 2019).

The soil density to harvest path was statistically higher than that of the leaf pile and diversified strip in the 0-10 cm depth and in the 10-20 cm depth, differed from the weeded circle oil palm and diversified strip (Table 1). The management of organic fertilization close to the oil palm and the continuous supply of mulch to leaf pile and diversified strip, tend to provide less soil density, while in the harvest path the passage of machines and less ground cover contribute to high values of soil density, above the ideal for sandy loam soils (1.4 g cm^{-3}), according Arshad et al. (1997). At 0-10 cm depth the bulk density values are close to the critical limit (1.75 g cm^{-3}), according to Arshad et al. (1997), which can hinder, for example, the growth of oil palm roots in this management zone. In fact, the use of machines for harvesting and other management operations can contribute to the deterioration of the physical conditions of the soil, which can restrict the growth and function of the oil palm roots (ZURAIDAH et al., 2010).

Thus, the management of organic fertilization and the continuous supply of litter on the soil favored greater physical quality of the soil, through greater aggregation and lower apparent density in agroforestry systems with oil palm. However, the traffic of machines for the management of the system deteriorates the physical conditions of the soil, causing compaction in the harvest path, which arouses attention, to weigh in management practices that mitigate the damage on the physical attributes of the soil.

Table 1. Mean weighted diameter of aggregates and soil density in a biodiverse agroforestry system (AFS-BIO) in the county of Tomé-Açu, eastern Amazon, Brazil.

System	Management zones			
	WED	**HAR**	**PIL**	**DIV**
	Mean weighted diameter of aggregates (mm)			
	Soil depth 0-5 cm			
AFS-BIO	4.78 ± 0.24 a	2.61 ± 0.35 b	5.78 ± 0.01 a	4.95 ± 0.33 a
	F= 25.45**		CV= 11.82	
	Soil depth 5-10 cm			
AFS-BIO	4.73 ± 0.14 a	2.61 ± 0.17 b	4.96 ± 0.23 a	5.02 ± 0.33 a
	F= 24.94**		CV= 10.65	
	Soil depth 10-20 cm			
AFS-BIO	4.06 ± 0.13 a	3.01 ± 0.30 b	4.08 ± 0.26 a	4.50 ± 0.11 a
	F= 8.69**		CV= 11.03	
	Soil depth 20-30 cm			
AFS-BIO	4.50 ± 0.12 a	3.06 ± 0.16 b	3.94 ± 0.33 ab	3.53 ± 0.16 b
	F= 8.49**		CV= 11.20	
	---------------- **Soil density (g cm^{-3})** -------------			
	Soil depth 0-5 cm			
AFS-BIO	1.53 ± 0.03 a	1.67 ± 0.02 ab	1.35 ± 0.03 b	1.35 ± 0.08 b
	F= 10.44**		CV= 6.44	
	Soil depth 5-10 cm			
AFS-BIO	1.58 ± 0.05 a	1.68 ± 0.03 ab	1.49 ± 0.04 b	1.46 ± 0.04 b
	F= 6.35**		CV= 5.16	
	Soil depth 10-20 cm			
AFS-BIO	1.48 ± 0.02 b	1.60 ± 0.02 a	1.52 ± 0.02 ab	1.46 ± 0.02 b
	F= 7.30**		CV= 3.13	
	Soil depth 20-30 cm			
AFS-BIO	1.52 ± 0.04 a	1.57 ± 0.01 a	1.54 ± 0.01 a	1.50 ± 0.02 a
	F= 1.17^{ns}		CV= 3.16	

**Significant at 1% probability of error; ^{ns} not significant; CV coefficient of variation; Same letters do not differ by Tukey test at 5% probability of error.

CONCLUSIONS

The organic management and the litter supply over the soil contributed to a better physical quality of the soil in the management areas without machine traffic. In the harvest path, due to the passage of machines, the physical quality of the soil is lower and the density of the soil has reached values close to the critical limit for soils with a sandy loam texture.

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TEMPORAL VARIATION OF PENETRATION RESISTANCE IN AN AGROFORESTRY SYSTEM WITH OIL PALM

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ABSTRACT

Soil penetration resistance penetration is property important to characterize the state of soil compaction in cultivated systems. Thus, this work aimed to evaluate the impacts of management and moisture on soil penetration resistance in an agroforestry system with oil palm. The research was carried out at an experimental site, located in the county of Tomé-Açu, eastern Amazon, Brazil. The system is called the Biodiverse Agroforestry System (AFS-BIO), with oil palm as the species with the greatest economic value. We collect soil samples weeded circle oil palm (ACP); Harvest path (CAR); leaf pile (PIL) and diversified strip (DIV) in depths 0-5; 5-10; 10-20; 20-30 and 30-50 cm of soil for determine gravimetric moisture. The penetration resistance is determined by means of an impact penetrometer with a cone angle of 30°. Soil resistance in periods of lower moisture is higher than in periods of high soil moisture. There is an increase in resistance with the depth of the soil, which may possibly be influenced by the increase in bulk density. In the period of lower moisture the soil resistance reached critical values, mainly in the harvest path, due to the passage of machines in this management zone. Soil moisture and management are the main factors that directly influence soil penetration resistance.

Key words: Amazon; Management zones; Mechanical resistance

INTRODUCTION

Soil penetration resistance has been considered an important property to characterize the state of soil compaction and has also been used in the assessment of physical soil quality in agricultural and forestry systems (DEARMOND et al., 2020; POLANÍA-HINCAPIÉ et al., 2021). The management practices carried out in the production systems can influence the organic matter content, the bulk density and the water status of the soil, which will consequently affect the resistance to penetration (GABRIEL et al., 2021; VAZ et al., 2011).

In the last decades, the cultivation of oil palm has grown strongly in the countries of the African and American continents, driven mainly by the world demand for vegetable oil (HANSEN et al., 2015). One of the characteristics of the production system of this agricultural commodity is the spatial variation of the soil due to the (NELSON et al., 2015). The spatial variation of soil carbon found in the studies by Frazão et al. (2013) and Carvalho et al. (2014), resulting from management in monoculture and agroforestry systems with oil palm, can indirectly affect penetration resistance. In the area of machine traffic, especially in periods of lower soil moisture, the resistance of the soil to penetration can reach critical values, which can restrict the growth of oil palm roots (SATO et al., 2017).

The cultivation of oil palm in agroforestry systems can provide numerous environmental benefits, such as carbon storage similar to that of natural vegetation areas (CARVALHO et al., 2014). In these production systems, the impacts of moisture and management on the temporal variation of soil resistance to penetration have not yet been reported. The most recent studies on physical attributes were carried out in monoculture systems (FERREIRA et al., 2019; SATO et al., 2017; ZURAIDAH, 2019), but not in diversified systems with oil palm.

Therefore, the objective of this work was to evaluate the impacts of soil management and moisture on soil penetration resistance in an agroforestry system with oil palm, in the eastern Amazon.

MATERIAL AND METHODS

The research was carried out at an experimental site, which is located in the county of Tomé-Açu, eastern Amazon, Brazil. The soil in the area is characterized as a medium textured dystrophic yellow Oxisol with a predominance of the sand fraction (EMBRAPA, 2018). The study was conducted in an agroforestry system that occupies an area of 2.0 ha and has oil palm as the main crop of economic value.

The system, called the Biodiverse Agroforestry System (AFS-BIO), was implemented in 2008 and consists of double lines of oil palm (spacing of 7.5 m between lines and 9.0 m between plants) alternated by lines of herbaceous, shrub and tree species. In addition to oil palm (*Elaeis guineensis* Jacq) the predominant species were *Euterpe oleracea* Mart (açaí), *Carapa guineenses* Aubl (andiroba), *Oenocarpus mapora* H. Karsten (bacabi), *Theobroma cacao* Linn (cacau), *Bertholletia excelsa* (castanha), *Adenanthera pavonina* (falso pau-brasil), *Inga edulis* Mart (ingá), *Tabebuia sp* (ipê), *Hymenaea courbaril* L (jatobá), *Mangifera indica* L (manga), *Swietenia macrophylla* King (mogno), *Azadirachta indica* (nim), *Virola surinamensis* (ucuuba). The fertilization is organic and consists of the application of empty bunches of the oil palm (that is, those remaining after the oil has been extracted in the industry) in the crowning area of the plant.

Four plots measuring 30 m x 30 m were delimited and, in each plot, we collected samples in the following zones: weeded circle oil palm (WED); harvest path (HAR), machine traffic location; leaf pile (PIL), stacking location of oil palm leaves and diversified strip (DIV). At each location in the plots, we collect deformed soil samples through the probe-type auger, in depths 0-5; 5-10; 10-20; 20-30 and 30-50 cm from the ground, to determine gravimetric moisture (EMBRAPA, 2017).

We determined the soil penetration resistance with an impact penetrometer (Stolf model) with an angle of the cone of 30°. The readings made in the field were recorded and later processed in an electronic spreadsheet (Excel VBA) developed by Stolf et al. (2014). The equation we used to transform the number of dm^{-1} impacts into mechanical resistance (MPa) was proposed by Stolf (1991) and restated by Stolf et al. (1998; 2005; 2014):

$$\mathrm{PR}\ (\mathrm{kgf\ cm^{-2}}) = 5.6 + 6.89 * \mathrm{N}\ (\mathrm{impacts\ dm^{-1}}),$$

$$\mathrm{PR}\ (\mathrm{kgf\ cm^{-2}}) = 5.6 + 6.89 * \mathrm{N}\ (\mathrm{impacts\ dm^{-1}}),$$

PR: soil penetration resistance, in MPa;

N: is 10 x number of impacts divided by penetration, in cm.

RESULTS AND DISCUSSIONS

Soil penetration resistance increased with the depth of the soil, especially in periods of lower soil moisture. In general, when the soil was drier, we observed a greater variation in resistance between the management zones. The trend we found is that in the period of lowest soil moisture, at the harvest path showed penetration resistance above the critical limit (2.0 MPa) in all layers of the soil, while in the weeded circle oil palm, leaf pile and diversified strip at resistance was lower than the critical limit in the most superficial layers and tended to increase, starting at 10 cm from the ground (Figure 1).

In the period of highest soil moisture, soil resistance to penetration varied little between management zones. Although the harvest path showed greater resistance, the values did not reach the critical limit in the most superficial layers of the soil, which are the most influenced by management, in these production systems. The management of organic fertilization and the contribution of mulch over the soil, from the pruning of the plants, contribute to decrease the resistance of the soil, especially in periods of lower soil moisture, in the weeded circle oil palm, leaf pile and diversified strip. However, the soil compaction in the harvest path, due to the traffic of machines in this management zone and less presence of mulch on the soil, presented greater resistance, mainly in the period of less precipitation and soil moisture.

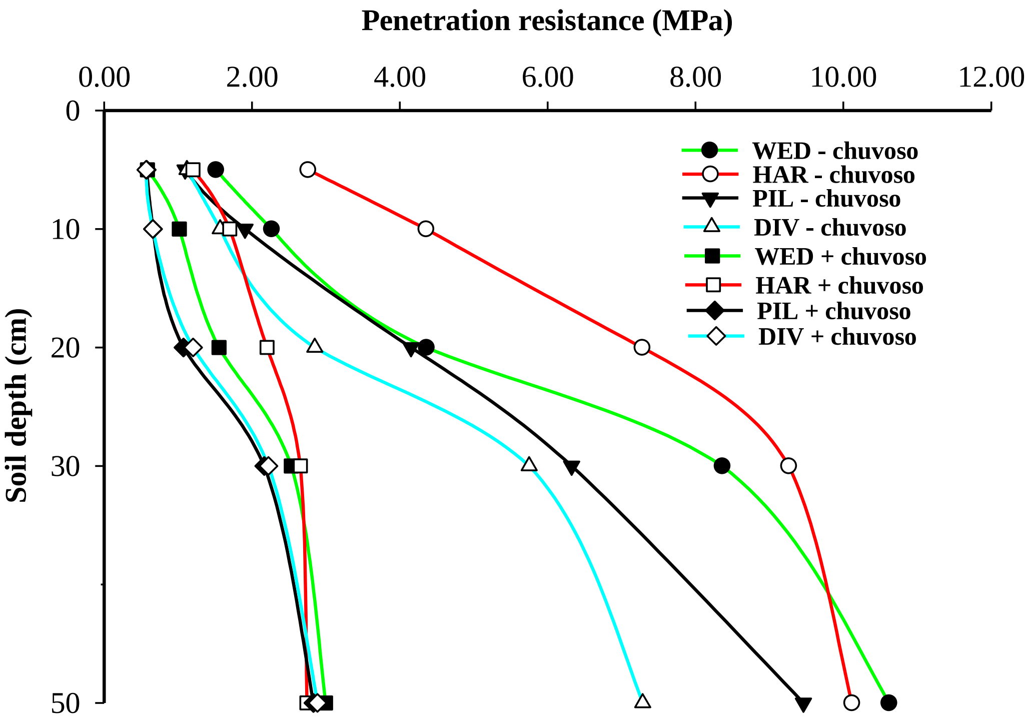

Figure 1. Variation of soil penetration resistance in a biodiverse agroforestry system (AFS-BIO) in the county of Tomé-Açu, eastern Amazon, Brazil.

The gravimetric moisture of the soil showed greater variation between the management zones in the less rainy period, compared to the wetter period. The harvest path was the area that had the lowest soil moisture up to the 30 cm depth, which was related to greater soil resistance to penetration in this management area. In the rainy season, there was less variation in moisture between the management areas studied (Figure 2).

Our results suggest that soil moisture was the main factor that influenced soil resistance to penetration, but other factors such as texture, soil density, organic matter content can be affected by the type of management used on the soil and, consequently, can also influence resistance (GABRIEL et al., 2021; SAYEDAHMED, 2015; VAZ et al., 2011). The type of soil cover that provides higher levels of organic matter can provide better water conditions and soil density, consequently positively impacting soil penetration resistance (GABRIEL et al., 2021; SAYEDAHMED, 2015). Future studies in our study area will assess the relationship of resistance to penetration with factors other than soil moisture.

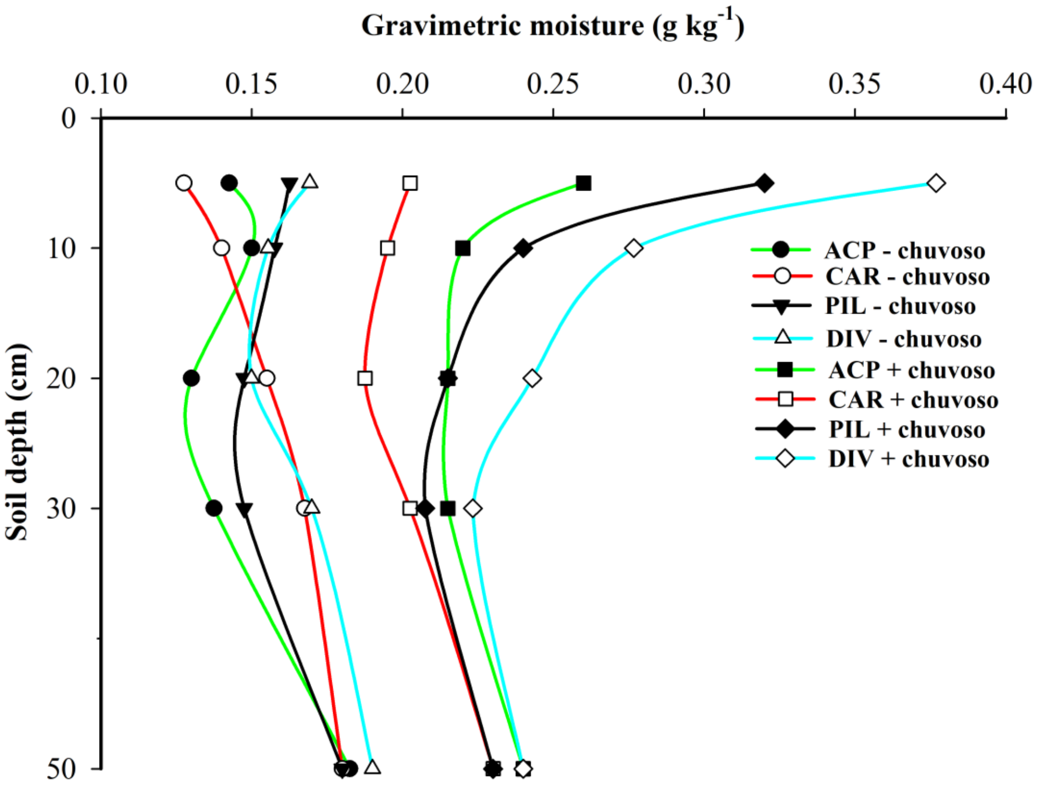

Figure 2. Variation of gravimetric moisture in a biodiverse agroforestry system (AFS-BIO) in the county of Tomé-Açu, eastern Amazon, Brazil.

CONCLUSIONS

The soil penetration resistance varies in time and space in the agroforestry system with oil palm. Soil moisture and management are the main factors that directly influence soil resistance.

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AGRICULTURAL PRODUCTIVITY OF A LONG-TERM CROP-LIVESTOCK SYSTEM IN THE CERRADO BIOME, BRAZIL

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ABSTRACT

Some regions of the Cerrado Biome present edaphoclimatic conditions restrictive to the maximum productive potential of agriculture and livestock. In these regions, experiments with crop-livestock system (CLS) show that this strategy allows the intensification of agricultural production in a sustainable manner. Rotation, intercropping and succession of crops producing grains or silage with forage species, and conservationist soil management such as no-till and correction of the soil profile favorable to root growth, allow the exploitation of the agricultural area, especially when there is a water deficit. In fifteen years of conducting the CLS, the production of agricultural crops met the demand for food and, also, provided grain yields above regional averages, and even national averages. In addition to the lower risk, the strategy adopted met internal demand and generated surplus grain and silage for commercialization, increasing income. In the temporal analysis of the CLS, the adoption of sustainable soil and crop management practices has, over time, overcome the region's edaphoclimatic limitations, in an economically viable way, based on adequate land use planning, and by the choice of appropriate combination of crops, properly aligned with the livestock activity of interest.

Key words: Consortium; Crop rotation; No-tillage system

INTRODUCTION

In the Brazilian Cerrado there are constant periods of water deficit even during the summer which vary in intensity, therefore, the use of available natural resources to enhance agricultural production is a constant challenge. Over the years, the possibilities of crops succession and rotation with the aim to improve soil and water conservation have proved to be important and indispensable, especially considering the time in which these cultivation systems are explored on the farm.

The world demand for food must be allied with the possibility of optimizing the use of the agricultural area without the need to open new areas. In this sense, CLS and the no-till system (NTS) using cultural practices such as intercropping species and maintaining crop rotation and succession to increase straw, are alternatives that enhance productivity.

Current production systems must be based on sustainable intensification, on the use of available resources, including the use of natural, social assets and human capital combined with the use of the best available technologies and inputs, which seek to minimize or reduce environmental damage as much as possible (GONTIJO NETO et al., 2018). Borghi et al. (2020) added that the use of systems that allow sustainable intensification in land use is important for improving the agricultural productivity indexes and meeting the world demand for food, fibers, and bioenergy. In this sense, the construction and maintenance of agricultural soil fertility, especially in areas with low natural fertility soils, allowed the exploitation of natural resources in a sustainable manner and was able to enhance agricultural and livestock productivity even in conditions apparently unfavorable to agricultural production. Long-term adaptive research models allowed us to assess how the management strategies conducted enabled gains in crop productivity, even in years of adverse climatic conditions (dry spell). The present work evaluated the dynamics of agricultural productivity of an CLS model implemented 15 years ago in Sete Lagoas-MG, Brazil.

MATERIAL AND METHODS

The CLS is located at the geographical coordinates 19°29'4.37" S, 44°10'25.66" W and altitude of 755 meters. The local and predominant climate in almost the entire Cerrado region is classified, according to the Köppen classification, as Aw - Type A: megathermic (tropical humid) - with average temperature of the coldest month above 18 ° C and subtype w - dry winter and maximum summer rains. The average annual precipitation is 1350 mm distributed between the months of October to March with the marked occurrence of dry spell in the month of January / February. The soil is a Oxisol (dystrophic Red Oxisol) according to the Brazilian Soil Classification System, clayey and smooth undulating relief, whose native vegetation was suppressed in 1968 for cultivation. The CLS has 22 hectares (ha) and was divided into four 5.5 ha plots where, each year in the spring/summer, the plots are rotated as crops for the production of grains (soybeans and corn) or silage (corn and sorghum) associated with grasses *Urochloa* (syn. *Brachiaria*) or *Megathyrsus* (syn. *Panicum*). Since of the first crop yield, the sowing of the cropping system using the premises of conservationist managements as the no-till and the consortium with grains cultures with forages species. In the fourth plot is the *Megathyrsus* pasture. In the fall/winter all the plots become pastures. Bovine animals with an average age of seven months were introduced in the system in July of each year and remained in it for twelve months.

Priority was given to the intercropping of agricultural crops with forage species, due to the opportunity of silage production associated with the implantation of pastures for use by cattle in the winter period. Over the years, this strategy has proven to be very efficient for the region, in view of the climatic characteristics that prevents a second crop or the sowing of grasses in post-harvest crops. In recent years, as described in the previous topic, in the case of corn, simultaneous intercropping with cultivars of the genus *Urochloa* is carried out, and in sorghum for silage the simultaneous intercropping occurs with cultivars of the genus *Megathyrsus*. Forages were chosen because of the potential for biomass production and coexistence in the consortium, without significant competition with corn or sorghum for silage crops. Simultaneous sowing takes place with a seeder-fertilizer machine with additional box coupling for forage seeds specific for this purpose.

The sowing and cover fertilizations, the latter for corn and forage sorghum crops, were dimensioned according to the results of soil analysis and regional recommendations. Agricultural practices for the control of pests, diseases and weeds have always been carried out following the concept of good agricultural practices for each specific crop. All operations were mechanized, simulating the conditions of a rural property.

In advance of the harvest, in each plot, samplings are carried out to collect agronomic and species productivity data. Through walking in the area, at random, each sampling makes up one repetition, and the set of these repetitions make up the average productivity of the crop. Considering that each plot has an area of 5.5 hectars (ha), it is possible to estimate, in addition to productivity per ha, the total volume produced by each component of the rotated system. The soybean and corn grain yield data were converted to 13% humidity (wet basis) and the silage yield to 35% dry matter.

RESULTS AND DISCUSSIONS

Table 1 contains data on average grain and silage yield, production of each crop considering the area of each plot (5.5 ha), as well as the indication of occurrence and the intensity of dry spell in each agricultural year during the 15 years of CLS.

It is observed that, in the 15 years of implantation of the crop rotation system, only in two agricultural years (2006/07 and 2019/20) there was no dry spell occurrence. In the other years, the presence of this phenomenon occurred in different proportions, however, always with a great impact on crop productivity. According to Table 1, there were 3 agricultural years with dry spell considered of medium intensity (2007/08, 2008/09 and 2009/10), one agricultural year with moderate dry spell occurrence (2010/11) and in the other agricultural years the dry spell was severe (2011/12, 2014/15, 2016/17, 2017/18 and 2018/19) and, in 3 agricultural years (2012/13, 2013/14 and 2015/16) the occurrence of two dry spell periods (November and January) significantly impacted the productivity of soybean and corn crops. Regardless of the species, sowing takes place preferably in the month of November. Thus, the period of greatest demand for water, which occurs during the flowering of crops, always occurs in January or beginning of February, which is the period most likely to occur dry spell.

At the end of the 2019/20 agricultural year, considering the 15 years of agricultural activities in the CLS and the size of the plots (5.5 ha), 442.5 tons of soybeans and corn and 4,890.3 tons of silage were produced corn silage + grass and silage sorghum + grass (Table 1), which demonstrates the versatility of plant production using this strategy outlined for the Central region of Minas Gerais.

As of the 2016/17 agricultural year, soybean yields were higher than the general average of the CLS driving period (2,560 kg ha^{-1}), even with the occurrence of severe dry spell. The productivity obtained in agricultural 2018/19 (4,110 kg ha^{-1}) is highlighted, the highest recorded, even in the presence of a dry spell period of 31 days, which started on 04/01/2019 and ended on 02/05/2019, precisely at the full flowering stage of soybeans. This fact demonstrates the assertiveness in choosing the crop rotation scheme. The maintenance of satisfactory conditions of chemical fertility in the soil profile over time also contributed to this performance. During 15 years of soybean cultivation in 5.5 ha, 197.2 tons of oilseed grains were produced (Table 1).

In analyzing the productivity of the corn + *Urochloa* consortium, it is important to note that until the 2011/12 agricultural year, all corn was used for grain production to simulate an opportunity for producers, in the case of opting for grain production instead of silage. Thus, in 5.5 ha cultivated annually between the agricultural years 2005/06 to 2011/12, the total corn yield grains were 245.2 tons (Table 1). From the 2012/13 agricultural year, the cultivation of corn + *Urochloa* was directed to the production of silage, which was used annually as silage by the animals during the confinement period. Between 2012/13 to the present agricultural year, 1,728.9 tons of silage corn intercropped with *Urochloa* were produced.

According to the crop rotation model used in the CLS, the corn + *Urochloa* was sown following the of soybean cultivation, in the summer. Thus, the same effects already demonstrated by the literature on the importance of the annual soybean / corn rotation can be seen by the grain yield history. The average grain yield in the period of conduction of the CLS was 7,310 kg ha^{-1} (Table 1).

The lowest productivity of corn grains occurred in the agricultural year 2014/15 (5,140 kg ha^{-1}) with the occurrence of a severe dry spell. In the following agricultural year (2015/16), in which corn was sown with the occurrence of two medium and high severity dry spell crops, the highest grain yield in the period (9,010 kg ha^{-1}) was recorded. Although the productivity occurred in different plots due to the rotation scheme adopted, there was an evident benefit of crop rotation. Analyzing the grain production data from these two agricultural years (2014/15 and 2015/16) with the respective silage productivity in each corresponding agricultural year, it was possible to observe that, although the dry spell of 2015 was aggravating for grain production, the silage productivity was not the lowest recorded in the period of conduction of the CLS (39 t ha^{-1}).

Regarding the productivity of corn silage + grass (Table 1), the general average recorded in the period was 39 t ha^{-1} of dry biomass. It is important to emphasize that the grass forage contributed to silage biomass, especially in dry spell years. The lowest silage productivity was registered in the agricultural year 2018/19 (21.2 t ha^{-1}), in which the dry spell period of 31 days between the months of January and February 2019 significantly reduced the productive potential of corn and *Urochloa*.

Table 1. Average productivity (Mg ha^{-1}, t ha^{-1}) and production (t) of soybean, corn + grass and forage sorghum + grass crops, between the agricultural years 2005/06 to 2019/20, in the plots conducted in a crop rotation scheme of the CLS, in Sete Lagoas / MG, Brazil.

Agricultural Year	**------- Soybean ------**		**-------- Corn + Grass -------**				**Silage Sorghum + Grass**		**Dry Spell Occurrence**
			---- Grain ----		---- Silage ---				
	Mg ha^{-1}	**t**	**Mg ha^{-1}**	**t**	**Mg ha^{-1}**	**t**	**Mg ha^{-1}**	**t**	
2005/2006	1.80	9.9	N A		N A		31.0	170.5	Severe = S
2006/2007	2.43	1.4	6.40	35.2	N A		53.0	291.5	Absent = A
2007/2008	1.98	1.9	8.17	44.9	N A		41.4	227.7	Light = L
2008/2009	2.80	1.4	8.07	44.4	N A		40.3	221.6	Light = L
2009/2010	2.20	1.1	8.72	47.9	N A		36.6	201.3	Light = L
2010/2011	2.37	1.0	6.09	33.5	N A		37.7	207.3	Moderate = M
2011/2012	2.90	15.9	7.15[£]	39.3	N A		20.1	110.5	Severe = S
2012/2013	0.85	4.67	7.28		53.0[£]	291.5	52.2	287.1	Two (Nov. = L e Jan = S)
2013/2014	N A[¥]	N A	6.67		32.0	176.0	32.0	176.0	Two (Nov. = L e Jan = S)
2014/2015	2.24	12.3	5.14		39.0	214.5	43.2	237.6	Severe = S
2015/2016	1.24 (Bean)	6.82	9.01		45.9	252.5	50.0	275.0	Two (Nov. = M e Jan = S)
2016/2017	3.81	20.9	7.67		49.8	273.9	25.4	139.7	Severe = S
2017/2018	3.65	20.1	8.53		30.2	166.1	37.2	204.6	Severe = S
2018/2019	4.11	22.6	6.12		21.2	116.6	31.4	172.7	Severe = S
2019/2020	3.51	19.3	8.42		43.3	238.1	43.3	238.1	Absent = A
Productivitie									
Maximum	4.11	22.6	9.01	35.2	53.0	291.5	53.0	291.5	
Minimum	0.85	4.67	5.14	44.9	21.2	116.6	20.1	110.5	
Average	2.56	13.15	7.39	35.0	39.3	216.1	38.3	210.6	
Accumulated[€]		197.3		245		1.729	574.8	3.161	

[¥] Not rated; [£] as of the 2012/2013 agricultural year, the area of 5.5 hectares was used entirely for the silage production. [€] for the calculation of production, the area of each plot (5.5 ha) was considered.

The yield of silage mass of forage sorghum + grass was satisfactory when compared to the regional average, except for the agricultural years 2011/12 and 2013/14 which, due to the occurrence of two dry spell periods and the sowing time of the consortium, was observed a severe impairment in development of forage sorghum, resulting in only 20.1 and 25.4 t ha^{-1}, respectively (Table 1). The choice of the consortium with *Megathyrsus*, under simultaneous consortium, has an important participation in the mass produced, especially in the dry spell years, where the sorghum culture suffers greater competition for water, although the sorghum is admittedly more tolerant to periods of water restriction when compared to corn.

Additionally, the implemented system reduced risks of livestock activity, because even in years of high grain prices, as occurred in 2015/16 and 2016/17, the results were positive, since the production cost of the concentrates and bulky on the property was considerably less than its acquisition in the market, allowing, still, to be able to commercialize the surplus. The author concluded that the model implemented allows the producer to enjoy ample market opportunities, with less dislocation of resources for the purchase of external inputs in the livestock phase, coupled with the possibility of significant gains with the commercialization of surplus production. This exploitation model differs from the modal agricultural and livestock activities in the region, traditionally exploited exclusively with a single activity, presenting low zootechnical indexes and, consequently, lower profitability.

CONCLUSIONS

The diversity of plants and the rotation of crops between the plots adopted in the CLS allowed us to infer that, in 15 years of implantation of the system, agricultural productivity, even in situations of moderate and severe water restriction, increased the resilience of agricultural crops and allowed, at least, incremental improvements to the CLS over time.

The edaphoclimatic limitations of this region can only be overcome in an economically viable way based on adequate land use planning, with careful management of its fertility and choice of appropriate combination of crops, properly harmonized with the livestock activity of interest. Some measures have proved essential to the success of any entrepreneurial initiative with this focus, among them: the construction of fertility in the soil profile, the adoption of the no-till with effective crop rotation and the adjustment of the animal load according to the capacity forage supply.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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ENERGY PERFORMANCE OF INTEGRATED CROP- LIVESTOCK SYSTEM WITH DUAL-PURPOSE WINTER CEREALS

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ABSTRACT

The aim of this work was to estimate the contribution of winter and of the summer crops in the conversion and energy balance of integrated crop-livestock systems (ICLS) under no-tillage, from 2009 to 2018, in Coxilha, RS. The treatments consisted of six ICLS: I (wheat/soybean and common vetch/corn); II (wheat/soybean and black-oat pasture/corn); III (wheat/soybean and black oat pasture/soybean); IV (wheat/soybean and peas/corn); V (wheat/soybean, common vetch/soybean, dual-purpose triticale/soybean); and VI (wheat/soybean, dual-purpose oat/ soybean and dual-purpose wheat/soybean). The treatments were allocated in the randomized complete block design, with four replicates. Corn was the species with the highest energy return compared to other winter and summer crops as well as winter pastures. Of the winter cover crops and green manure crops, vetch was the most efficient in energy conversion. Systems I and IV and, systems I and II were the most efficient in energy conversion and energy balance, respectively. The ICLS under no-tillage was feasible, as it showed conversion and positive energy balance.

Key words: energy conversion; energy balance; no-till

INTRODUCTION

The inputs and services used in crop systems represent energy costs (FERREIRA et al., 2014) and depend on crop yield, animal performance and N incorporated by green manure. The energy expenditure will determine the efficiency of the energy conversion of each particular production systems. If the energy produced is less than the energy consumed, the energy balance will be negative (SANTOS et al. 2015a; SANTOS et al., 2019) making the system unsustainable.

Zentner et al. (1984) working in Canada with 12 crop rotation systems for wheat, along 12 years, found differences in energy conversion in rotation wheat systems. One winter without wheat (0.93) and two winters without wheat (0.97) compared to monoculture of wheat (0.68). However, Zentner et al. (1989), evaluating these systems for 18 years, found no differences between them. It must be due to, in both cases, there were no summer crops and cool season pasture as well, such as in southern Brazil.

In the work developed by Santos et al. (2005) comparing the crops alone, from 1995 to 2000, reported that the mixed pastures of black-oats/common vetch (0.77), black-oats/common vetch/ryegrass (0.65) and pearl millet (0.90), Had negative response in energy balance. The same authors in the 2001-2002 study, including the straw on the soil, the same species had positive energy conversion. Mixed pastures of black-oats/common vetch (33.28), pasture of black oats/common vetch/ryegrass (34.16) and pearl millet pasture (64.88) (SANTOS et al., 2011).

Monoculture systems using intensive inputs reduce energy efficiency, in addition of the low soil coverage. The use of practices that reduce the problems outlined can be the alternatives to increase the efficiency of the production systems, especially by the use of crop rotations and the management of specific species for green manure, impact positively the soil coverage, carbon sequestration and nitrogen fixation (SANTOS et al., 2011; SANTOS et al. 2015b).

In the southern Brazil, Santos et al. (2020) reported conversion rates for oat (10.68), common vetch (11.51), soybean (11.11), sorghum (13.93) and wheat (9.03). The authors also found conversion rates for crop rotation systems for wheat monoculture (9.04), one year wheat rotation (11.32) and two years wheat rotation (11.34). Dates of crops and pastures yields of production systems with ICLS were reported by Santos et al. (2013). The authors observed that the systems with wheat/soy, oats and common vetch/corn (14,74); with wheat/soybean, oats and common vetch/corn after perennial cool-season pasture (13.99); with wheat/soybean, oats and common vetch /corn after perennial warm-season pasture (14,19); and with wheat/soybean, oats and common vetch/corn after alfalfa (13.80) were the most efficient in energy conversion, compared to the system with wheat/soybean, oats/soybean and black-oat/common vetch mixed pasture/corn (11.73).

The present work was to assess the conversion and energy balance of integrated crop-livestock systems (ICLS) in comparison just with grain crops.

MATERIAL AND METHODS

Data of crop yield, pasture dry matter yield, as well as amount of N of the dry matter cover crops and straw remaining after winter and summer harvest in the experiment of integrated crop-livestock systems (ICLS), installed in the Coxilha county (RS) from 2009 to 2018. The soil classified as an Oxisol typical Dystrophic Red Latosol. The treatments consisted in six ICLS: I - wheat/soybean and common vetch/corn; II: wheat/soybean and black-oat pasture/corn; III: wheat/soybean and black-oat pasture/soybean; IV: wheat/soybean and pea/corn; V: wheat/soybean, dual-purpose triticale/soybean, and dual-purpose oat / soybean and common vetch/soybean; VI: wheat/soybean, dual-purpose oat and oat/soybean and dual-purpose wheat/soybean. Plot size was 10 x 20 m (200 m^2) in the randomized complete blocks design, with four replicates. No-till system was used on the winter and summer crops. In 2009, dual-purpose oat, wheat and triticale, as well as black-oat pastures were grazed by dual-purpose crossbred cattle, grazing every time that height plants reached about 0,3-m tall to stubble height was 0,07 to 0,1-m tall along of 1 to 2 days each block. Management always done without excess soil moisture, grazing once or twice a fall-winter season. From 2010 to 2018, pasture was cut using a sickle-bar mower with the forage removed of area.

From production matrices, transformations were made to account for the energy available and consumed in these processes. For the calculations of the various indexes that involve ICLS, with grain yield, dry matter yield, amount of remaining straw, amount of N in dry matter and field operations, data and guidelines generated were based on Santos et al. (2013). In the case of pea and common vetch, the contribution made based on the percentage of nitrogen and straw dry matter was considered as yield.

As available energy or energy revenue (MJ/ha), the transformation into energy of grain yield, dry matter yield, the amount of N in dry matter and the amount of straw remaining from winter and summer species was considered. As energy consumed (MJ/ha), it was estimated the sum of the energy coefficients corresponding to the correctives, fertilizers, seeds, fungicides and insecticides used in each ICLS, as well as the energy consumed by the operations (sowing, fertilization, application of agrochemicals and harvesting). The energy conversion results from the division of the available energy by the consumed, in each ICLS. The energy balance results from the difference between the available and consumed energy, in each ICLS. The data were transformed into MJ (kcal x 1,000 x 4,186).

The statistical analysis consisted of the analysis of the variance of conversion and energy balance, within each year (winter + summer) and the joint average of the years, in the period of 2009 and 2018. In the analysis of variance, the available and consumed energy was considered by the cultures that make up the ICLS. In the joint analyzes, treatments with a fixed effect were considered, and the effect of the year, as random. The means averages were compared using the Tukey's test, at of 5% probability.

RESULTS AND DISCUSSIONS

The averages of the conversion and the annual energy balance for the period 2009 to 2018 as a whole, and the statistical comparisons of grain yield, dry matter, winter and summer crops, of the six CLIS, will be reported below.

The analysis of variance of the conversion and the energy balance of the set of years had a significant effect for years and CLIS production.

Regarding the isolated energy conversion of the winter and summer crops of the six CLIS, in the period from 2009 to 2018, there was a difference between the averages of the years and the average of that period. Of the winter and summer grain producing species, corn (85.91 MJ/ha) was the most efficient in converting energy from all the other crops studied.

Soybean (78.43 MJ/ha), common vetch (42.15 MJ/ha), wheat (37.45 MJ/ha), dual-purpose wheat (35.53 MJ/ha), dual-purpose triticale (27.45 MJ/ha) and dual-purpose oats (25.39 MJ/ha), were in an intermediate position for energy conversion. It should be taken into account that, during this period, some species were sown with a dual purpose, that is, to offer biomass to the animals and still produce grains, as was the case with white oats, one of the wheats and triticale cultivars.

During this study period, vetch (42.15 MJ/ha) was more efficient at converting energy than peas (16.02 MJ/ha). It must be taken into account that the vetch was sown without maintenance fertilizer and had practically no attack of disease or pest during this study period. Both vetch and peas were sown as cover, with the purpose of producing straw to the soil and green manure, preceding the cultivation of corn. It was also noted that the pea did not produce as much biomass over the years as the common vetch, consequently, it produced a lower percentage of N in relation to this. In the case of ground cover legumes and green manure, the entry of fossil energy was reduced, especially that related to the application of fertilizers, in other words, in these, the 45 kg ha of N in cover, indicated for the crop, was not used of corn boats (18.40 MJ/ha), for grazing and peas, were the species with the lowest energy return.

However, ICLS analysis is preferable to analyzing cultures alone. In the period from 2009 to 2018, in six of the ten years studied, in the annual conversion (winter + summer) and in the average of the years, there was a difference between the ICLS. Over the years, systems I (wheat/soybean and common vetch/corn - 62.28 MJ/ha) and IV (wheat/soybean and peas/corn - 59.50 MJ/ha) were the most energy efficient, differing significantly from the systems II (wheat/soybean and black oat pasture/corn - 49.49 MJ/ha), III (wheat/soybean and black oat pasture/soybean - 45.04 MJ/ha), V (wheat/soybean, triticale for pasture and grain/soybean and common vetch/soybean - 50.83 MJ/ha) and VI (wheat/soybean, white oats for pasture and grain/soybean and dual-purpose wheat/soybean - 45.41 MJ/ha). The reason for this difference in favor of systems I and IV, in relation to the other systems studied (II, III, V VI), may be related to the presence of the corn crop, which in turn, was preceded by peas and common vetch. As the winter fertilization crops were sown without maintenance fertilization, this demanded less energy consumed and, at the same time, more energy available to the referred systems, and to corn that was grown without nitrogen cover fertilization. This in itself made systems I and IV more energy efficient, with a direct impact on the energy conversion of the systems.

All production model with integrated crop livestock systems showed energy conversions higher than the unit (1.0), producing 45.04 to 62.28 MJ/ha, times more energy than the non-renewable energy consumed. In this way, grain production systems or SPILP need to be energetically sustainable, since they are open systems and the amount of energy that enters should preferably be equal to or less than that that leaves.

Regarding the isolated energy balance of the winter and summer cultures of the six ICLS, in the period from 2009 to 2018, there was a difference between the averages in most years and the average of the period. Corn (201,364 MJ/ha) was the most efficient in energy balance of all other winter and summer crops studied.

Soybean (109,867 MJ/ha), wheat (84,587 MJ/ha), dual-purpose wheat (88,373 MJ/ha), dual-purpose triticale (78,395 MJ/ha), and dual-purpose oats (59,447 MJ/ha), were in an intermediate position for the energy balance values. The cultures of soil cover (pea and common vetch) and black oats pasture were the species with the lowest energy return. However, all species studied, both in winter and in summer, consumed less energy than they removed from the system.

Similar to energy conversion, it is preferable to analyze the energy balance in the form of ICLS, rather than to analyze the cultures in isolation. In eight of the ten years studied, in the annual energy balance (winter + summer) and in the average of the years, there was a difference between the ICLS. In the average of the years, the systems I (wheat/soybean and common vetch/corn - 213,358 MJ/ha) and II (wheat/soybean and pasture of black oats/corn - 217,613 MJ/ha) were the most energy efficient, in relation to the other systems studied. System IV (wheat/soybean and peas/corn -203,302 MJ/ha) was placed in an intermediate position for the energy balance indices. It can be said, in part, that the biggest difference in the energy balance, in this case, in relation to systems I, II and IV, is due to the corn crop, which was the species with the highest energy return. As the studied ICLS showed a positive energy balance, they can be considered as sustainable in terms of energy.

According to this report, agricultural technologies applied to complex systems were benefits in conversion and energy balance. In the case of ICLS I, II and IV stood out. However, energy consumption may increase with changes in production technology.

CONCLUSIONS

Corn stood out as highest energy return in comparison of soybean, wheat, oat crops as well as cool-season pastures.

Among the cover crops and winter green manure, common vetch was the most efficient in energy conversion among other cover crops. Systems I (wheat / soybean and common vetch/corn) and IV (wheat/soybean and peas/corn) were the most efficient for energy conversion. Systems I and II (wheat/soybean and black oat pasture/corn) were detach for energy balance.

Crop-livestock integration systems, under no-tillage, were feasible based on conversion and energy balance.

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FORAGE BIOMASS PRODUCTION IN THE INTEGRATED CROP – LIVESTOCK – FOREST SYSTEM IN THE CAATINGA BIOME

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ABSTRACT

Native vegetation management like thinning in strips can be applied in crop-livestock-forest (ICLF) systems in semiarid regions. Our objective was to quantify the production of pasture biomass in the ICLF systems designed for the Caatinga. It was observed that strips of 20 m enriched with massai grass accumulated three times more then strips of 10 m. However, a total biomass of the native and cultivated strata is not dissipated during the dry period and the beginning of the dry-rain transition (115.6 mm). Raining triggered changes in the chemical composition of the biomass by reducing the percentage content of dry matter, elevation of fiber and crude protein. Animal of three different breeds (Santa Inês, Somalis and Morada Nova) grazing the area did not show significant variation in body weight measurements, body score, rib eye area and biometric parameters (abdominal perimeter, chest perimeter, chest width and croup width), indicating that the ICLF system in the Caatinga provided sufficient nutrients for adequate performance of the animals. The integration of the crop with the native Caatinga pasture presents an important technique for producing food for small ruminants even during a dry season.

Key words: ILPF; Native vegetation; sheep

INTRODUCTION

When grazing animals have a great selection capacity ability. In the dry season the consumption of nutrients may not be sufficient to meet the requirements of the animals, making selection capacity an important behavior. Supplementation might be an important management tool to ensure animal performance.

In semiarid regions, the adoption of integrated crop – livestock – forest (ICLF) aims to intensify the use of small areas by increasing pasture biomass production and stocking rate, avoiding the degradation process of the natural vegetation.

The integration of exotic pasture can also minimize the pressure and the frequency of grazing on native species, decreasing the fragility of the ecosystem, increasing the forage supply and contributing to the maintenance of vegetation cover, which provides thermal comfort to animals (ASSIS et al., 2019).

Therefore, the proper planning of the system's spatial arrangement is fundamental for obtaining good results. In this context, the present study presents an ICLF arrangement that implies techniques for handling woody vegetation through thinning in strips and enriching the pasture. With exotic species. The aim of the work was to quantify the pasture biomass production in the ICLF systems designed for the Caatinga.

MATERIAL AND METHODS

Experimental site

The study was conducted in an ICLF system at Fazenda Três Lagoas, Sobral - Ceará, latitude 3°44'53" S and longitude 40°21'47" W, from oct/2018 to dec/2018 (65 days). The climatic classification of the region according to Köppen-Geiger is BSh type, hot semiarid. During the trial the average temperature was 30.1 °C and rainfall was 115.6mm.

Pasture characterization

The ICLF has 5.8 hectares and was implanted in an area of native Caatinga that was thinned in alternating strips of native vegetation suppressed or not. In the suppressed area, annual agricultural crops of sorghum (*Sorghum bicolor*) or millet (*Pennisetum glaucum*) were planted in consortium with the perennial grass (*Megathyrsus maximus* cv. Massai) and pigeon pea (*Cajanus cajan*). The system has a spatial arrangement of ten strips of native Caatinga vegetation alternating with nine strips of 20 m and 10 m wide deforested Caatinga (Figure 1).

At the end of the rainy season (June 2018) all the biomass produced (crop + pasture + legume) was harvested and ensiled all together. After that the area was put in a rest period of 90 days, allowing the pasture to regrow and accumulate biomass.

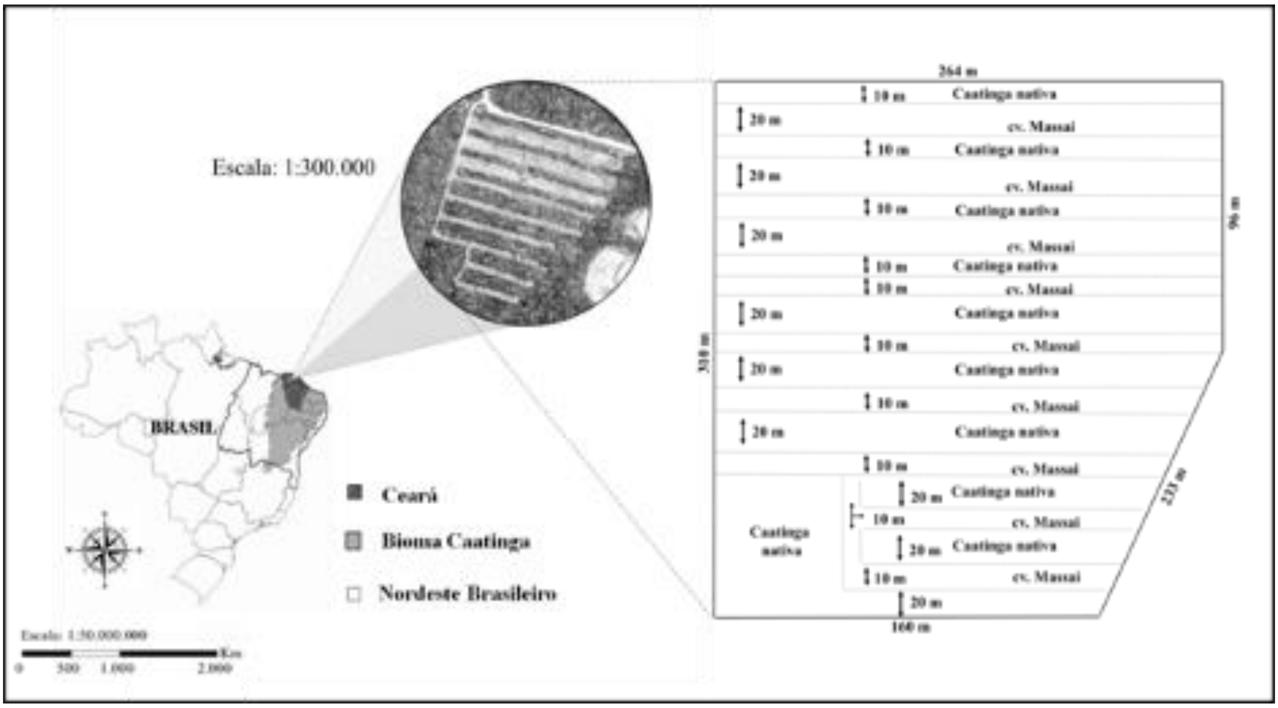

Figure 1. ILPF Caatinga scheme, Sobral-CE.

The biomass production in the system was estimated by means of a weighted average of the biomass present in the frame (1.0m x 0.5m for the thinned strips and 1.0m x 0.25m for the native Caatinga strips) and soil cover following methodology by (Araujo Filho et al., 1986). Total biomass (BT) was obtained by sample weight in the frame multiplied by the total suppressed area (2.2 ha) and the total conserved area (3.6 ha), also called native pasture.

Pasture quality was assessed by analyzes of dry matter (DM) according to AOAC (1990); Fiber in Neutral Detergent (NDF), Fiber in Acid Detergent (FDA) and Lignin (LIG), according to Van Soest et al., (1991) adapted by Senger et al., (2008); Crude Protein (PB) by the LECO® equipment (CN628, St. Josesh, MI, USA) and in vitro dry matter digestibility (IVDMD), according to the method of Tilley & Terry, (1963) adapted by Senger et al. (2008).

Animals

The use of experimental animals was approved by CEUA / Embrapa Caprinos e Ovinos (protocol n° 015/2018). Twenty one animals in three different breeds, seven of each, were used. The herd characteristics were Santa Inês age 349 ± 5.7 days, weight 37.8 ± 1.7 kg; Morada Nova age 430 ± 6.4 days, weight 23.5 ± 1.8 kg; and Somalis age 540 ± 4.9, weight 22.5 ± 1.9 kg. The animals remained in the pasture from 8:00 am to 3:00 pm and were fed exclusively from deferred pasture of massai grass, native pasture (consisting of shrubs, litter especially of dry leaves, bark, small seeds), water ad libitum and mineral supplement.

The measures were measured: BW = Body Weight (kg); BP = abdominal perimeter (cm); PT = thoracic perimeter (cm); LP = Chest Width (cm) and LG = Croup Width (cm); ECG = Subcutaneous Fat Layer Thickness (cm) and AOL = Loin Eye Area (cm²) at the 1st and 65th days of stay in the SI. For the ECG and AOL variables, a Kai Xin 5000® device was used equipped with a 4.5 MHz linear transducer following the methodology of Souza et al. (2016).

Statistical analysis

The data were submitted to a Tukey test to compare means using the InfoStat® software version 2020e at the level of 5% probability.

RESULTS AND DISCUSSIONS

Pasture characterization

The suppressed strips enriched with massai grass showed 27.8 ± 5.7% of total soil coverage and the height of the pasture showed an average of 27.1 ± 3.9 cm. The strips conserved with native vegetation showed an average coverage of 78.3 ± 10.4% due to native vegetation, leaf and litter fall.

The 20 m wide suppressed strips showed three times more forage accumulation in relation to the 10 m wide strips. In the system, massai grass showed reduced vigor in regrowth after cutting the forage making the pasture uneven and did not present a desired establishment with formation of mosaics in the pasture. In the 20 m wide strips of native pasture, the biomass accumulation was twice as high as the 10 m strips, being proportional to the proposed thinning dimension for the system.

The accumulated precipitation 115.6 (01/12/2018 to 12/12/2018) - characterized the dry-rainy transition period (TSC) - triggered the emergence of herbaceous dicots, originating from the seed bank of the system, which presented 10 % of covered area, in the latest evaluation. The productivity of the herbaceous extract, used as fodder to the animals, was three times higher in the 20 m wide ranges compared to the 10 m ranges.

The total biomass (BT) of the strata cultivated in the SI did not show significant differences, on average, the forage biomass was composed of 466.6 kg of DM for massai grass; 5735.5 kg DM for native pasture; 447.1 kg DM of the sorghum crop stubble; 210.9 kg DM of the millet cultural stubble and 129.2 kg DM of the herbaceous stratum.

The presence of natural matter in the system, cultivated and native strata, contributed to the maintenance of the soil cover and the edaphic characteristics of the pasture, desirable factors especially during the drought because it brings to the system a greater supply of organic matter and reduces the action of erosive processes.

The lowest levels of DM were observed in the TSC period, December 2018, in which there was an increase in the fibrous fraction (NDF and ADF) and CP in massai grass and native pasture. TSC increased ($P < 0.05$) the quality of forage, in which it was found a reduction in DM levels and an increase in CP levels by about 7% for massai grass and 3% for native pasture (Table 1).

The chemical composition of the herbaceous strata that flourished in the TSC was 37.8% DM; 68.6% NDF; 40.2% ADF; 5.7% LIG; 57.1% IVDMD and 6.9% CP. The increase in CP levels in TSC is due to the emergence of new leaves, a component of the plant with a higher concentration of the nutrient (Queiroz et al., 2000).

Table 1. Total Biomass and chemical composition of Massai grass and nativa pasture in the Caatinga-CLF system.

	Period	DM	NDF	ADF	LIG	IVDMD	CP
		%	%	%	%	%	%
Massai grass	Oct	59.5B	75.1B	38.1B	1.9	36.9	5.0B
	Nov	71.8A	76.4B	41.0A	1.8	35.3	5.9B
	Dec	40.7C	79.1A	40.0AB	2.2	40.8	12.3A
Native Pasture	Oct	74.1A	67.4C	51.1B	2.0	36.1A	5.1B
	Nov	76.6A	73.5B	52.5B	1.5	32.2AB	6.0B
	Dec	59.9B	82.2A	68.6A	1.9	28.9B	8.0A

Means followed by different letters in same column are significantly different, p = 0.05. DM = dry matter; NDF = neutral detergent fiber; ADF = acid detergent fiber; LIG = lignin; IVDMD = *in vitro* dry matter digestibility; CP = crude protein.

Santana et al. (2011) associated the low digestibility with the high content of lignin and tannins in the forage, also giving low degradability of the BP associated with the insoluble protein in acid detergent. When evaluating forage quality the same variation in the percentages of LIG and IVDMD of the massai grass and of the native pasture was observed.

Animals

Breeding affects all performance variables (P <0.05), reflecting differences in the animals' morphometry. The Santa Inês breed had the highest BW (35.7 kg), AOL (9.2 cm^2), PA (83.7 cm), PT (76.4 cm) and LG (20.6 cm). The LP of Santa Inês (17.1 cm) and Somalis (17.7 cm) did not present significant differences.

Somalis had the largest ECG with 1.7 cm, followed by Santa Inês (1.0 ± 0.03 cm); and Morada Nova (0.7 ± 0.13 cm). The measurements of AOL, PC, PA and PT of the Somalis and Morada Nova did not differ, presenting averages of 6.1 cm^2, 22.5 kg, 75.9 cm, 67.5 cm, respectively. The LG measurements of Somalis and Morada Nova were 17.6 cm and 16.1 cm, respectively.

The low variability of the data indicated that the animals did not show significant reductions in the biometric parameters. Body weight, ECG and AOL, showing that the integrated system provided enough nutrients to keep the animals in the maintenance phase during the dry season in the Caatinga.

CONCLUSIONS

The integration systems in the Caatinga, in addition to provide the implantation of crops associated with native vegetation, are an important source of food for small ruminants during the dry season.

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EFFECTS OF INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEM ON TIMBER, SOYBEAN, GRASS FORAGE AND CATTLE YIELDS

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ABSTRACT

A descriptive analysis of the second rotation cycle was carried out involving three production systems, one system under integrated crop-livestock (ICL) and two systems under integrated crop-livestock-forestry, ICLF14 (14x2m, 357 trees/ha) and ICLF22 (22x2m, 227 trees/ha), both with *Eucalyptus urograndis*, clone H13 trees. Grass forage used was *Brachiaria brizantha* cv. BRS Piatã through a period of three years for rearing of beef cattle followed by a soybean crop season, completing a rotation cycle of four years, in the Brazilian Cerrado. Results of this cycle are here presented, from 2013 to 2016, covering yields from, crop, forestry and, beef cattle. In the second cycle, it was observed that the influence of trees on the understory was accentuated, resulting in lower productivity from both crops and pasture, responding to density of trees, which, in contrast, increased their total timber production accordingly. Reductions in cattle yields were more pronounced during the dry season. At the end of this second cycle, thinning was carried out to remove 50% and 75% of the trees in ICLF22 and ICLF14, respectively, in order to increase light incidence and improve biomass production in the understory in the starting third rotation cycle.

Key words: animal production; forage production and quality; shading

INTRODUCTION

With the growing economic globalization and the consequent international markets opening, along with new demands over production processes, linked to sustainability, agriculture has been under pressure to reach levels of efficiency and competitiveness never seen before. Integrated systems have been developed in Brazil since the 1970s and have been adopted with greater intensity since 2010, due to the support from National Low Carbon Agriculture Plan (Plano ABC).

These production systems are a valuable option for sustainable intensification. They improve land use efficiency and farm profitability while reducing environmental impacts, especially related carbon sequestration and mitigating effects of greenhouse gases emissions. In research conducted in several regions of Brazil, integrated crop-livestock-forestry (ICLF) systems have shown excellent results (ALMEIDA et al., 2013). The impact of natural shade on cattle itself is favorable, as it improves thermal comfort and well-being in general. This leads to improvements on reproductive and productive performance (OLIVEIRA et al., 2014), however, for grass forage, shade can be either positive, with improvements in nutritional value, or negative, in case of shading at levels greater than 50%, which cause physiological, morphogenic and structural changes on plants that lead to decreased forage production (PACCIULLO et al., 2019).

In order to investigate details and develop strategies to recover degraded pastures and to adjust species, cultivars, tree densities, animal stocking rates and cultivation techniques in areas of the

Brazilian Cerrado under ICLF systems, a long-term experiment was implemented in 2008 in an area of 18 hectares, combining one year soybean cultivation followed by three years of grazing *Brachiaria brizantha* with *Eucaliptus urograndis* trees (227 and 357 trees/ha) for beef cattle production, in four-year rotation cycles. Below are shown results of the second rotation cycle, from 2013 to 2016.

MATERIAL AND METHODS

The experiment was conducted at the technological reference unit (URT) of Embrapa Beef Cattle, in Campo Grande, MS, Brazil (20°24′54.9″ S, 54°42′25.8″ W, altitude 530 m), in the biome Cerrado, belonging, according to the Köppen-Geiger climate classification, to the transition strip between Cfa and Aw tropical humid (KOTTEK et al., 2006). It has average annual precipitation of 1,560 mm and has hot and rainy summer with rather moderate cold but dry winter.

The experimental area consists of 3 treatments with 4 repetitions, having as forage component *Brachiaria brizantha* cv. BRS Piatã, a system under integrated crop-livestock (ICL, used as witness) and two systems under integrated crop-livestock-forestry, ICLF14 (14 x 2m with 357 trees/ha) and ICLF22 (22 x 2m with 227 trees/ha), both composed of *Eucalyptus urograndis*, clone H13.

Figure 1 illustrates how the experimental area was managed throughout the two rotation cycles. The farming practices adopted in the experimental area and the results of forage, crop and animal yields, from the first rotation cycle (2008 to 2012), are described in Pereira et al. (2014).

Year/ month		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	2008	Degraded pasture					1	1	1	1	1	2	2
1st cycle	2009	2-3	2-3	2-3	4-5	4-5	4-5	4-5	5	5	5	6	5
	2010	5	5	5-7	5-7	8	8	8	8	8	8	8	8
	2011	8	8	8	8	8	8	7-8	7-8	8	8	8	8
	2012	8	8	8	8	8	8	7-8	7-8	8	8	2	2
2nd cycle	2013	2	2	2	5	5	5	5	8	8	8	8	8
	2014	8	8	8	8	8	8	8	8	8	8	8	8
	2015	8	8	8	8	8	8	9	9	9	9	8	8
	2016	8	8	8	8	8	8	8	9	9	9	8	8
	2017	8	8	8	8	8	9-10	9-10	9-10	9-10	9-10	2	2

Figure 1. Cultivation scheme at the integrated crop-livestock-forestry system experiment at Embrapa Beef Cattle in Campo Grande-MS, Brazil: (1) Clearing, tillage, liming and fertilizer application; (2) Soybean cultivation; (3) Planting and care of Eucalyptus over soybean; (4) Sorghum cultivation over Brachiaria; (5) Brachiaria establishment for grazing; (6) Haying of Brachiaria; (7) Pruning of Eucalyptus; (8) Grazing with cattle; (9) Deferred pasture; (10) First Eucalyptus cut. Adapted from Pereira et al. (2014).

The second rotation cycle (2013 to 2016) started with the planting of soybeans in the 2012/2013 season. After soy harvest (March 2013), Piatã grass was sown and further managed under continuous grazing using variable stocking rate (put and take method), keeping sward height at least 20 cm, for the three years grazing. Nellore heifers were used, in the rearing phase. These were annually replaced by animals of the same category. Animals were weighed at intervals of approximately 30 days, when forage sampling was also carried out. The trees on the ICLF systems were measured twice annually, in the months of February/March and July/August. Annual maintenance fertilizer application was carried out, with 50 to 75 kg/ha of nitrogen, in the form of urea, and 200 to 300 kg/ha of the formula 0-20-20 (NPK), in January (rainy season).

Evaluations and analysis of the productive components were carried out from November 2013 to July 2016, following the methodology adopted in the first rotation cycle (PEREIRA et al., 2014).

RESULTS AND DISCUSSIONS

In the second evaluation cycle, the average heights of eucalyptus trees in 2013 and 2016 were 24.43 and 28.98 m in ICLF14 and 22.24 and 28.25 m in ICLF22, respectively. Shading observed in ICLF14 was 41% in February 2013 and 76% in August 2016 and, in ICLF22, it went from 40% to 61%, respectively (SANTOS, 2018). As for the average annual timber increment, the system with the highest tree density, ICLF14, showed higher productivity than the ICLF22, with averages of 24.04 and 13.78 m^3/ha in 2013, and 39.93 and 17.19 m^3/ha in 2016.

In the 2012/2013 soybean season, the ICLF14 and ICLF22 systems did not differ from each other and presented an average productivity of 2,154 kg/ha, which represented 74% of the ICL productivity (2,915 kg/ha) (QUINTINO et al., 2013).

As for the forage component, the average height of the Piatã grass in the rainy season (October to April) was 62.33, 65.67 and 64.67 cm and, in the dry season (May to September), 43.70, 47.00 and 52.00 cm, for the ICLF14, ICLF22 and ICL systems, respectively. Emphasizing that, in the drought, height of pasture sward above the expected is due to the fact that entry of the animals in the systems started exactly at that time of the year (Table 1).

Table 1. Average productive traits of three integrated systems (ICL, ICLF22 and ICLF14) during two seasons of the year, from 2013 to 2016: pasture sward height, forage dry mass, forage crude protein content (CP), stocking rate (SR), average daily gain (ADG), live weight gain by area (LWG) and soybean yield (2012/2013 harvest).

System	Sward height (cm)	Forage (kg/ha)	CP (%)	SR (AU/ha)	ADG (kg/day)	LWG (kg/ha)	Soybean (kg/ha)
Rainy season (October to April)							
ICL	64.67	2,718	10.43	2.23	0.505	303	2,915
ICLF$_{22}$	65.67	1,897	12.73	1.89	0.437	234	2,270
ICLF$_{14}$	62.33	1,209	13.47	1.47	0.437	148	2,038
Dry season (May to September)							
ICL	52.00	2,268	6.65	1.89	0.243	99	X
ICLF$_{22}$	47.00	1,283	8.83	1.28	0.211	40	X
ICLF$_{14}$	43.70	633	9.00	0.79	0.180	18	X

The averages of forage mass (kg/ha) and stocking rate (SR: animal unit/ha or AU/ha) in systems with trees were lower than on the system under full sun, mainly in the ICLF14 system, with a higher tree density. Average forage mass and the respective SR in the ICLF14 system was 1,209 kg/ha and 1.47 AU/ha, in the rainy season, and 633 kg/ha and 0.79 AU/ha, in the dry season; for ICLF22 it was respectively 1,897 kg/ha and 1.89 AU/ha, and 1,283 kg/ha and 1.28 AU/ha, and for ICL it was 2,718 kg/ha and 2.23 AU/ha and 2,268 kg/ha and 1.89 AU/ha (Table 1).

Higher content of crude protein (CP, %) and *in vitro* organic matter digestibility (IVOMD, %) were found in the green forage mass of systems with trees: ICLF14 with 13.47% CP and 58.1% IVOMD (rainy season) and 9.0% CP and 49.53% IVOMD (dry season), ICLF22 with 12.73% CP and 57.4% IVOMD (rainy season) and 8.83% CP and 50.0% IVOMD (dry season). The system under full sun (ICL) presented CP and IVOMD contents of 10.43% and 50.4% in the rainy season and 6.65% and 47.13% in the dry season (Table 1).

The average daily live weight gain (ADG) for the three-year grazing period in the rainy season did not vary between the ICLF systems (average 0.437 kg/day) but it was greater for the ICL system (0.550 kg/day). In the dry period, the ICLF14 system had the lowest ADG (0.180 kg/day), whereas the ICLF22 system had an intermediate result (0.211 kg/day) and the ICL had the highest ADG (0.243 kg/day). The average annual animal live weight gain per area, in the second cycle (2013 to 2016), was 402 kg/ha under ICL, 274 kg/ha under ICLF22 and 166 kg/ha under ICLF14 (Table 1).

Soybeans yield in the ICL system was slightly higher than the average for the 2012/2013 harvest in the state of Mato Grosso do Sul, that was 2,880 kg/ha (CONAB, 2013) where the experimental area is installed. The ICLF systems have harvested 75 % of this value, even with a tree density ranging from 257 to 357 trees/ha.

During the second cycle, there was a greater intensity of shading in the understory of the systems with trees (GAMARRA et al., 2017). As reported by Barros et al. (2020), in the same experimental area, this implies that the lower availability of radiation in the understory reduced the productive potential of the forage, making necessary to remove the animals from July to October in two consecutive years of grazing (2015 and 2016). This period is characterized by a lower availability of forage (PEREIRA et al., 2021). Details on dynamics of soil moisture are discussed in Glatzle et al. (2021).

Higher levels of crude protein and IVOMD were found in the forage mass in the shaded systems, contributing to the ADG of the animals being similar in the systems over the years, except for the dry period of the third year, when the ICLF systems were with intense shading, presenting ADG smaller than the system in full sun (SANTOS, 2018). There was no difference for the rainy season of the last year of the second rotation cycle in regards to animal ADG.

When observing the animal production by area in the second rotation cycle, we see that the ICLF14 and ICLF22 systems produced 41% and 68% of what was produced in the ICL, respectively. However, this reduction was more accentuated in the dry period, with relative yields of 18% and 40% for ICLF14 and ICLF22 in relation to ICL, while in the rainy season they were 49% and 77%, respectively, as demonstrated by Pereira et al. (2021) and Glatzle et al. (2021). Always relating to the ICL system, when comparing animal production by area between the first (2009 to 2012) and the second cycle (2013 to 2016), we see a decrease from 89% to 61% in ICLF22 and from 85% to 31% in ICLF14, due to the increased shading imposed by tree growth (ALMEIDA et al., 2019). Between systems with trees, ICLF22 proved to be promising for animal production. Despite shading interfering in forage production, there is a compensation through better nutritional quality in terms of crude protein content and IVOMD, thus favoring animal performance, since reduction in animal gain weight was only observed in the last years of the second cycle, when the shading of the pasture was more intense.

Recommendations from literature indicate that the tree component must undergo thinning in order not to damage forage productivity, being the ideal time to perform thinning when the understory has about 50% shading (PORFÍRIO-DA-SILVA et al., 2009). Results here obtained suggest that thinning at the right time can determine significant gains in animal productivity in the system. Although shading intensity was above 50% in the sixth year of implementation of the system, thinning occurred only in the eighth year (non-expected in the original project). But it was carried out just before the new crop cycle began, resulting in higher light incidence on soybeans and harvesting older timber, with higher added value. Thus, in the period from June to October 2017, selective thinning was carried out. There as a removal of 75% of trees in the ICLF14 system and 50% in the ICLF22. Spatial arrangements were adjusted to 28 x 4m and 22 x 4m, with 89 and 113 trees/ha, respectively, initiating the third rotation cycle, with the purpose of increasing light incidence in the understory to obtain greater forage and animal yields in these systems, in addition to providing revenue with the diversification of products.

In an investment analysis carried out by Pereira et al. (2017), it was observed that all systems in the present study were viable under several scenarios evaluated, but always having the ICL as more profitable than the ICLFs. However, in scenarios with greater timber value and possibility of environmental services and certification rewards, such as Carbon Neutral Brazilian Beef®, livestock systems with the forestry component tend to be more valued (PEREIRA et al., 2019).

CONCLUSIONS

Although ICLF systems offer forage with better nutritional value, it is clear from the results of the second rotation cycle that under intense light restriction (shading above 50%) forage growth is negatively affected, decreasing animal production animal per unit of area. Thus, the challenge remains on testing new spatial tree arrangements, forage cultivars more tolerant to shading and management practices involving all components, put together in long-term studies for different biomes, in order to support decision making towards adoption of ICLF systems.

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DIVERSITY OF EPIEDAPHIC FAUNA IN LONG-TERM INTEGRATED CROP-LIVESTOCK SYSTEMS IN THE CERRADO REGION

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ABSTRACT

The epi-edaphic macrofauna are important for soil functioning and their populations are sensitive to soil management. In this study, the effect of integrated and continuous cropping systems on the edaphic macrofauna was evaluated in a long-term experiment at Embrapa Cerrados in Planaltina-DF, Brazil. Sampling took place in the wet and dry seasons of 2019, using pitfall traps in nine treatments with two replicates, including crop-livestock integration with or without cover crops and with minimum cultivation or no-tillage; continuous pasture of pure grass or intercropped with legumes; continuous tillage with and without cover crops; and a fragment of native Cerrado vegetation. A strong seasonality was observed, with 56 indicator macrofauna morphospecies in the rainy season and 38 in the dry season. Integrated systems in the cropping phase had greater dominance of some groups of fauna, such as ants, beetles and moth catterpillars, leading to lower Shannon diversity values. No-tillage, integrated systems with cover-crops and the native Cerrado had the highest morpho-species richness, showing potential as repositories of local epi-edaphic macroinvertebrate biodiversity.

Key words: Soil invertebrates; Macrofauna; Agropastoral systems

INTRODUCTION

Agricultural and animal production are important global environmental forces, affecting climate change, soil degradation, loss of biodiversity and water pollution (GERBER et al., 2013). Considering current restrictions for the expansion of agricultural frontiers, agricultural systems must be intensified and increased (SAATH; FACHINELLO, 2018) in an environmentally friendly manner, in order to reduce degradation and loss of productive capacity. Fortunately, many farmers have been replacing conventional systems with integrated agricultural production systems in Brazil (EMBRAPA, 2018), taking advantage of synergies between various components of the agroecosystem, instead of relying on higher input levels (PETERSON et al., 2019).

Integrated agricultural systems can be divided into four categories: agropastoral or integrated crop-livestock systems (ICL); silvopastoral or integrated livestock-forestry systems (ILF); silviagricultural or integrated crop-forestry systems (ICF); and agrosilvopastoral or integrated crop-livestock-forestry systems (ICLF) (BALBINO et al., 2011).

The use of pastures in rotation with cropping systems is an important option for soil improvement, with a change in plant species and root systems in the soil, as because the pasture grasses increase soil protection, carbon contents, and aeration, water infiltration capacity (BALBINO et al., 2011) and soil fauna populations (MARCHÃO et al., 2009). Hence, there is increasing interest in the adoption of agropastoral practices in no-tillage systems (NT), due to the benefits of forage straw on soil quality (MENDONÇA et al., 2013; GARCIA et al., 2014). However, in the Cerrado region, the occurrence of a prolonged dry season may be an important limiting factor to be considered (MOTA et al., 2020).

Soil and litter can offer different niches for edaphic fauna, with different microclimate conditions and space-time resources, consequently stimulating the development of a diverse community of fauna and microorganisms (CORREIA, 2002). Soil fauna are sensitive to changes in soil and climatic factors, especially those that determine the availability of food resources, changing these communities (LAVELLE et al., 1994). Their communities are also frequently related to various soil chemical (e.g., pH, organic matter, Ca, Mg, N and P contents) and physical (e.g., bulk density, porosity, aggregation) soil properties, so these animals can and are frequently used as bioindicators of disturbance and of soil quality (PAOLETTI, 1999).

Therefore, the present study aimed to evaluate the effect of integrated and non-integrated production systems on the epi-edaphic macrofauna populations, in a long-term trial in the Brazilian Cerrado.

MATERIAL AND METHODS

The study area is an experiment established in 1991 in Embrapa Cerrados, in Planaltina-DF, (15º36’S and 47º42’W), in the Central Plateau of Brazil, at 1100 m altitude. The climate of the region according to Köppen is tropical rainy (Aw) with a defined dry season in the Fall and Winter (May-September) and a rainy season in Spring and Summer (October-April). Sampling was conducted in February (0 mm rainfall) and August (149 mm rainfall) of 2019. The soil of the area was characterized as an OXISOL (Santos et al., 2018) with a clay texture (572 g kg^{-1}). The experiment had two replicates (random block design) and nine treatments as briefly described in Table 1.

Table 1. Description of the treatments evaluated at the long-term experiment in Planaltina-DF.

Treatment	Initials	Land use systems evaluated	Variations
Crop-livestock integration (ICL)	CL-L1 CL-L2	Crop rotation/intercropped pasture; pasture phase	1 = Minimum cultivation (sowing in stover/spontaneous vegetation) 2 = No-tillage (predominance of forage as cover crops)
	CL-C1 CL-C2	Pasture/crop rotation; crop phase	1 = Minimum cultivation (sowing in stover/spontaneous vegetation) 2 = No-tillage (predominance of forage as cover crops)
Annual continuous crop	MC	Continuous minimum tillage	MC = Minimum cultivation (sowing in stover/spontaneous vegetation) NT = No-tillage (predominance of forage as cover crops)
	NT	No tillage	
Pasture	P1	Continuous pasture	1 = Pure grass
	P2		2 = Intercropped with legumes
Cerrado	CE	Cerrado sensu stricto (Control)	

The epiedaphic macrofauna were sampled using pitfall traps with 400 mL of 70% alcohol and two drops of neutral detergent in a plastic cup (10 cm height x 9 cm diameter) placed in holes in the soil. A plastic plate was placed over the cup to protect from rainfall (AQUINO et al., 2006). The traps were arranged in two parallel transects 60 m long, separated 5 m from each other and at least 20 m from the plot border. A total of 144 traps were installed, with 8 traps per block per treatment and season. Duplicate traps from each transect point were combined to create a single sample, resulting in four samples per plot and eight samples per treatment per sampling date. Traps remained in the field for 72 hours, and, after removal, were taken to the laboratory, where the material was washed in running water to remove impurities using a 0.35 mm sieve, and placed in preservative solution (80% ethanol).

All individuals were counted under a binocular stereoscopic microscope and separated at the level of Order and Family and then at the morphospecies level within each main taxon, based on the external morphological features using appropriate identification keys (RAFAEL et al., 2012; BACCARO et al., 2015). All morphospecies were photographed and the frequency data were submitted to PAST (statistical software) where the richness and other ecological indices (Shannon, Simpson, Pielou) were calculated (HAMMER et al., 2001). Means were tested for significant differences between treatments with a Tukey test ($p < 0.05$) in R (R CORE TEAM, 2019).

RESULTS AND DISCUSSIONS

The total number of invertebrates captured with the fall traps was 14,392 individuals (ind.) in a total of 22 different taxa, with 9,140 being collected in the rainy season (February) and 5,252 ind. in the dry season (August) (Table 2). In the rainy season, the greatest number of individuals was found in the ICL system CL-C1 in the crop phase (1,344 ind.), followed by annual crop in NT (1,276 ind.) and the native Cerrado (1,233 ind.). The lowest abundance was in the annual crop under MC (742 ind.) and in the ICL system CL-L1 in the pasture phase (737 ind.). In the dry season, highest abundance was found in ICL in the CL-C2 in the crop phase (1,319 ind.), followed by the crop area under no-tillage with NT cover plants (889 ind.). The lowest abundances were in the Cerrado, in the continuous pasture P2 and the area of ICL in the pasture phase CL-L2, with 311, 282 and 245 ind., respectively.

In total, 368 morpho-species (morphosp.) of epiedaphic fauna were found in all the traps. In the rainy season richness ranged from 58 morphosp. in the ICL system CL-C1 up to more than 90 in the Cerrado (95 morphosp.) and the NT system with cover crops (93 morphosp.). In the dry season richness decreased considerably, being highest in ICL system CL-C2 and in the annual NT crop, with 54 and 52 morphosp., respectively. The systems with the lowest richness were the ICL systems in the pasture phase (CL-L1 and CL-L2), with 31 and 29 morphosp., respectively. Regardless of season, the taxa with the greatest abundance and highest morphosp. richness were Formicidae (ants), Araneae (spiders) and Coleoptera (beetles).

In the rainy season, the annual crop under NT had the highest diversity (Shannon) with significantly higher value than the annual crop under MC, and in the ICL systems CL-C2 and CL-C1. In the dry season, the integrated system CL-C2 in the crop phase had the lowest Shannon diversity, being lower than in all systems except CL-L2, MC and P2. Diversity measured using the other indices (Simpson, Pielou dominance and equitability) in the rainy season, was significantly lower in the ICL system CL-C1 in the crop phase than all the other systems, while in the dry season, it the ICL system CL-C2 in the crop phase that had the lowest diversity.

Climate seasonality, typical of the Cerrado region, is an important determinant of the activity of soil fauna that are affected by the higher soil temperature and lower humidity (Lima et al., 2020). In the present experiment, macroinvertebrate abundance in the traps was 1.7 times greater in the rainy than the dry season. Coleoptera larva were observed only in the rainy season, probably because their larval stage occurs only in the period with adequate soil moisture (Assis Júnior, 2000). Macrofauna diversity was also affected by climate, with higher average richness and Shannon index in all systems in the rainy than dry season.

The NT cropping system with cover plants proved to be an important niche for the maintenance of a larger and more diverse community of epiedaphic macrofauna in both seasons. The lack of soil preparation and presence of straw protects the soil and provides food and shelter for these invertebrates. The ICL systems in the crop phase (such as CL-C1 and CL-C2), had lower diversity indices than the pasture systems (P1 and P2) and similar to the annual crops in MC, despite the relatively high morphospecies richness in the CL-C2 system in both seasons. This lower diversity is probably due to higher dominance of some morphospecies (Martins et al., 2018; Rousseau et al., 2014).

Tabela 2. Total number of individuals and morphospecies, and various diversity indices in areas with ICL systems (CL-C1, CL-C2, CL-L1, CL-L2), native Cerrado vegetation (CE), annual crops (MC, NT), and pastures (P1, P2) in February and August of 2019.

Treatment	Nº total ind.	Nº total morphosp.	Shannon	Simpson	Dominance	Equitability
			Rainy season - February 2019			
Cerrado	1,233	95	2.48 ABC	0.85 A	0.15 B	0.74 A
ICL						
CL-C1	1,344	58	1.24 D	0.50 B	0.50 A	0.46 B
CL-C2	1.133	80	1.94 C	0.73 A	0.27 B	0.63 AB
CL-L1	737	72	2.11 ABC	0.78 A	0.22 B	0.71 A
CL-L2	1,055	70	2.09 ABC	0.77 A	0.23 B	0.67 A
Tillage						
MC	742	69	1.99 BC	0.75 A	0.25 B	0.68 A
NT	1,276	93	2.53 A	0.85 A	0.15 B	0.74 A
Pasture						
P1	828	89	2.09 ABC	0.77 A	0.23 B	0.69 A
P2	792	82	2.31 AB	0.82 A	0.18 B	0.75 A
			Dry season - August 2019			
Cerrado	311	41	1.84 A	0.76 A	0.24 B	0.78 A
ICL						
CL-C1	706	45	1.93 A	0.76 A	0.24 B	0.72 A
CL-C2	1,319	54	1.06 B	0.39 B	0.61 A	0.39 B
CL-L1	560	31	1.75 A	0.75 A	0.25 B	0.74 A
CL-L2	245	29	1.52 AB	0.67 A	0.33 B	0.76 A
Tillage						
CM	617	37	1.51 AB	0.63 A	0.37 B	0.66 A
NT	889	52	1.74 A	0.67 A	0.33 B	0.63 A
Pasture						
P1	323	35	1.65 A	0.80 A	0.30 B	0.73 A
P2	282	34	1.53 AB	0.65 A	0.35 B	0.71 A
Total	14,392	368	2.26	0.77	0.23	0.66

* capital letters mean significant differences between treatments in the same sampling period (Tukey p <0.05).

CONCLUSIONS

Abundance and diversity of epiedaphic macrofauna are strongly influenced by season, decreasing dramatically in the dry season. In the integrated systems in the cropping phase, greater dominance of some groups of fauna such as ants, spiders and moth caterpillars lead to lower diversity (Shannon). The no-tillage system, the integrated system in the crop phase with cover crops, and the native Cerrado vegetation maintain the greatest richness of epiedaphic macrofauna, highlighting their potential as local macroinvertebrate biodiversity repositories.

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FARM LEVEL SUSTAINABILITY ASSESSMENT: CHOOSING SUITABLE TOOLS FOR LOCAL CHARACTERISTICS

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ABSTRACT

The state of Mato Grosso do Sul, in Central Brazil, is one of the main players on Brazilian agribusiness. This is clear from the value of its agricultural production, which has shown steadily growing figures in the last decade. Linked to this, there is the importance of economic growth associated with measuring parameters and monitoring sustainability in agriculture. As the use of systems that evaluate farm sustainability is already a reality, this research assessed characteristics of agribusiness in Mato Grosso do Sul using indicators present in different sustainability assessment systems to find out which of these systems could have more applicability in local agribusiness. From the systems used in this research: IDEA, APOIA-NovoRural, MESMIS, FESLM and SAFA, only the last three demonstrated to have indicators capable of measuring, in full, agribusiness characteristics of the MS selected for this study.

Key words: Sustainability Indicators; Agribusiness Management; Sustainability Assessments

INTRODUCTION

The State of Mato Grosso do Sul (MS) has an important participation in Brazilian agribusiness from the perspective of rural development. As for December 2018, it was as the fourth state with the largest cattle herd in the country, corresponding to 9.8% of national production. It also reached the fourth place in 2018 in maiz production (10.1%) and fifth in soybeans, which is equivalent to 8.2% of all national production (IBGE, 2018). With a Gross Domestic Product (GDP) of R$ 83.1 billion, MS increased from 1.2% to 1.4% the participation of the State in the national GDP in 2017. With an Agricultural Production Value of BRL 28.519 billion, it surpassed the national average in exports from agribusiness, presenting a growth of 13% in 2017 in relation to 2016, with US$ 96.01 billion traded (GOVERNO..., 2018).

The state has 71,164 agricultural establishments, which cover an area of 30.5 million ha. The distribution of land use in the State is proportionally divided into 60% with pastures, 12% crops, 24% reserved for forests and other natural vegetation and 4% for other purposes (IBGE, 2017). More specifically, according to the 2017 Agro Census, in regards to pastures, in the state, 71% are man sown and are in good condition, while 2% are sown and are in poor condition, while 27% are natural pastures. Regarding crop farming, 99% of the area has temporary and annual crops while 1% has permanent crops.

Regarding crop farming, it is important to remark not only for the quantity produced, but also agricultural practices these crops and the benefits they offer to the environment. Among the main crops and their characteristics, soybeans stands out, with a harvested area of 2.8 million hectares, a total harvest of 8.6 million metric tons and a production value of up to BRL 9,5 billion. Next is maize farming, with a harvested area close to 2 million hectares, a production of almost 10 million metric tons and a production value of BRL 4.3 billion. Added to Sugarcane and Cassava, the production value of these crops exceeds BRL 18.1 billion (PESQUISA AGRÍCOLA MUNICIPAL, 2019).

This result is also possible thanks to a reality in the state, which is the low-carbon agriculture, favored by technologies used for production and innovation into the systems that benefit the environment, such as no-till, crop consortium and integrated crop-livestock-forestry systems. In Central Brazil, 61% of the farmed area produces two crops per year, between interseasonal maize and interseasonal cotton combined with soybeans and others (AGROEMDIA, 2020). Therefore, the use of these means of production results in gains for the environment and for farmers, after all, soybean production in MS, in the period from 1998 to 2018, grew 320%, a result attributed in large part by the use of no-till seeding that revolutionized the form of land cultivation in the State (FAMASUL, 2018). The 2017 Agro Census reported that in MS, only 17% of farms obtained some type of credit, the objective of which was mainly for cash-flow (49%) and investments on farm (42%).

Considering the importance of monitoring to improve sustainability of local production systems as well as seeking to verify and eventually quantify differences between traditional systems and integrated systems, objective of this work was to analyze different systems or tools designed for sustainability assessments applicable to farms, including integrated farms, in order to investigate which tools, through their indicators, could be more applicable to farm level sustainability assessments in the State of Mato Grosso do Sul.

MATERIAL AND METHODS

A comparative method was used, which consists of investigating and explaining facts according to their similarities and differences. In this method, two or more approaches of a similar nature are confronted in order to know what is common for both. “Comparing similarities and divergences, the importance between groups can be better explained” (FACHIN, 2011, p.41).

The procedures for this research consisted of investigating and highlighting the indicators used in five sustainability assessment systems applicable to farm level, based on the characteristics peculiar to farms in the State of Mato Grosso do Sul. The chosen assessment systems were selected through a comprehensive search for the most cited in the scientific publication bases, for instance: Web of Sciences, Science Direct, Scielo, Scopus, Redalyc, DOAJ and CAPES, using keywords related to the theme, such as: environmental and agricultural sustainability indicators, farm and environment sustainability assessment, programs, software, methods, systems or assessment tools agricultural sustainability. Thus, the systems considered for this work followed a decreasing order of number of citations:

- Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad (Masera, Astier, Lopez-Ridaura, 2000);
- Sustainability Assessment of Food and Agriculture systems (FAO, 2014);
- Indicateurs de Durabilité des Exploitations Agricoles (VILAIN, 1999);
- Sistema APOIA – NovoRural (Rodrigues e Campanhola, 2003);
- Framework for the Evaluation of Sustainable Land Management (Dumanski e Smyth, 1995);

In other words, the idea was to ascertain which one or which ones of these systems would have indicators would be more suitable to assess sustainability and propose a comparative sustainability score for agricultural systems withing the context of Mato Grosso do Sul agribusiness. As these characteristics can be measured qualitatively or quantitatively and they reflect the condition of sustainability of a farm on itself and affecting its surroundings, the chosen characteristics were summarized in descriptors because, in this way, according to Pompei (2010), the descriptor is able to provide more reliability to the search carried out.

Therefore, the method chosen was to assign at least two of these descriptors to each dimension of sustainability. As the dimensions are: environmental, economic and social, it resulted in a total of six descriptors and after this assignment, a check was made against the list of indicators of the five systems selected for this research. In an objective way, similar to a mathematical set, the study had to describe whether or not the analyzed sustainability assessment system contains any indicator capable of measuring the characteristic determined within the dimensions of sustainability already mentioned according to the respective descriptors.

And in this way, to explore the possibility of stating that at least one of the systems selected in this research is suitable to be applied for assessing sustainability in typical farms of Mato Grosso do Sul.

RESULTS AND DISCUSSIONS

Assessment systems that best match the reality of agribusiness in Mato Grosso do Sul: Descriptors x Indicators

The descriptors used as reference for checking against indicators of each system are shown in Table 1, together with the sustainability dimension related to them and a code to optimize demonstration of the information in the results table (Table 2).

Table 1. Descriptors used analyze the five systems selected in this research.

Dimension	Descriptor (Indicator)	Code
Environmental	Crop rotation	A1
Environmental	Control over pesticides usage	A2
Economic	Financial planning and crisis management	E1
Economic	Maintenance of production quantity and quality	E2
Social	Social responsibility	S1
Social	Good management practices	S2

Table 2 below shows the results found from the search made in each of the five evaluated systems based on the descriptors listed in Table 1. Table 2 is subdivided with the specific dimension of sustainability: environmental, economic and social, together with the code to distinguish each descriptor. In addition to each system separated by column, whose cells are filled with the result of the search carried out in the list of indicators of each system regarding the presence or not of any indicator that represented that respective descriptor.

Table 2. Suitability of the evaluation systems evaluated with farms in Mato Grosso do Sul.

Dimension		MESMIS	SAFA	IDEA	APOIA	FESLM
Environmental	A1	Stability	Production diversity	Diversity of cultures	Productive Diversity	Production diversity
	A2	Reliability	Dangerous pesticides	Pesticide pollutant pressure	Potential impact of pesticides	Chemicals and Fertilizers
Economic	E1	Self-reliance	Risk management	Financial autonomy	Diversity of income sources	Debt planning
	E2	Productivity	Guaranteed production levels	Does not contain	Does not contain	Soil Productivity and Animal Health
Social	S1	Equity	Public health	Social involvement	Does not contain	Working with socio-cultural grains
	S2	Self-management	Effective Participation	Does not contain	Responsible profile	Farm management skills

CONCLUSIONS

As demonstrated, the tools or assessment systems IDEIA and APOIA do not have indicators that cover all the descriptors that represent the reality of the State. In this case, IDEIA does not have indicators related to the descriptors: maintenance of quality and quantity of production and good management practices. While the APOIA-NovoRural tool did not present any indicator that dealt with the levels of quality and quantity in terms of soil productivity. Nor did it present an indicator that addressed social responsibility over farm surroundings.

The tool MESMIS has no predefined indicators. What it brings in its methodology are attributes, and those were used in our verification. In this way, it was possible to adapt them in order to meet all dimensions of sustainability, confirming the flexible and adaptable format of this tool according to each local analyzed, thus being able to be used to assess farms in Mato Grosso do Sul.

Finally, the most complete, promising and possible to recommend tools in terms of presenting pre-established indicators in their structure, which, in turn, meet all the characteristics had as mandatory to study farm sustainability in Mato Grosso do Sul were FESLM and SAFA.

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HOW TO EVALUATE SUITABILITY OF GLOBAL TOOLS FOR FARM LEVEL SUSTAINABILITY ASSESSMENT?

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ABSTRACT

The importance of promoting sustainable agriculture is vital, as well as the means that enable measurement and evaluation of this sustainability. For this study, five systems also called tools, were selected for being capable of estimating environmental sustainability at farm level, namely: MESMIS, SAFA, IDEA, APOIA-NovoRural and FESLM, culminating in the understanding that reasonable comparison of suitability of these systems happens when the criteria are previously established and discussed. In this case, the following criteria were adopted for evaluating the above-mentioned tools: concept of sustainability, objective, target audience, flexibility, adaptability and systemic approach. It could be noticed that these systems keep their focus on the individual farmer when it comes to target audience, however, the biggest divergences among them were in regards to the other defined criteria, actually because each of them shapes their concept of sustainability towards what they propose to analyze and disseminate. Another point to be highlighted is the flexibility of each system, as there are systems that can be shaped according to the each investigated environment. However, this trend is sometimes easier when it comes to extrapolating and comparing data, but it also makes it difficult to compare different contexts when placing these data in a series.

Key words: Rural Development; Sustainability Indicators; Agribusiness Management

INTRODUCTION

Labelling a farm as “sustainable” or “unsustainable” is a complex and high responsibility deed, as it involves considering various characteristics related to the environment and the context in which the farm is inserted. In this sense, the role of systems or tools that propose to diagnose and evaluate production systems is reinforced, taking into account sustainable development. In this way, with the use of these systems, it may be possible to monitor the progress of the implementation of sustainable actions in rural areas.

As there is a good perception of the importance of such analyzes, tools or systems grouping sustainability indicators have been developed to this end in several countries, serving as instruments to control social and environmental impacts, to communicate information, and to encourage behavior and cultural changes. Due to its importance for supporting decision making, the use of tools containing sustainability indicators has been considered a very important aspect in the promotion of a sustainable society and agriculture. However, sustainable development indicators are numerous and cover different levels and scales. Thus, identifying and comparing appropriate sustainability assessment systems or tools, based on scope, focus and operability, pointing out similarities and differences between them, becomes a currently important contribution to the sustainability analyzes of Brazilian agribusiness.

Therefore, purpose of this research was to select sustainability analysis systems applied in empirical studies on agribusiness at national and international level in the period from 2010 to 2019 and published in scientific or technical literature. And from this selection, to carry out a comparative assessment based on pre-established criteria to highlight the similarities and divergences between these systems or tools.

MATERIAL AND METHODS

A comparative method was used, which consists of investigating and explaining facts according to their similarities and differences. In this method, two or more approaches of a similar nature are confronted in order to know what is common for both. “Comparing similarities and divergences, the importance between groups can be better explained” (FACHIN, 2011).

The initial research explored scientific databases such as: Web of Sciences, Science Direct, Scielo, Scopus, Redalyc, DOAJ and CAPES, using the keywords: environmental and agricultural sustainability indicators, farm and environment sustainability assessment, programs, software, methods, systems or tools for farm sustainability assessment and with this, 17 systems composed of indicators capable of assessing agricultural sustainability were identified. All of them had technical-scientific support, were created, sponsored or used by institutions with a solid reputation in the context of sustainability assessments, and these systems are capable of assessing environmental impacts and qualifying agricultural properties within some degree or sustainability score.

The criterion adopted to select some of these systems for a more detailed analysis was was to pick the most cited and mentioned in scientific articles in the period from 2010 to 2019. Thus, the selected systems are described in Table 1.

Table 1. Description of the five most cited or mentioned sustainability assessment systems selected as potentially suitable for farm level assessments.

System	Initials	Country	Total Citations
Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad (Masera, Astier, Lopez-Ridaura, 2000)	MESMIS	Mexico	329
Sustainability Assessment of Food and Agriculture systems (FAO, 2014)	SAFA	United Nations	39
Indicateurs de Durabilité des Exploitations Agricoles (VILAIN, 1999)	IDEA	France	27
System APOIA – NovoRural (Rodrigues e Campanhola, 2003)	APOIA-NovoRural	Brazil	23
Framework for the Evaluation of Sustainable Land Management (Dumanski e Smyth, 1995)	FESLM	United Nations	21

Having these systems described in Table 2 selected and described, we proceeded to the second stage of this research, which was based on an exploratory-qualitative approach, performing the comparison between the five systems that assess environmental sustainability based on selected criteria.

The criteria selected for comparison were defined based on the research by Candido et al. (2015) because it is a study similar on scope, considering tools comparison and these criteria have a greater influence on information extraction, adequacy and applicability at farm level. The criteria were: concept of sustainability, analysis goals, target audience, flexibility, adaptability and systemic approach. Synthesizing and explaining what Candido et al. (2015) mention in their research regarding these criteria, we have:

- Sustainability Concept: the understanding of the sustainability concept ensures coherence to the adopted evaluation method.
- Goal and Target audience: both reveal the concern and focus of each chosen method and with this, achievement of purposes of those involved and benefited with the evaluated object.

- Flexibility and adaptability: each method has its own structure, some flexible, others more rigid, allowing or not adjustments to the place of analysis. These differences interfere in the result of each analysis and both receive specific criticism and support.
- Systemic approach: dealing with environmental or sustainable aspects goes far beyond a simple perception of the natural world, fauna or flora. Systems that assess sustainability need to carry a holistic and systemic characteristic, translating the complexity of their understanding when dealing with and exploring the economic, social and environmental aspects present in all indicators, themes and sub-themes present in the assessment tool. In addition to dealing with all the relations inherent to farm level assessments.

RESULTS AND DISCUSSIONS

Obviously, there is a certain distance between defining a concept of sustainability and putting it consistently into practice. As it can be seen in the table below, of the systems explored in this work, each present their own concept of sustainability, based on principles, attributes and dimensions, defined from studies and values, which despite bearing a lot of similarity between them, they also have individual variations.

Table 2. Comparison of systems for sustainability assessment by given criteria.

CRITERIA	MESMIS	SAFA	IDEA	APOIA	FESLM
Concept of sustainability	It considers seven attributes: productivity; reliability; resilience; stability; adaptability; equity; and self-management or self-dependence.	There are four dimensions: good governance; environmental integrity; economic / resilience; social well-being.	Attributes from the quantification of local characteristics related to the environmental, social and economic dimensions.	It considers five dimensions: landscape ecology, the quality of environmental compartments, socio-cultural values, economic values, management and administration.	It relates to sustainable land management, combining technologies, policies and activities with socioeconomic principles, such as: productivity, security, protection, viability and acceptability.
Goal	Assess sustainability of different natural resource management systems on a local scale.	Support implementation of effective sustainability management and communication in the food sector.	Give farmers a sense of rural sustainability by thinking over their agricultural practices.	Propose a general index of the activities' contributions to the sustainability of the analyzed farm.	Directly assist in the planning, in the comparison of alternative forms of land use in a certain period of time.
Target audience	Farmers themselves and farms surroundings.	Public and private organizations.	Educational, development and agricultural agents.	Farmers themselves.	Farmers themselves.
Flexibility and Adaptability	Flexible structure molded from the evaluation of an interdisciplinary team and adaptable to different types of information and production systems analyzed.	It allows to adapt its structure to all contexts and sizes of operations. It values performance, promotes diversity in the implementation of possible means and encourages continuous improvement.	It has a more rigid structure, with well-defined indicators, form of calculation, evaluation criteria and aggregation method, but it is capable of adapting to other contexts depending on the adjustments made to its indicators.	Rigid tool with predefined indicators, however, the method is simple to apply, allowing active participation of farmers and those responsible for the analyzed production system.	It is suitable for any type of land use, however, it maintains its fixed structure of indicators and parameters in the assessment.
Systemic Approach	It proposes the promotion of interaction between the technical, economic, social and environmental dimensions, without a specific number of indicators.	It offers a global holistic framework for assessing sustainability across the food and agriculture chains. They cover 21 themes, 58 subthemes and 116 indicators.	It evaluates from 41 quantified indicators, subdivided into 10 components that analyze the strengths and weaknesses of the production system and identify ways to improve.	Comprises 62 indicators, organized to cover the possible range of environmental effects directly defined as impacts applied in their entirety to any agricultural activity.	It covers the analysis of the land from four fronts of indicators: physical, agronomic, economic and social, totaling 54 indicators.

CONCLUSIONS

It could be noticed that most of the evaluated tools are focused on the individual farmer when it comes to target audience, however, the greatest divergences between them were related to the other criteria considered. It was noticed that each tool shapes its concept of sustainability from what they propose to do and disseminate through their analysis outputs. One must also consider the flexibility of each system, as, as discussed in this work, there are systems that can be shaped according to each investigated environment. However, this trend makes it difficult to compare different contexts when placing these data in series. In other cases, standardization, even if rigid, contributes to extrapolation of results and comparison with other systems.

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USING INDICATORS TO ASSESS THE PRODUCTIVITY AND ECOSYSTEM SERVICES OF NATIVE GRASSLANDS MANAGED AS PASTURELANDS IN THE PANTANAL WETLAND, BRASIL

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ABSTRACT

Integrated management approaches are essential for the sustainability of the beef cattle production system in the Pantanal wetland, and it would direct the adoption of adequate management practices that favor multiple ecosystem services and biodiversity. This paper exemplifies the evaluation of the pasture attributes in a ranch at the Nhecolândia sub-region, Pantanal. The evaluation is based on an indicator of natural pasture conservation status (PCS) applied to landscapes with dominance of native grasslands. To estimate the net primary productivity (NPP) and forage provision, the vegetation at two different landscapes was mapped, one with "regular" and another with a "good" PCS performance. Grassland landscape with "good" PCS presented more than three times NPP than the "regular" one, reflecting the greater forage provision and grazing capacity. This result indicates the PCS indicator is suitable to differentiate among grassland condition with potential positive impact on animal performance and ecosystem services. The integration of different complementary evaluation tools provides useful information for decision making on sustainable grassland management.

Key words: forage provision; net primary productivity; rangeland

INTRODUCTION

The Pantanal wetland is a large floodplain whose biodiversity and ecological processes are driven mainly by the flood pulse (JUNK et al., 1989). The landscapes consist of a mosaic of woodland savannas), open grasslands and forests, as well as aquatic habitats. A major part of the plain is used for livestock ranching based on abundant provision of native forage (SANTOS et al., 2013). However, grazing capacity has spatio-temporal variation because it depends mainly on proportions of landscapes with dominance of native grasslands and climatic conditions. For instance, extreme flood events can decrease forage availability, as well as extreme droughts may decrease its quality.

Santos et al. (2017) developed a comprehensive tool to assess the sustainability of beef cattle ranching in Pantanal, Sustainable Pantanal Ranch (SPR). The SPR tool uses a hierarchical structure of attributes and indicators of the three dimensions of sustainability (economic, social, and environmental). Among the indicators used by the SPR there are four adopted to evaluate the native grasslands attributes (economic and environmental dimension). The pastureland conservation status indicator (PCS) evaluates the conservation and degradation status, as well as the degree of invasion by undesirable species in the grasslands. This diagnosis allows the identification of the causes of degradation and the solutions to prevent degradation and to further rehabilitate degraded pastures.

A comprehensive and adaptive grazing management plan requires an understanding of the animal vs. plant vs. soil interaction at landscape scale to establish the best practices, which in turn also produce multiple ecosystem services such as supply and flow regulation of water and carbon storage

(BENGTSSON et al., 2019). Conserved native grasslands landscapes enable capture, infiltration, and storage of rainwater into soils that promote higher soil organic carbon (SOC) storage, increase forage covering, increase carbon dioxide sequestration, reduced methane emissions among other services.

An effective strategy to develop multifunctional ranches in the Pantanal in which livestock production and biodiversity are integrated involve adopting good pasture management practices. In this study we aim to evaluate the applicability of indicator of the SPR framework in assessments of ecosystem services related to the provision of forage by the native grasslands in the Pantanal wetland.

MATERIAL AND METHODS

The study was conducted in two actual management unit (enclosures) with 300 hectares at Nhumirin ranch, representative of the Nhecolândia sub-region, Pantanal, Wetland, Brazil (S 18°59'49.5”, W 56°38'16.1”). The region is characterized by a mosaic of forest, savanna, grasslands, and wetlands. The different landscapes were mapped (RODELA et al., 2007) as forests (FA), woodland savannas (SA), non-floodable grasslands (OG), intermediated floodable grassland (SOG), and wetland grassland (WG). Intermediated floodable grasslands are strips of open wetlands located in the ecotone between non-floodable grasslands and those often inundated, with flood lasting up to 6 months, while wetland grasslands are often flooded up to 9 months. These areas present different plants species composition.

The indicator of the SPR tool (Figure 1) for the natural pasture conservation status (PCS) was applied to two different situations: one for grasslands with "regular" PCS and another with a "good" PCS. The net primary productivity (NPP) was estimated for each grassland landscape according to Santos et al. (2020), and the available forage was estimated according to Santos et al. (2013). The net primary productivity (NPP) was estimated by summing the aerial and the root dry mass (considered to be 40% of aerial dry mass). The available forage (AF) was estimated according to the proportion of key forage species following the SPR protocol (Santos et al., 2015) and considering a grazing utilization degree of 50%. The total NNP and the total available provision were estimated based on the proportion of these landscapes in the management unit.

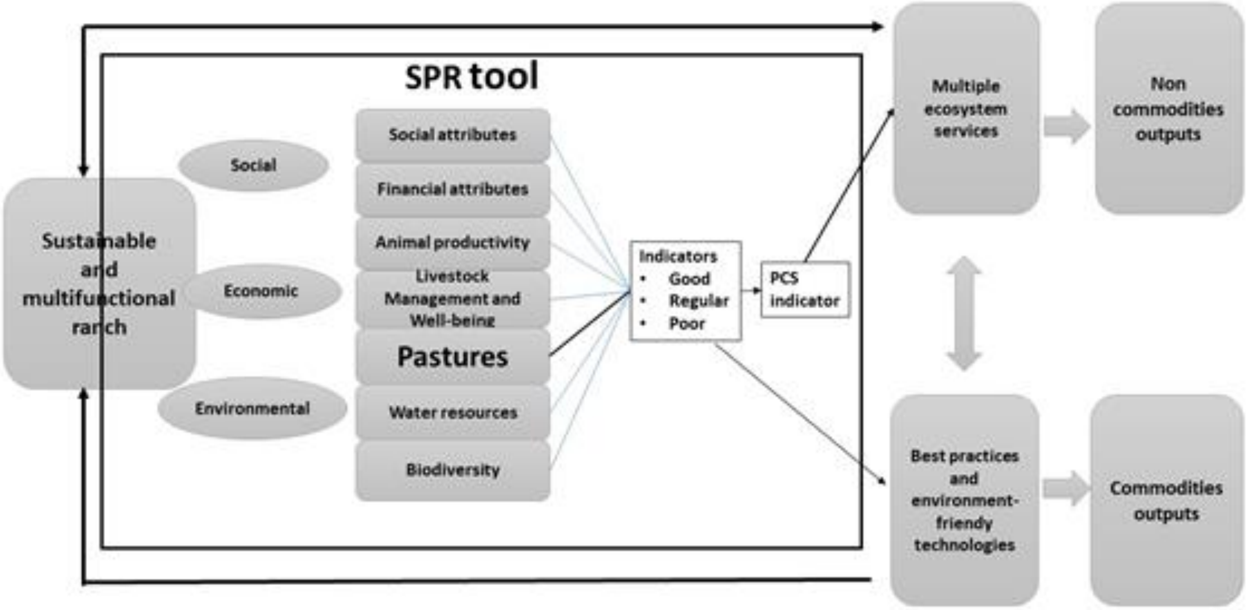

Figure 1. A simplified assessment model of the cattle ranch sustainability in the Pantanal wetland, Brazil, using the SPR tool and multiples ecosystem services, exemplifying the PCS indicator.

RESULTS AND DISCUSSIONS

The performance of the PCS indicator clearly differentiated the two assessed grassland landscapes. Table 1 shows the proportion of landscapes used for grazing and respective key forage species, the net primary productivity (NPP), and total available forage in a management unit assessed using the PCS indicator.

Pasture landscape with good PCS performance presented more than three times total NPP than landscape of the poor PCS. These values reflected on total available forage. Although most of the key forage species are similar between scenarios, their percentual cover is different. Moreover, the result suggest that several key forage species may disappear if good management practices are not applied to the native grasslands in the Pantanal.

Pantanal has a diversified landscape with high spatio-temporal variation. Estimates of NPP and forage production are variable in function of climatic conditions and management practices. In our assessment pasture landscape with "good" conservation status had higher NNP and forage provision, reflecting an impact on the productivity potential and ecosystem services. NNP is considered the basis of all ecosystem services (WAD, 2019) and affect the grazing capacity of the grassland landscapes used as pastureland for cattle ranching. The NPP value relates to the carbon that can be sequestered by grasslands and it is an indicator often used to evaluate ecosystem response to climate change (BILGILI et al, 2020). These values are important to estimate the soil organic carbon (SOC), composed of part of the vegetation NPP (their roots) and soil mineralization (YU et al., 2020). Thus, sustainable management strategies to improve the performance of the PCS indicator of the SPR tool contribute with several ecosystem services. Preventing and restoring degraded pastures in the Pantanal may contribute to mitigate climate change effects and increase the productivity and the maintenance of several ecosystem services, some eligible for environmental service payment schemes.

Table 1. Estimates of net primary productivity (NPP) and total available forage in two pastures at the Pantanal wetland, Brazil, assessed using the PCS indicator.

Status of pastureland conservation (PCS): Good (forage cover >65%)					
Pasture Landscapes	**Proportion/area, % (ha)**	**Forage species**	**NPP[1] (t DM ha^{-1} year $^{-1}$)**	**Available forage (t DM ha^{-1} year $^{-1}$)**	**Total available forage**
Non-floodable grasslands	14.4 (43.2)	*Mesosetum chaseae*	2.8	1.0	43.2
Intermediated floodable grassland	66.3 (98.9)	*Axonopus purpusii* *Reimarochloa brasiliensis* *Steinchisma laxum*	4.2	1.5	298.3
Wetland grassland	7.8 (23.4)	*Hymenachne amplexicaulis* *Luziola subintegra Leersia hexandra*	14.1	5.1	119.6
Total			**21.1**	**7.6**	**461.1**
Status of pastureland conservation (PCS): Regular (forage cover 30-65%)					
Non-floodable grasslands	14.4 (43.2)	*Mesosetum chaseae* *Richardia grandiflora*	0.6	0.6	8.6
Intermediated floodable grassland	66.3 (198.9)	*Axonopus purpusii* *Reimarochloa brasiliensis* *Steinchisma laxum*	1.4	0.5	99.5
Wetland grassland	7.8 (23.4)	*Hymenachne amplexicaulis* *Luziola subintegra Leersia hexandra*	4.2	1.5	35.1
Total			**6.2**	**2.2**	**143.2**

In the "good" scenario we evaluated, the fact of presenting higher forage availability would allow a moderate grazing aiming higher individual animal performance, and even improve the methane emission rate (methane/kg of meat produced). The moderate grazing in the rainy season also may help to extend pasture availability and, therefore, help to alleviate the dry spells that have been predicted for the region by climate change models. Thus, proper management may be key to adapt to the climate change, and to mitigate its impacts on ecosystems and productivity.

Integrated evaluation tools such as SPR tool may be relevant to induce the adoption of good management practices, to ensure multiple ecosystem services in multifunctional landscapes, to conserve biodiversity and to ensure food provision (BENGTSSON et al., 2019).

CONCLUSIONS

Pasture conservation Status Indicator provides useful information for decisions making in sustainable grassland management approaches and development of multifunctional ranches in the Pantanal wetland integrating livestock production and ecossytem services.

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STRAW PRODUCTION IN DIFFERENT INTEGRATED CROP LIVESTOCK SYSTEMS UNDER NO-TILLAGE SOIL MANAGEMENT

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ABSTRACT

An important annual crops management system for carbon sequestration from the atmosphere is the crop livestock integrated system managed under no-tillage system. In the Brazilian state of Mato Grosso, the problems pointed out in the integrated NT system are lack of crop options for rotation and insufficient soil cover. The research activities of the present study were and extension activity as demonstrative unit of crop options of combinations of plant species producing high amount of vegetable dry matter. In which were focused on the contribution of varied amounts of dry mass and straw production and surface accumulation to the soil from production models consisting of annual cultures, successions, rotations and/or crop consortiums. The results confirm crop sequence soybean and cotton, provide low dry mass production. The crop sequences and second crop season that contain high-biomass sorghum and the maize consortium with palisade grass are the ones that provide higher dry matter production in the form of straw, being often above that minimum values in the tropical humid conditions, to keep the soil organic matter content stable. The sequence of crop that includes hybrid biomass sorghum was the one that showed higher mass production and has the potential for recovery of soil cover for those soils.

Key words: crop-livestock integrated systems; no-till systems; crop biomass production

INTRODUCTION

One of the most important annual crops conservative management system for carbon sequestration from the atmosphere is the crop livestock integrated system managed under no-tillage system. The no-tillage system (NT) has three basic assumptions: no soil revolving, crop rotation and permanent and adequate soil cover with straw. The lack of soil cover or inadequate cover, for a prolonged period, has been a problem pointed to the adequate soil management of crops conducted with NT system in the tropical region of Brazil. One of the factors that contribute to the effective success of the no-tillage system is based on crop rotations that provide high addition of different types of crop residues to the soil (FIDELIS et al., 2003). In the state of Mato Grosso, the problems pointed out in the integrated NT system are lack of crop options for rotation and insufficient soil cover. This may compromise the quality of crops managed with integrated NT system, mischaracterizing them as Low Carbon Agriculture (DERPSCH et al., 2010).

The annual crops of Mato Grosso state are usually managed without soil tillage, but not always in accordance with the precepts of NT systems. One of the factors that contribute to the effective success of the no-tillage system is based on crop rotations that provide high addition of different types of crop residues to the soil. In conservationist managements, under tropical and subtropical climate, it is recommended the addition of high amounts of cultural residues, offsetting the rapid decomposition, in order to keep the soil surface protected for as long as possible and to increase soil organic matter (BOER et al., 2008; DERPSCH et al., 2010). Bayer et al. (2000) and Petter et al. (2017) suggest that it is necessary to produce by the crop sequences about 12 to 16 Mg ha^{-1} of straw to maintain stable or increase the organic matter levels of tropical soils under cultivation.

MATERIAL AND METHODS

The field research activities, developed between 2013 and 2016, was a research and extension activity in the form of demonstrative unit of crop options of combinations of plant species producing high amount of vegetable dry matter. In which were focused on the contribution of varied amounts of dry mass and straw production and surface accumulation to the soil from production models consisting of annual monocultures, successions, rotations and/or crop consortiums. The systems studied for straw production, reflecting different intensities of plant dry mass production were soybean/biomass sorghum, soybean/maize + palisade grass 1 (recommended sowing density), soybean/maize, soybean/millet, soybean/maize + palisade grass 2 (twice the recommended sowing density), which constituted the treatments. An experiment was used in the experimental area of Embrapa Agrossilvipastoril, in the municipality of Sinop, Mato Grosso state, on crop rotation managed with NT system. The soil class of plots area are a Typic Clayey Dystric Haplustox. The experiment included the study of crop rotations in the mitigation of soil compaction and began in 2013.

The plots, with 30 m^2, with five replicates, were sown with soybean (cultivar BR 8665 RR) in the first harvest, rotated with five crop sequences: cotton, only in the 2nd season 2013/2014 (cultivar BR 365 RRF), millet (cultivar AMN 17), palisade grass *(Brachiaria brizantha* cv. Marandu) and maize (hybrid DKB 390 PRO) associated with palisade grass sown in the second crop, except for the soybean/maize + palisade grass 2 treatment, which from the second year replaced second crop season cotton due to difficulties to manage cotton crop. The cover and accumulation of straw in the systems were evaluated. The accumulation of straw from the plants of the production systems was determined by collecting straw samples in the treatments. The straw samples, five replicates, positioned close to the soil, were collected at intervals ranging from 30 to 45 days (Oliveira and Borszowskei, 2012). Six samples were collected in the first and second harvests, totaling twelve evaluations per crop. In the present work, only the results of the end evaluations of each crop are presented. The means of the straw sum of 1st and 2nd crop seasons were compared with Dunnett test ($\alpha = 0.05$), and the treatment soybean/maize was the control.

RESULTS AND DISCUSSIONS

In this paper are presented results obtained in the 2013/2014, 2014/2015 and 2015/2016 harvest obtained in a four-year experiment conducted at Embrapa Agrossilvipastoril, in Sinop-MT, in clayey tropical soil.

The treatment soybean/high-biomass sorghum (hybrid BRS 716) was added in the crop season 2014/2015. Were obtained in each plot, the values of grain yield and dry matter of the straw added to the soil at the time of harvest, from six samples of 1 m^2. The results of dry mass production for the three crop seasons were showed in Table 1. In the three crops seasons, 2013/2014, 2014/2015 and 2015/2016, the soybean and maize plots were obtained grain yields around the regional average respectively of 3,200 and 6,300 kg ha^{-1} (data not shown). The results presented in Table 1 show the need to maintain crop rotations in NT systems, mainly with crops or crop consortia that generate high amounts of straw in the post-harvest (CECCON et al., 2011; SEREIA et al., 2012). In the 2013/2014 harvest, the average dry mass after cotton crop harvest had the lowest value among all evaluated during the three years of the experiment. This common crop sequence in the state of Mato Grosso has resulted in low production of residual straw for soil cover, often with values far below those considered by Bayer et al. (2000) and Petter et al. (2017) as minimum for the maintenance of a soil cover with adequate straw and for stabilization or increase of the organic matter content of soils of the humid tropic region.

Table1. Dry mass production means and season accumulations, in kg by hectare, of soybean, cotton (crop season 2013/2014 only), maize, millet, sorghum, and palisade grass.

After harvest Crop Dry Mass, kg ha^{-1}

Crop season 2013/14

	Soybean	Maize	Cotton	Millet	Palisade grass	Total 1st season	Total 1st + 2nd season
Soybean* /cotton	3,725	-	2,146	-	-	3,725	5,871 B
Soybean* /maize	3,774	5,988	-	-	-	5,988	9,762 A
Soybean* /millet	3,811	-	-	6,152	-	6,152	9,963 A
Soybean /maize + pal. grass 1	3,622	6,336	-	-	4,991	11,327	14,949 C

Crop season 2014/2015

	Soybean	Maize	High-biomass Sorghum	Millet	Palisade grass	Total 1st season	Total 1st + 2nd season
Soybean* /sorghum**	3,715	-	14,666	-	-	14,666	18,381 B
Soybean* /maize + pal. grass 2	3,564	7,558	-	-	4,261	11,819	15,383 B
Soybean* /maize	3,536	6,413	-	-	-	6,413	9,949 A
Soybean* /millet	4,789	-	-	5,714	-	5,714	9,250 A
Soybean* /maize + pal. grass 1	3,535	6,786	-	-	5,157	11,943	15,479 B

Crop season 2015/2016

	Soybean	Maize	High-biomass Sorghum	Millet	Palisade grass	Total 1st season	Total 1st + 2nd season
Soybean* /sorghum**	4,329	-	17,575	-	-	17,575	21,904 C
Soybean* /maize + pal. grass 2	3,969	12,201	-	-	3,125	15,327	19,296 C
Soybean* /maize	4,057	7,869	-	-	-	7,869	11,926 A
Soybean* /millet	3,612	-	-	6,700		6,700	10,312 A
Soybean* /maize + pal. grass 1	4,109	10,034	-	-	2,325	12,359	16,468 B

*Soybean grown in the 1st crop. Intercropping soybean/maize + palisade grass 1, sown at the recommended sowing density¸ i.e., 5 kg ha^{-1} of viable seeds; soybean/maize + palisade grass 2, sown with twice the recommended sowing density. Means compared by Dunnett test (α = 0.05) with control treatment soybean/maize. ** High-biomass sorghum BRS 716.

In the 2014/2015 and 2015/2016 crop season, it was observed that the sequences of soybean/high-biomass sorghum and soybean/maize + palisade grass 2 crops were the treatments that resulted in higher dry straw mass production, especially the first sequence. It can be affirmed that treatments involving maize or millet in the second crop season, despite providing high dry mass production, do not always reach those values considered adequate for the study region. Guimarães Jr. et al., 2010; Ceccon et al. (2011); Sereia et al. (2012) and Cavalli et al. (2018) observed that for maize grown in the second harvest to reach high values of grain yields and dry mass, it is necessary that the crop has adequate rainfall supply and that the rainy season also extends until the end of April or beginning of May. This also allows the maize + palisade grass intercropping, with forage sown in higher density, to produce a high amount of biomass, without reducing maize grain production (GUIMARÃES JR. et al. 2010; COLETTI JR. et al., 2015). It is important to highlight that higher dry mass yields will have as favorable results to the NT system, greater soil cover with straw, greater persistence of this cover until the beginning of the subsequent harvest and greater contribution of organic matter, and, consequently, greater addition of organic carbon in the soil, increases in organic matter and greater amount of nutrients being cycled for subsequent harvests (DERPSCH et al., 2010; OLIVEIRA & BORSZOWSKEI, 2012; PETTER et al., 2017).

CONCLUSIONS

In the crop season 2013/2014, the sequence of soybean followed by cotton, provided low dry mass and a not suitable soil cover.

The results obtained show the need to maintain crop rotations in no till systems and crop livestock integrated systems, and mainly with crops that generate high amounts of straw in the post-harvest.

The crop sequences (soybean only) and second crop season that contain high-biomass sorghum and the maize consortium with palisade grass are the ones that provide higher dry matter production in the form of straw, being often above the value of 15 Mg ha^{-1}, above that minimum values in the tropical humid conditions, to keep the soil organic matter content stable.

The sequence of crops in harvest and second crop season that includes hybrid biomass sorghum was the one that showed higher mass production and has the potential for recovery of soil cover for those soils that have reduced soil cover due to management problems or with low in the ability of agricultural use.

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EFFECTS OF BEEF HEIFERS GRAZING WITH DIFFERENT LEVELS OF SUPPLEMENTATION IN CROP-LIVESTOCK INTEGRATED SYSTEM

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ABSTRACT

Intensive supplementation of grazing animals may increase livestock profitability, system yield and increase soil fertility. The objective of this study was to evaluate how different levels of supplementation for grazing heifers affects the chemical composition of the biomass at sowing of the next crop in succession. The experimental area was divided in nine paddocks with 1.54 ha each, being three repetitions for each level of supplementation: mineral salt (*ad libitum*), 0.5% of live weight (LW) and 1.5% of LW. The three different supplementation levels did not change the biomass availability at the soybean seeding. The supplementation at 1.5% of LW compared to mineral salt supplementation increased the levels of calcium, magnesium, phosphorus, potassium, and sulfur in the forage biomass at the time of soybean seeding. These results reinforce the hypothesis that the cattle supplementation during grazing period can increase nutrient availability for the following crop in succession. Therefore, further studies evaluating soil fertility and crop yield are important to provide a better view of the interaction between animal management, soil fertility and overall yield of crop-livestock integrated system.

Key words: soybean; animal nutrition; nutrient cycling

INTRODUCTION

Crop-livestock integrated systems involve the cash and cover crops rotation and/or succession with an animal grazing period. Research about the long-term effects of animal management decisions on the following cash crops are beginning to be explored. Some studies in other climatic conditions have shown that soil parameters and crop yield were affected by different grazing intensities during the pasture phase of the system (KUNRATH et al., 2020). Therefore, the livestock management has been related to resilience of the system and sustainability of the agroecosystem (SZYMCZAK et al., 2020).

Supplementation for grazing beef cattle aims to achieve animal nutritional demand, increase efficiency of pasture management, increase efficiency of production systems, enhancing animal growth and decrease age at slaughter (REIS et al., 2012). However, supplementation effects in nutrient cycling in crop-livestock integrated systems were not explored yet (POSSAMAI et al., 2020). It is necessary to evaluate the management decisions considering the whole production system, as the soil-plant-animal interact and can change the final yield and nutrient efficiency (GLÉRIA et al., 2017). Thus, the objective of this study was to evaluate the quantity and chemical composition of biomass at the time of soybean sowing after heifer grazing period with different levels of supplementation.

MATERIAL AND METHODS

The field trial was realized in Encanto Farm, in Montes Claros de Goiás city, Goiás State, Brazil. Pasture (*Megathyrsus maximum* (*Syn. Panicum maximum*) cv. BRS Zuri) was sown after soybean harvesting with distribution of five kilograms of pure viable seeds per hectare (ha) and incorporating with leveling harrow. The grazing period occurred during the offseason, which is a dry period in Brazilian savannah. Soybean was cultivated during the regular crop season (rainy period).

The experimental area was divided in nine paddocks with 1.54 ha each, being three repetitions for each level of supplementation: mineral salt, 0.5% of live weight (LW) and 1.5% of LW. Mineral salt (6.5% of phosphorus) was provided *ad libitum*. Supplement offered at 0.5% of LW was composed by 75% of corn, 15% of soybean meal, 4% of urea and 6% of same mineral salt at dry matter basis. The supplement offered at 1.5% of LW was composed by 87.7% of corn, 9% of soybean meal, 1.3% of urea and 2% of mineral salt. The estimated composition of the supplements was 25% of Crude Protein (CP) and 78% of Total Digestible Nutrients (TDN) for 0.5%LW supplement and 16% of CP and 84% of TDN for 1.5%LW supplement.

It was placed five, seven and nine animals in each paddock with mineral salt, 0.5% LW and 1.5% LW supplements, respectively. Stocking rate was adjusted at each 28 days to maintain forage availability similar between paddocks, based on the amount of forage dry matter available per hectare. Heifers were slaughtered according to subcutaneous fat thickness measured by ultrasound, which should be higher than three mm. All animals were removed from the pasture on July 30 of 2020, being 87 days of grazing period in total.

Biomass sampling was realized on November 4th of 2020, immediately before the desiccation for direct soybean sowing. Biomass sampling was performed at five points of 1 m² in each paddock cutting at 10 cm from the ground. Samples were weighed together and a subsample was placed in forced air oven (65 ºC) during 72 hours for determination of dry matter (DM) proportion. Thus, the biomass availability per area was determined (kg of DM ha^{-1}). The dry samples were grounded and the chemical composition (nitrogen – crude protein, calcium, magnesium, phosphorus, potassium and sulfur) evaluated. Neutral detergent fiber (NDF) and ruminal digestibility of NDF were also determined by the sequential method of Van Soest et al. (1991).

Data per paddock were submitted to analysis of variance (ANOVA) considering the fixed effect of supplementation levels and least squared means were compared by Tukey test ($p<0,05$). The software R (R CORE TEAM, 2020) with *emmeans* (LENTH, 2020) e *car* (FOX & WEISBERG, 2019) packages were used in statistical analyses.

RESULTS AND DISCUSSIONS

Supplementation level during the grazing phase did not affect the biomass availability at the time of soybean sowing in the following crop season (Table 1). The higher supplementation level increased CP and NDF digestibility (dNDF240 and uNDF240) in the forage regrowth on beginning of the following rainy season (Table 1). Ash content in biomass was higher in 1.5% LW supplementation in comparison with the paddocks where animals received mineral salt. At the same time, it was observed higher calcium, phosphorus, potassium, magnesium, and sulfur in biomass from paddocks where animals received 1.5% LW of supplement during the dry season compared to mineral salt supplementation. The higher nutrient cycling due animal supplementation can be related to higher nutrient content in biomass. High animal fecal and urine deposition during grazing period with the higher nutrient content in biomass at desiccation as showed here could reflect in higher soybean yield (VEGEN et al., 2020).

The further results in the production system are essential to determine the long-term effects of using different levels of supplementation for grazing heifers in the whole crop-livestock integrated system.

The hypothesis is that the higher supplementation levels would intensify the nutrient cycling and increase the soil fertility. These first results presented here already indicated the differences between supplementation levels, reinforcing the need to continue the long-term evaluations of crop yield, soil properties and animal and plant parameters.

Table 1. Mean chemical composition of the biomass available at soybean seeding after beef heifer grazing period with different supplementation levels.

Treatments	**DM**	**CP**	**NDF**	**dNDF 240**	**uNDF 240**	**Ash**	**Ca**	**P**	**K**	**Mg**	**S**
MS*	437	12.5^{b}	38.0	58.5^{b}	31.8^{a}	9.0^{b}	0.53^{b}	0.18^{b}	1.39^{b}	0.19^{b}	0.15^{b}
0.5% LW	336	14.1^{ab}	28.4	60.2^{ab}	29.1^{ab}	9.8^{ab}	0.62^{ab}	0.20^{ab}	1.39^{b}	0.23^{ab}	0.17^{ab}
1.5% LW	313	18.4^{a}	43.2	65.2^{a}	23^{b}	11.5^{a}	0.82^{a}	0.26^{a}	1.58^{a}	0.30^{a}	0.21^{a}
SEM	179	1.09	2.53	1.91	1,92	0.40	0.06	0.01	0.19	0.03	0.01

^{a,b}: different letters at the same column means statistical difference at Tukey test ($p<0.05$); DM: dry matter availability (kg of DM per hectare); CP: crude protein (% of DM); NDF: neutral detergent fiber (% of DM); dNDF240: digestibility of NDF after 240 hours of incubation (% of NDF); uNDF240: undegraded NDF after 240 hours of incubation (% of DM); Ca: calcium (% of DM); P: phosphorus (% of DM); K: potassium (% of DM); Mg: magnesium (% of DM); S: sulfur (% of DM); SEM: Standard error of the mean; MS: Mineral salt; 0.5% LW: supplement offered at 0.5% of live weight of the animals; 1.5% LW: supplement offered at 1.5% of live weight of the animals.

CONCLUSIONS

The supplementation of heifer grazing during the dry period increase the nutritional value of the grass in the regrowth during the beginning of rainy season. The supplementation of 1.5% of live weight increased the mineral composition of the biomass at the time of desiccation to direct soybean sowing. Further evaluations are need to verify if this higher nutrient availability will reflect in higher soybean yield.

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BIOLOGICAL ATTRIBUTES OF THE SOIL UNDER INTEGRATED SYSTEMS IN THE EASTERN AMAZON

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ABSTRACT

Agricultural integration systems provide a series of social, economic and environmental benefits, by integrating different production systems. There is a need to study their impact on the soil of the Amazon biome. The objective of this work was to evaluate the biological attributes of the soil (basal soil respiration, carbon from microbial biomass and organic matter) under the different production systems and seasonality: Continuous Pasture (S1), Livestock-Forest Integration System (S2 and S3), Homogeneous Forest (S4) and Secondary Forest (S5), in an experimental area of EMBRAPA Eastern Amazon, located in the Municipality of Terra Alta, Pará. There was variation in the biological attributes of the soil under different uses and management. The integration systems S2 and S3, showed results similar to those for the Secondary Forest system (S5), indicating their possible use during the initial stages in the recovery of degraded areas.

Key words: Basal Respiration; Soil Microbial Biomass; Clean Development Mechanisms

INTRODUCTION

The inappropriate use of natural resources impacts the soil-water-air environment, accelerating the extinction of some animal and plant species, in addition to causing social damage (DIAMOND, 2012). Discussions about economic development and clean development mechanisms can contribute to the maturation of a production and consumption model that emphasises the social, environmental and economic pillars. In this context, the development of agricultural production systems that provide a variation in income for rural producers and, simultaneously, allow improvements in soil quality, reducing the use of inputs while generating income, are being evaluated (OSÓRIO, 2013; GASPARINI et al., 2017).

It is known that crop-livestock-forest integration systems (CLFIS) can proportion various environmental services, such as mitigating the generation of greenhouse gases and retaining carbon as biomass and in the soil, as well as controlling the risk of soil degradation, minimizing the effects on plants, improving soil aggregates, reducing resistance to root penetration and presenting significant increases in production, in addition to preserving the environment (BALBINO et al., 2011; SILVA et al., 2015; SILVA et al., 2016a). Furthermore, the integration of production systems provides benefits to animals, with regard to their ambience and well-being (ALVES et al., 2019). In addition to the diversification promoted by these systems, they are a viable, low-risk and long-term alternatives, to maximize the economic return of the producers (DOS REIS et al., 2018).

Biological indicators of the soil stand out as suitable to evaluate the efficiency of these systems, because they are more sensitive to soil use and the applied management practices when compared to the chemical and physical indicators (POWLSON et al., 1987; DEBOSZ et al., 2002; ARAÚJO & MONTEIRO, 2007). Although there have been studies focused on the biological attributes of the soil, mainly in the southeast and central-west of Brazil (ASSIS et al., 2019; SOUZA et al., 2019), there is a need to expand these studies, especially to the Amazon region, to demonstrate the efficiency and sustainability of this production model. The necessity for these studies is due to the diversity of native species in the Amazon that can be used as the forest component, in contrast to other Brazilian studies that, in large part, use Eucalyptus (*Eucalyptus urophyla*) as the forest component (SERRA et al., 2019; BONINI et al., 2016; MACEDO & DE ARAÚJO, 2019).

The objective of this work is to evaluate the biological attributes of the soil (basal respiration of the soil, carbon from microbial biomass and organic matter (OM)) under different systems and seasonality: Continuous Pasture (S1), Livestock-Forest Integration Systems (S2-African mahogany and S3-Teak), Homogeneous Forest (S4 – African mahogany) and Secondary Forest (S5) in an experimental area of EMBRAPA Eastern Amazon, located in the municipality of Terra Alta, Pará.

MATERIAL AND METHODS

The study area is located in the northeast of Pará state, in the Experimental Area of Terra Alta (Terra Alta, PA) of EMBRAPA Eastern Amazon (Belem, PA), at an altitude of 35 meters, latitude 1°1'36.60” S and longitude 47°53'58” W, originally under natural vegetation in Legal Amazon. The regional climate is Af, tropical rainy (humid), according to the Köppen classification, with an average annual temperature of 26.6 °C and an average annual rainfall between 2,500 and 3,000 mm. The soil of the experimental area is classified as yellow Latosol medium texture, according to the Brazilian Soil Classification System (EMBRAPA, 2018).

The experiment occupied a total area of 13.10 ha divided into: 9.50 ha of Livestock-Forest Integration Systems (LFIS), 2.51 ha of pasture, 0.65 of homogeneous crops, in addition to an area of 0.44 ha of homogeneous forest at a 5 x 5 meter spacing with African mahogany. In the areas of LFIS, the tree species Teak (*Tectonia grandis*) were spaced at 3 x 3 meters with four lines of this forest species and African Mahogany (*Khaya ivorensise*), at 5 x 5 meters with three lines of this forest species, interspersed with a distance of 50 meters between each series for planting annual crops and forage.

For soil sampling, the seasonality of rainfall in the region was taken into account. Thus, collections were carried out in the months of May and November 2019, with May being the period with the highest precipitation, while November has the least precipitation. Soil samples were taken at depths of 0-15 cm, at points representative of each studied area, with four replications.

Laboratory analyses for determining the carbon of soil microbial biomass followed the fumigation-extraction method proposed by Vance et al. (1987). For the determination of the Organic Carbon content of the soil, the volumetric method using potassium dichromate was used and, finally, Basal Soil Respiration was determined by the quantification of CO_2 released during incubation of the soil in a closed system (JENKINSON & POWLSON, 1976).

RESULTS AND DISCUSSIONS

The highest values of organic matter were observed in the pasture area - S1 (PST), when compared to all the other systems evaluated (Table 1), especially in periods with low rainfall in the region. The presence of grasses can favour the incorporation of organic matter because this type of vegetation is more efficient in the production of biomass than most other types of plants (RODRIGUES et al., 2018; DORTZBACH et al., 2015). In addition, its abundant root system, mainly near the surface, provide a greater supply of carbon into the system, due to the higher concentration of microorganisms in this area (OLIVEIRA, 2018; ASSIS et al., 2019).

The integrated systems S2 (LFIS-M) and S3 (LFIS-T) also showed relatively high values, when compared to the control area of secondary forest. According to Batista et al. (2018), integrated systems are more diverse and present a plurality of ways for the entry of C into the soil, when compared to conventional ones. Oliveira et al. (2016) highlighted this diversity as a favouring element for the formation of a more diversified and richer litter, for nutrients, C and, consequently, of OM.

Table 1. Average Attribute Values at a depth of 0-15 cm, evaluated during different periods and under different systems: S1 (Pasture), S2 (LFIS - Pasture + African mahogany), S3 (LFIS - Pasture + Teak), S4 (Homogeneous African mahogany Forest) and S5 (Control Area - Secondary Forest).

System	**Period**	
	May/19	**Nov/19**
	Organic Matter (g kg^{-1})	
S1 (PST)	35.16 c	26.76 a
S2 (LFIS -M)	38.42 b	25.79 b
S3 (LFIS -T)	33.61 d	23.08 d
S4 (MF)	39.04 a	21.52 c
S5 (SF)	18.63 e	19.75 e
	Basal Respiration of the Soil (mg CO$_2$ g^{-1})	
S1 (PST)	43.34 a	53.87 a
S2 (LFIS -M)	21.61 d	30.13 c
S3 (LFIS -T)	25.98 c	24.65 d
S4 (MF)	29.06 b	53.41 b
S5 (SF)	20.72 e	19.80 e
	Microbial Biomass Carbon (mg C kg^{-1})	
S1 (PST)	210.91 c	33.94 d
S2 (LFIS -M)	147.88 d	37.58 c
S3 (LFIS -T)	287.88 a	42.42 b
S4 (FM)	240.61 b	50.30 a
S5 (FS)	87.25 e	28.45 e

Averages followed by the same letter in the same column do not differ significantly from each other, using the Tukey test at the level of 5% probability.

The pasture system - S1 (PST) and homogeneous forest of African mahogany (*Khaya ivorensise*) - S4 (MF), presented the highest values in terms of basal soil respiration (Table 1), with lower values for the integrated systems, S2 (LFIS-M) and S3 (LFIS-T), and in the secondary forest area S5 (SF). The highest values observed in the pasture area can be attributed to the development and cycling of the rhizospheric system under grasses, which in turn, favours the increase in biological activity of the upper layers of the soil. In addition, the deposition of animal excrement onto the soil surface in this area promotes an increase in the biomass of microorganisms (ASSIS et al., 2019).

Colodel et al. (2018) also pointed out that the greater release of C in the form of CO$_2$ in pasture areas may indicate that this environment has a lower equilibrium level in relation to other areas, mainly due to greater microbial activity. The results presented by the secondary forest areas and the integrated systems indicate a greater stabilization of these systems. For Coleman et al. (2017) this is due to the fact that as a given microbial biomass becomes more efficient, less carbon is lost as CO_2 through respiration.

The homogeneous forest of African mahogany (*Khaya ivorensise*) presented the highest values of microbial biomass carbon (MBC) (Table 1). This can be attributed to the root distribution of this species on the soil surface. Similar results were observed by Silva et al. (2016b). Following the homogeneous African mahogany forest, the integrated systems S2 (LFIS-M) and S3 (LFIS-T) showed higher values for MBC. This can be attributed, in the same way as for OM, to the accumulation of plant residues (litter), which, in turn, provide higher levels of C and N for the development of the microbiota in the soil (BATISTA et al., 2018; OLIVEIRA et al., 2016; COLODEL et al., 2018).

CONCLUSIONS

The biological attributes analysed varied with different land uses. The most significant values, in general, were registered in the Homogeneous Forest system, while the values registered in the two integrated systems, using African mahogany or Teak, were the closest to those registered for the control area of secondary forest. This proximity could indicate a possible use of these types of systems during the initial stages of restoration projects in degraded areas.

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PHYSICAL-CHEMICAL CHARACTERISTICS OF A BODY OF WATER UNDER THE INFLUENCE OF SOIL USE SYSTEMS IN THE EASTERN AMAZON

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ABSTRACT

Inappropriate land use and management can affect the quality of water resources. The objective of this work was to evaluate and interpret the physical-chemical parameters of water bodies under the direct and indirect influence of different land use systems: Livestock-Forest Integration; Pasture and monoculture of the forest species - African Mahogany (*Khaya ivorensise*). For assessment, the respective framework of the CONAMA Resolution Nº 357/2005 and the Water Quality Control Manual for Technicians working in Water Treatment Plants (WTPs) were taken into account. The results showed that the integrated system had minimal influence on the quality of the water body, showing no evidence of negative environmental impacts relating to these two areas in the study. The pH was the only parameter in disagreement with that established in the legislation, and it could be attributed to the decomposition of organic material from the existing vegetation in the surrounding areas, in addition, the values were similar to those normally found in Amazonian water bodies.

Key words: Integrated Production Systems; Eutrophication; Surface Water

INTRODUCTION

In recent years, water resources have been modified by anthropic action, resulting in a lowering of the quality and the availability of water, with a growing need to monitor the induced changes, so as not to compromise the multiple use of water, minimizing the negative impact on the environment (FRANCO & HERNANDEZ, 2009).

In this context, Law nº 9.433 / 97 (BRASIL, 1997), reaffirmed that the National Water Resources Policy is based on the fact that water, although recognized as a renewable natural resource, is also a public domain resource. There are several ways to assess the quality of water in water bodies, among them, the physical-chemical analyses stand out and are widely used as parameters indicating quality, with CONAMA resolution 357/2005 setting the norms that define the standards for water classes.

It is known that areas occupied with agricultural activities under inadequate management cause soil compaction and erosion, and can silt up and contaminate rivers. The development of agricultural production systems that provide a variation in income for rural producers and, simultaneously, allow improvements in the quality of the soil, reducing the use of inputs while generating income, are currently being evaluated (OSÓRIO, 2013; GASPARINI et al., 2017). Crop-Livestock-Forest Integrated Systems (CLFI) with the practice of no-tillage have contributed to maintaining soil quality (SILVA, 2016). For Balbino et al. (2012) the CLFI system is a management strategy that aims at achieving synergy between the components of agroecosystems. Thus, knowledge about this process and its relationship with the surrounding areas is essential for the efficient management of the system.

The objectives of this project are: to assess water quality, by determining physical-chemical parameters, under the possible influence of three different land use systems: Livestock-Forest Integration, Pasture and African Mahogany Monoculture (*Khaya ivorensise*); to check for possible changes in the water body, taking into account their respective framework in accordance with CONAMA Resolution No. 357/2005 and the Water Quality Control Manual for Technicians working in Water Treatment Plants (WTPs).

MATERIAL AND METHODS

The study area is located in the northeast of Pará state, in the Experimental Area of Terra Alta (Terra Alta, PA) of EMBRAPA Eastern Amazon (Belem, PA), at an altitude of 35 m, latitude 1°1'36.60" S and longitude 47°53'58" W, originally under natural vegetation in Legal Amazon. The regional climate is Am, tropical rainy (humid), according to the Köppen classification, with an average annual temperature of 26.6 °C and an average annual rainfall between 2,500 and 3,000 mm. The soil of the experimental area is classified as yellow Latosol medium texture (EMBRAPA, 2018).

The experimental area is divided into different production systems: Livestock-Forest Integration Systems (LFIS) with Teak and African mahogany as tree species; Pasture and Homogeneous Forest of African mahogany. Adjacent to the experimental area there is a stream characterized as a lotic body belonging to the western region of the Northeast Atlantic basin and the Gurupi sub-basin (MMA, 2006). This is classified by the National Environment Council (CONAMA) No. 357 of 2005, as a class II fresh water.

Water sampling was carried out at three points along the course of the stream adjacent to the experimental area (approximately 45 m in a straight line), between November 2018 and February 2020, at 5 sampling times over the experimental period, considering the seasonality of the region. Point 1 (P1) is located upstream of the experimental area, representing the water source, at the edge of the PA-136 highway; Point 2 (P2) is located within the experimental area; and point 3 (P3) represented the water discharge downstream of the CLFI experiment area (Table 1).

Table 1. Geographical Coordinates of the water collection points.

Point 1	S 01°01'19.8" W 47°53'59.8"
Point 2	S 01°01'18.8" W 47°53'51.8"
Point 3	S 01°01'18.1" W47°53'29.9"

Point 1 (P1) is located upstream of the experimental area; Point 2 (P2) is located within the experimental area; Point (P3) represented the water discharge downstream of the CLFI experiment area.

The collection of data at each sampling time was carried out in two stages. The first corresponded to "on-the-spot" analyses, acquired using an *ORION*-model 115 probe. In this step, the parameters determined were: Water surface temperature, Total Dissolved Solids (TDS), Electrical conductivity (EC) and salinity. The pH was also calculated using a potentiometer – pH meter *Handylab1*.

The second stage was carried out at the Laboratory for the determination of water quality parameters using titrometry methodologies and ion chromatography (Dionex-DX120). Water collection was carried out using properly sanitized containers for the storage of the samples that were stored in thermal boxes (CETESB, 2011). The measurement methodologies followed the Laboratory's own criteria and procedures, based on "*Standard Methods for the Examination for Water and Wastewater*" (APHA, 1995). The other analyses and determinations for this study were: alkalinity, turbidity, total acidity, total hardness, Cl^-, Ca^{2+}, Na^+, Mg^{2+}, K^+, SO_4^{2+}, NO_3^-, NH_3 and P_{total}.

In all, 18 physical-chemical parameters of the water body were analysed represented by 36 water samples (18 *in loco* and 18 at the UFPA laboratory). Sampling took place on sunny or cloudy days, with no incidence of rain on the day previous to sampling.

RESULTS AND DISCUSSIONS

The results of the determination of the physical parameters of the water samples were in compliance with current legislation (Table 2), within their classification as a freshwater class II water body (salinity equal to or less than 0.5 ‰).

Table 2. Determination of the physicochemical parameters in the stream present in the EMBRAPA Experimental Field in the Eastern Amazon, located in the Municipality of Terra Alta, Pará. There were 5 sampling times presented in chronological order from: 1 - November 2018; 2 - February 2019; 3 - May 2019; 4 - August 2019; 5 - November 2019.

Parameter (Unit)	**P1**					**P2**					**P3**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Temperature (°C)	26.7	25.8	26.6	26.1	26.5	26.7	25.6	28.5	27.7	26.8	26.3	26.2	27	27.4	27.4
Total Dissolved Solids (mg/L)	8	8	8	8	8	17	7	8	8	8	20	8	8	24	8
Electrical Condutivity (µg/cm)	17.1	17	17.3	17.8	17	16.3	15.5	18.1	16.8	17.3	18	17.7	16.3	52.1	16.5
Salinity (‰)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turbidity (NTU)	4.68	15.2	4.44	4.96	4.68	3.31	18.3	3.13	3.64	3.31	2.73	18.9	6.11	4.62	2.73
pH	5.41	5.13	5.19	4.95	6.17	5.43	5.17	5.51	4.79	6.59	5.63	4.51	4.97	7.13	7.27
Alcalinity (mg/L)	2.08	2.60	2.11	0	0	3.13	0.10	1.05	0	0	2.08	1.56	1.05	0	0
Total Acidity (mg/L)	4.32	11	4	2	8	6.91	8.5	9	4	4	4.32	17	4	4	7
Total Hardness (mg/L)	2.85	2.37	2.85	7.1	4.75	3.80	2.85	7.6	2.85	3.8	4.75	2.37	4.75	2.85	2.85
Cloride (mg/L)	3.1	2.13	1.7	2.2	2.12	1.9	1.6	1.9	1.5	1.9	3.0	1.9	1.78	1.5	2.08
Ammonia (mg/L)	0.14	0.18	0.18	0.04	0.04	0.09	0.16	0.19	0.04	0.2	0.1	0.10	0.19	0.01	0.11
Nitrate (mg/L)	0.16	0.0	0.3	0.3	0.4	0.0	0.25	0.2	0.18	0.28	0.32	0.6	0.35	0.17	0.18
Na^+ (mg/L)	0.85	1.3	1.1	1.56	1.02	0.87	0.8	1.1	1.2	0.99	0.8	0.85	1	1.3	0.91
Ca^{2+} (mg/L)	0.0	1.0	1.0	0.6	0.4	0.1	0.1	1.	0.65	0.49	0.0	0.06	0.9	0.17	0.16
Mg^{2+} (mg/L)	0.0	0.2	0.3	0.2	0.1	0.05	0.1	0.3	0.16	0.12	0.0	0.05	0.3	0.13	0.1
K^+ (mg/L)	0.5	1.3	0.4	0.3	0.3	0.1	0.8	0.6	0.3	0.33	0.1	0.3	0.4	0.3	0.19
SO_4 (mg/L)	0.0	0.0	0.6	1.1	1.1	0.65	0.6	0.8	0.85	0.9	0.7	0.5	0.84	1	0.7
P_{total} (mg/L)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Higher water surface temperatures were observed in less rainy months (May, August and November). The highest value for this attribute was observed in point 2, in the month of May 2019 (28.5°C). This collection point is characterized as the point where the pasture present in the experiment area ends, there is a canopy opening and exposed soil, in addition the stream is shallower. These factors influence the thermal stability of the air, where the water suffers direct incidence of sunlight and intensified wind flow, indicating an increase in the temperature of the water column (SANTOS et al., 2011).

Although the water temperature is not included in CONAMA Resolution No. 357/2005, it is known that this parameter is fundamental in determining the quality in a body of water. Several studies show the proportional relationship between temperature and the change in dissolved oxygen, speed of chemical reactions and decomposition of organic matter, parameters that are fundamental for aquatic life (TAKEDA et al., 2011).

Total Dissolved Solids (TDS) and Electrical Conductivity (EC) are directly correlated (GOMES, 2009), which was also observed in this work. TDS and EC showed higher values in P3, downstream from the experimental area during the less rainy period (Table 2). Esteves et al. (2011) concluded that there is a reduction in the volume of the water body in drier periods of the year, resulting in a greater concentration of these ions and solids in the water. The average TDS values of point 1 were lower than all the other points (8.5 mg / L) and can be attributed to the fact that this point is located before the experimental area and is not influenced by the change in land use (ESTEVES et al., 2011). In addition, at this point there is no movement of cattle between the experiment and the intact vegetation cover, which favours the reduction of runoff (SILVA, 2001). According to CONAMA 357/2005 the maximum value for TDS is 500 mg L^{-1}, for Class II. In this work, both TDS and EC did not pass the maximum limit determined by the resolution.

The highest values of turbidity were observed in the months of February at all the evaluated points, a period with high rainfall in the region. It is known that when there is the occurrence of rain near the collection period, there is an increase in turbidity values as material from the banks of the stream are carried into the stream, increasing the turbidity of the water (LUÍZ et al. 2012). However, all samples taken under different rainfall regimes did not show values above what is acceptable under the resolution CONAMA 357/2005 for class II standards, which allows turbidity values up to 100 NTU.

These are satisfactory results to show the minimal influence of the implementation of CLFI systems on the physical quality of the water in the stream. Even with the use of NPK-based fertilizers in the implanted systems, there is no evidence that the excess of these nutrients leach into the water body, explained by the reduced values of TDS, EC and turbidity observed (TAKEDA et al., 2011).

The determinations of the chemical parameters showed that the changes corresponding to each variable analysed were caused mainly by the seasonality present in the study region, that is, influenced by the run off and frequency of precipitation, as well as by the morphological character of the stream.

The calculated pH values varied from 4.51 to 7.27 between 2018 and 2019. Although most of these values were not within the standards established by CONAMA 357/2005, these values are acceptable, since they represent the typical character of rivers in the Amazon basins and the Gurupi sub-basin (CATUXO et al., 2017). Point 3, in the months with the lowest rainfall, presented the highest pH values, however, tending towards neutrality, favourable for water quality. The other points presented pH values below 6 (Table 2). The amount of dead and decomposing matter has a great influence on the pH of the water and the greater the amount of organic matter available, the lower the pH, since during decomposition of this material many acids are produced (DA SILVA, 2013). The vegetation around the stream may also be responsible for the production of acids, resulting from the decomposition of organic matter. Another factor that increases the acidity of these waters is the geological formation and morphometry of the region's soil, based on ion leaching (CUNHA & PASCOALOTO, 2006).

Although sodium, calcium, magnesium and potassium cations are not used in the classification of water bodies or present in the guidelines for their classification, these variables are often studied to understand possible anthropic interference with the environment and the relationship with other water quality analyses, such as hardness, EC and TDS. For this study in Terra Alta, the determinations of the selected ions are not enforced by law, but presented concentrations well below those found in other Amazonian rivers (MIRANDA et al., 2009). For the cations evaluated, only total phosphorus and ammonia presented high values according to CONAMA 357/2005, but both variables remained below the established limit at all sampling times. Since they are below the maximum allowed, it is possible to state that they are in compliance with the resolution.

The same behaviour was observed for the anion concentrations in the study (nitrate, chloride and sulphate) (Table 2). Following the current legislation, none of these parameters can be considered harmful, without influencing the quality of the studied water. The changes during the seasonality of the region can be explained by the morphological characteristics of the water body and the dissolution of soils and rocks (CETESB, 2011).

From the low concentration of anions and cations in the studied water body, it is probable that the CLFI system implanted in the experimental area had a minimal effect on the levels of these ions in the stream. This is consistent with the fact that many studies have evaluated these parameters and conclude that the most probable sources of contamination are domestic and industrial effluents and fertilizer leaching (CETESB, 2011; DE LIMA et al., 2021).

Regarding the alkalinity results, the highest value obtained was at point 3 in the month of November 2018, with a value of 3.13 mg L^{-1} (Table 2). According to FUNASA (2014), most natural waters have alkalinity values in the range of 30 to 500 mg L^{-1} of. The obtained values can be considered low probably due to the effect of the decomposition of the organic matter from the surrounding vegetation, which produces acid (HILLEBRAND & BENETTI, 2020). This is consistent with the fact that the vegetation remained intact around collection points 1 and 3.

For the hardness values, the month of May in 2019 presented the highest average, with point 2 reaching 7.6 mg L^{-1} and for calcium and magnesium, the highest values were also observed in May 2019. The relationship of calcium and magnesium to hardness justifies the results, where the hardness of a water refers to the amount of dissolved calcium bicarbonates, carbonates, sulphates or chlorides of calcium and magnesium. All samples analysed in this study showed values below 8 mg L^{-1}, classified as mild or soft water, following the classification of FUNASA (2013).

The highest values of water acidity were observed in February 2019 (Table 2). Total acidity is represented by the content of free carbon dioxide (CO_2), mineral acids, organic acids and strong acid salts (NOGUEIRA-DE-ALMEIRA & RIBAS FILHO, 2018). According to FUNASA (2014), based on the pH found in this study, the form of acidity in the samples is carbonic acidity.

CONCLUSIONS

The systems present in the evaluated experimental area had minimal influence on the quality of the water body. There is no evidence of any negative environmental impact relating to these two areas in the study. Although the pH value varies from the established range of values, this lower pH can be attributed to the decomposition of organic material from the surrounding vegetation. In addition, these values are similar to those of other Amazonian water bodies. Thus, our study strongly suggests that a properly managed integrated system can generate sustainable productivity.

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PRODUCTION AND QUALITY OF UROCHLOA BRIZANTHA PASTURES GRAZED UNDER CONTINUOUS STOCKING IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS

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ABSTRACT

Season may change pasture responses even in innovative, sustainable crop-livestock-forest (ICLF) systems. The objective of this work was to evaluate production and quality of *Urochloa brizanta* cv. Piatã pastures grazed by buffaloes under continuous stocking in open pasture system (OP), ICLF with African mahogany (*Khaya ivorensis*) (ICLF-M) and ICLF system with teak (*Tectona grandis*) (ICLF-T) in the dry and rainy seasons. Forage mass was lower in the ICLF systems than in the OP system in the dry season. In contrast, ICLF-T system produced forage with higher crude protein content in this season. In the rainy season, no difference between systems was observed. ICLF systems may be less productive in forage than the OP system in the dry season. However, they can deliver forage with higher crude protein content in this season depending on the tree species.

Key words: Amazon; Buffalo; Humid Tropics

INTRODUCTION

Integrated crop-livestock-forest (ICLF) systems combine sustainable production of crops, grazing animals and forest species in a same area simultaneously or over time (BALBINO et al., 2011). By combining different economic activities, ICLF systems have been found to be a low risk, economically viable enterprise (MULLER et al., 2011; OLIVEIRA JUNIOR et al., 2016). For livestock, these systems can provide thermal comfort for grazing animals by decreasing the air temperature due to presence of trees, resulting in better animal welfare (KARVATTE Jr. et al., 2016). Furthermore, decrease in greenhouse gas emission (GHG) is a potential benefit of integrated systems for animal production, as found by Figueiredo et al. (2017), who estimated carbon (C) footprint for beef cattle at –28.1 kg CO_2eq per kg body weight in an ICLF system with eucalyptus, value expressively lower than those in managed pasture (of 7.6 kg CO_2eq per kg BW) and degraded pasture (18.5 kg CO_2eq per kg BW). Due to these and other economic advantages and environmental benefits, ICLF systems have been adopted at large scale in Brazil, covering an area of at least 11 million ha (ICLF NETWORK, 2019).

However, shade of trees can consecutively decrease photosynthesis and growth of tropical forage plants (DIAS-FILHO, 2000; DIAS-FILHO, 2002; GUENNI et al., 2008; GÓMEZ et al., 2012) and consequently influence both productivity and quality of forage in pasture under continuous grazing in ICLF systems. Studies conducted in the tropics have shown lower forage mass in integrated systems compared with open pasture (OP) systems, but this difference can depend on the season. Lima et al. (2019) found 36% less forage mass of *Urochloa decumbens* cv. Basilisk in a silvopastoral system with legume trees in relation to the OP system in the rainy season (summer). In the dry season (autumn), however, the forage mass was similar between the systems. For crude protein content, it was higher in silvopastoral system in both seasons. These results contrast with those of Santos et al. (2018), according to which the forage mass of *U. brizantha* cv. Piatã in two silvopastoral systems with eucalyptus was at least 27% lower than that in the OP system in both the rainy and dry seasons, but no difference was observed for the crude protein contents in forage between the systems. Such conflicting findings may be due to a complex interaction between systems and weather conditions in each season. Therefore, influence of season is a matter to be studied in ICLF systems.

The objective of this work was to evaluate production and quality of *Urochloa brizanta* cv. Piatã pastures grazed by buffaloes under continuous stocking in open pasture system (OP), ICLF with African mahogany (ICLF-M) and ICLF system with teak (ICLF-T) in the dry and rainy seasons.

MATERIAL AND METHODS

The field study was conducted in an Embrapa Amazônia Oriental's experimental station (01°01'33.4" S, 47°53'58.3" W, elevation 40 m) located in the Terra Alta municipality, state of Pará, Brazil. The local climate is Am (tropical monsoon) by the Köppen's classification. Mean annual precipitation ranges from 2300 to 2800 mm, with a mean annual temperature of 26°C (Moraes et al., 2005). The soil in this area is an *Argissolo Amarelo Distrófico textura arenosa/média* (Gama et al., 2000) (Ultisol) and it was being occupied with a degraded pasture of *Urochloa humidicola* (Rendle) Morrone & Zuloaga for a number of years previously to the beginning this study. This soil had the following characteristics in the layer of 0-20-cm depth before the installation of the study: pH in water (1:2.5 soil:water ratio) 5.4, OM (organic matter by the Walkley-Black method) = 17.76 g/kg, Mehlich-1 P = 1 mg/dm^3, exchangeable K = 0.07 cmol$_c$/dm^3, exchangeable Ca = 0.7 cmol$_c$/dm^3, exchangeable Mg = 0.4 cmol$_c$/dm^3, exchangeable Al = 0.5 cmol$_c$/dm^3, H+Al (potential acidity) = 3.3 cmol$_c$/dm^3, CEC (cation exchange capacity) at pH 7 = 4.5 cmol$_c$/dm^3, V (base saturation) = 26%, m (aluminum saturation) = 30%, sand = 779 g/kg, silt = 86 g/kg, and clay = 135 g/kg.

Two integrated crop-livestock-forest (ICLF) systems were installed in the study area in February 2009. A system was implanted with African mahogany (*Khaya ivorensis* A. Chev.) (ICLF-M) and the other with teak (*Tectona grandis* L. f.) (ICLF-T) as forest components since these species produce high-quality woods (WIEMANN, 2010). Initially, 1.5 t/ha of limestone was applied to the soil surface following a conventional soil tillage. Then three forest species strips spacing 50 m to each other were established in the area of each system. In the ICLF-M system, three rows of African mahogany with trees spacing 5 × 5 m were planted in each strip, while four rows of teak with trees spacing 3 × 3 m were planted in each strip in the ICLF-T system. For both forest species, fertilization consisted of 100 g P_2O_5 (reactive phosphate rock) per hole at planting, 25 g N (urea) and 25 g K_2O (potassium chloride) per plant in March 2009 and also 20 g N and 20 g K_2O (20-0-20) per plant in April 2009.

In both ICLF systems, maize (*Zea mays* L. cv. BRS 1030) was cultivated in the areas between tree strips in 2009, 2010, 2011, 2012 and 2013. Soil tillage was conventional in the first year, as cited above, and no-tillage system was adopted in the subsequent years. Fertilization in each year was carried out to supply 33 kg N/ha, 92 kg P_2O_5/ha and 66 kg K_2O/ha (10-28-20) at sowing, and 40 kg N/ha and 40 kg K_2O/ha (20-0-20) at top-dressing. Cowpea [*Vigna unguiculata* (L.) Walp cv. BRS Guariba] was only sown in the first year after harvest of maize as a second crop. No fertilizer was applied for cowpea.

In 2013, a pasture of *Urochloa brizantha* (Hochst. ex A. Rich.) R. Webster cv. BRS Piatã [syn. *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf cv. BRS Piatã] was established in the areas between the tree strips in both ICLF systems. Grass seeds were distributed together with the fertilizer applied at top-dressing for maize. In 2015, an open pasture (OP) of the same grass was also established in an area contiguous to the areas with ICLF systems in order to serve as a reference of conventional pasture system (i.e., only pastoral system, not integrated to other production systems). At the establishment of this pasture, 70 kg N/ha (urea), 110 kg P_2O_5/ha (triple superphosphate) and 60 kg K_2O/ha (potassium chloride) were applied.

In 2017, the areas between tree strips for each ICLF system were divided into four subareas. Similarly, OP system area was also divided into four subareas. Thus, the three production systems (OP, ICLF-M and ICLF-T) were replicated Divisions of the areas were done using electric fences, and mineral salt trough and water trough were shared every two subareas. Each subarea was considered as a paddock of approximately 0.6 ha. The ICLF-M and ICLF-T systems had trees with average height of 14.24 and 12.72 m and average diameter at breast height of 23.78 and 19.61 cm, respectively.

All pastures were mown and then fertilized in May 2017. For fertilization, 50 kg N/ha (urea), 50 kg P_2O_5/ha (single superphosphate) and 50 kg K_2O/ha (potassium chloride) were applied. No fertilizer was subsequently applied to the pastures until the end of this study. In July 2017, pastures were again mown at a height of 35 cm for standardizing the sward canopy height.

Pastures were grazed from July 2017 to April 2018 (252 days) by buffaloes (*Bubalus bubalis* L.) under continuous stocking with variable stocking rate. Two tester steers at age of 18 months and each one weighting 332 kg [standard error of the mean = 14 kg, n = 24] were put into each paddock. However, only one animal was maintained until October 2017 in the ICLF-M system's paddocks in order to stimulate the plant growth in sward patches with a very low canopy. Additional buffaloes (regulator animals) were occasionally put into and take from the paddocks (i.e., put-and-take stocking) as an attempt to maintain the canopy height by about 35 cm. All animals received both mineral salt and water freely.

Ten points in the pasture in each paddock were selected randomly every 28 days July 2017 to April 2018. In each point, plants in an area of 0.25 m^2 (0.50 ´ 0.50 m) were cut at the soil level. Plant samples collected in each paddock were bulked, and three subsamples were taken. Subsamples were then oven-dried at 65°C until constant weight. The weighted plant material was used to estimate the forage mass. Crude protein in forage was calculated by multiplying the total nitrogen (TN) content by 6.25, with TN determined by the Kjeldahl method (AOAC, 1990).

Data were analyzed using a randomized complete block design with four replicates, each one allocated in a paddock. Replicates were considered as blocks in order to capturing possible variability among paddocks. Effects of production systems were tested using an analysis of variance (ANOVA) performed for each season (dry and rainy). When F test showed significance means were compared according to the least significant difference (LSD). Spearman's correlation was processed between selected variables. All analyses were performed at $P < 0.05$ using the R software (R Core Team, 2018).

RESULTS AND DISCUSSIONS

There was difference in forage mass between production systems in the dry season (Figure 1a), with OP having greater mass as compared with the ICLFs systems. However, for rainy season, no difference was observed among the systems (Figure 1b). The greater forage mass in the OP system compared with ICLF systems was probably a consequence of a low (re)growth of plants in these integrated systems due to shading imposed by trees. Similar results were obtained by Santos et al. (2018) for the same grass used in this study (i.e., Piatã grass) in silvopastoral systems with *Eucalyptus urograndis* as tree species. Lima et al. (2019) have also found lower forage mass of other *Urochloa* species (*U. decumbens*) in a long-term silvopastoral system with three tree species (*Acacia mangium, Eucalyptus grandis* and *Mimosa artemisiana*) as compared with a OP.

Severe decrease in growth of genus *Urochloa* grasses has been found under shading conditions (CASTRO et al. 1999; DIAS-FILHO, 2000; GUENNI et al., 2008; GÓMEZ et al., 2012). The mechanisms that account for this decreased growth are not fully understood. However, decline in net photosynthesis rate (DIAS-FILHO, 2002) accompanied by less tillering and reduced relative growth rate (DIAS-FILHO, 2000) resulting in lower shoot dry matter (GUENNI et al., 2008; GÓMEZ et al., 2012) have been observed in shaded *U. brizantha*. In addition, this species submitted to shading has shown lower total nonstructural carbohydrate (TNC) content in stem base due to negative impact on photosynthesis derived of decrease in incident light (CASTRO et al., 1999). As a consequence, regrowth of shaded *U. brizantha* can be affected negatively, since TNC is potentially important in recovery of forage plants defoliated by cut or grazing animals, especially when a considerable proportion of leaves are removed (PEDREIRA et al., 2000). All these negative effects associated with shading may have occurred in the ICLF systems tested in the present study. Although the degree of shading was not determined as it did in the work of Lima et al. (2019), who have measured photosynthetically active radiation (PAR), shade due to trees in these systems covered by about one-third of paddock area. This relatively extensive shade cover may then have inhibited grass growth such that the forage mass in the whole paddock was decreased as we found. However, less forage mass in the ICLF systems occurred only in the dry season, which suggests a seasonal fluctuation for the effect of shading on forage mass.

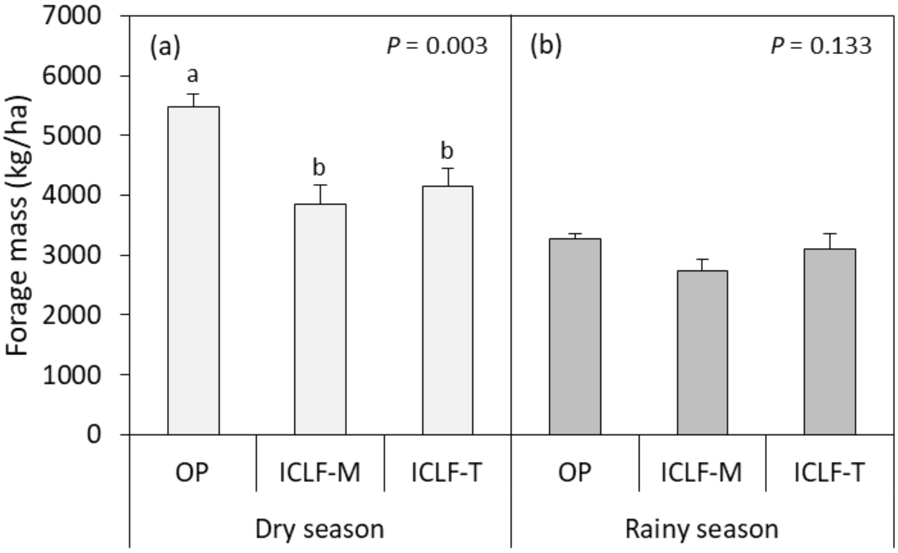

Figure 1. Forage mass of *Urochloa brizanta* cv. Piatã grazed by buffaloes under continuous stocking in open pasture system (OP), integrated crop-livestock-forest system with African mahogany (ICLF-M) and ICLF system with teak (ICLF-T) within the dry season (Jul-Nov 2017) (a) and the rainy season (Dec 2017-Apr 2018) (b). *P*-value: probability for the *F* test from ANOVA. Different letters on the bars within the dry season indicate difference between means according to LSD ($P < 0.05$). Bars without letters within the rainy season indicate *F* test from ANOVA not significant ($P > 0.05$). Lines on the bars represent standard error of the mean.

The systems also influenced the crude protein content in forage but only in one of the seasons. Crude protein in the ICLF-T system was higher than those in the OP and ICLF-M systems in dry season (Figure 2a). However, in the rainy season, no difference was observed among the systems (Figure 2b). Shading also seems to have been the cause of the higher crude protein content in forage in the ICLF-T system in the dry season. Increase in crude protein in *Urochloa*-grass pastures shaded by trees at silvopastoral systems have been found in other studies (PACIULLO et al., 2007; FARIA et al., 2018; LIMA et al. 2019). Several factors have been pointed out to explain this phenomenon (LIMA et al. 2019). However, the "concentration effect" of N in forage is believed to have been a important factor in this work, since the crude protein content, which is proportional to N content, was negatively correlated with the forage mass in the the dry season ($r = -0.5874$, $P = 0.049$, $n = 12$).

The greater crude protein content found in forage of the ICLF-T can be considered an advantage for nutrition of animals grazing in this system. This is especially important because the increase occurred in the dry season, when the forage nutritive value, particularly in terms of crude protein, is generally low as compared with that in the rainy season. The less crude protein content in forage in the ICLF-M system than in the ICLF-T system is likely a consequence of apparent difference in shading between the tree species. African mahogany canopy was visually less dense than that of teak, resulting in a shade less uniform for the former in relation to the last. As a result of this less uniformity, more light reached the sward canopy in the ICLF-M system, thus limiting the concentration effect of N and consequently the accumulation of crude protein in forage. This greater crude protein content in forage in the ICLF-T system in relation to the ICLF-M system indicates that the effect of ICLF system on crude protein could be dependent on tree species.

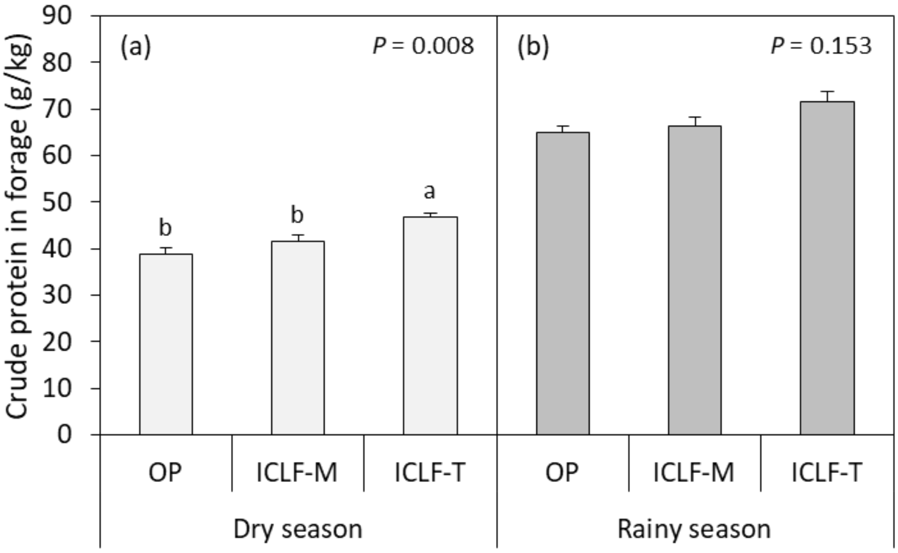

Figure 2. Crude protein in forage of *Urochloa brizanta* cv. Piatã grazed by buffaloes under continuous stocking in open pasture system (OP), integrated crop-livestock-forest system with African mahogany (ICLF-M) and ICLF system with teak (ICLF-T) within the dry season (Jul-Nov 2017) (a) and the rainy season (Dec 2017-Apr 2018) (b). *P*-value: probability for the *F* test from ANOVA. Different letters on the bars within the dry season indicate difference between means according to LSD ($P < 0.05$). Bars without letters within the rainy season indicate *F* test from ANOVA not significant ($P > 0.05$). Lines on the bars represent standard error of the mean.

CONCLUSIONS

ICLF systems may be less productive in forage than the OP system in the dry season. However, they can deliver forage with higher crude protein content in this season depending on the tree species. In the rainy season, all these differences tend to be eliminated.

ACKNOWLEDGMENTS

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PERFORMANCE AND PRODUCTIVITY OF BEEF CATTLE IN OFF-SEASON PASTURE

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ABSTRACT

The crop-livestock integration system is a practice that aims at sustainability within the production chain of beef cattle. The objective of this study was to evaluate the performance and weight gain of beef cattle subjected to management in pastures of *Brachiaria brizantha* cv. BRS Piatã and *Brachiaria brizantha* cv. Paiaguás. A total of 5,656 animals were followed, being 3,280 crossbred (½ Angus & ½ Nelore) and 2,376 Nelore in a 1,900 hectares pasture area divided into 40 pickets of approximately 47.5 hectares each. The animals were weighed at the entrance and exit of the areas. The off-season pasture provided greater daily weight gain (0.800 kg/animal/day in crossbred animals and 0.717 kg/animal/day in Nelores). In relation to the productivity of kg of meat per hectare, higher production was observed in cv Piatã when compared to cv Paiaguás (97.98 kg/ha and 73.53 kg/ha, respectively). The use of off-season pasture increased the production capacity of the system, providing higher meat production and lower environmental impacts.

Key words: Gain; Crop-livestock integration; Sustainability

INTRODUCTION

Agribusiness is one of the sectors that has sustained the economy in Brazil, in 2020 had a growth of 24.31% equivalent to an increase of 387 billion, among this growth the branch of livestock had an increase of 24.56% (CEPEA, 2020). Being a sector that has such a large participation in the national economy, in recent years much has been demanded about a more sustainable production. Within this context the adoption of new technologies and breeding systems has intensified in beef cattle breeding.

The crop-livestock integration system (SILC) is one of the practices that aim for sustainability within the production chain, it allows grain production and animal breeding in the same area, which enables the increase in farm productivity without the need to increase the production area, thus reducing the demand for opening new areas for the implementation of pastures or crops.

The SILC also has the benefit of nutrient cycling, since cattle return to the environment via feces and urine part of the nutrients consumed, redistributing them in the soil. The cycling of certain nutrients such as K, for example, increases with grazing intensity (FERREIRA et al., 2011).

This integration when well employed provides biological and economic advantages, such as: high nutrient cycling, improved soil quality, income diversification, reduced risks of economic failure and increased income per area when compared to non-integrated systems (BALBINOT JUNIOR et al., 2009).

However, the objective of this study was to evaluate the performance and weight gain of beef cattle subjected to management in off-season pastures of *Brachiaria brizantha* cv. BRS Piatã and *Brachiaria brizantha* cv. Paiaguás cultivars.

MATERIAL AND METHODS

The study was conducted at São Miguel da Catequese farm, in the Nova Andradina / Mato Grosso do Sul, in the months of May to November 2017. A total of 5,656 animals were followed, being 3,280 crossbreds (½ Angus & ½ Nelore) and 2,376 Nelores in an area of 1,900 hectares of pastures divided into 40 paddocks of approximately 47.5 hectares each. The pastures were implemented after the soybean harvest (off-season pasture) in February/2017 by serial and mechanical sowing of the cultivars Piatã and Paiaguás.

To monitor the performance and weight gain of the animals, they were weighed at the entrance and exit of the areas, always after fasting for 12 hours. Batches of animals standardized in breed and weight were prepared weekly and transferred to the areas according to the time of implementation of the pastures, and the first batches entered the pastures approximately 100 days after sowing.

In order to remove the animals from the off-season pasture area in time for the agricultural practices of summer farming, and in order to be ready for sale and shipment to the slaughterhouses on the removal date, we applied as an estimate a daily weight gain of 800 g and a maximum permanence period of 150 days for the animals in the system. Thus, homogeneous lots of breed and weight were prepared, observing the entry weight of animals above 420 kg.

In order to evaluate the nutritional value of pastures, monthly collection of the paddocks was performed using the simulated grazing method and for the availability measurements the visual observation methodology was applied (HAYDOCK & SHAW, 1975).

Animal performance was evaluated using an entirely randomized design, considering the average gain of the animals in the batch as the measure to be compared. The T-Student test was applied at the 5% level to compare the mean weight and weight gain of the animals.

RESULTS AND DISCUSSIONS

The use of off-season pasture provided greater daily weight gain (DWG), and decreased the fattening time, DWG of 0.800 kg/animal/day was observed in crossbred animals and 0.717 kg/animal/day in Nelores (Table 1). Evaluating the effect of different types of supplements in the termination of Nelore cattle on *Brachiaria decumbens* pasture, Andrade et al. (2015) found a DWG of 0.42 kg/animal/day with protein-energy-mineral supplement, a gain 52.5% higher in the off-season pasture when compared to conventional.

In conventional systems, the daily gain in the dry period with the inclusion of 0.3% protein and energy supplement in the diet, ranged between 188 and 370 g/animal/day, values well below the results found in this study (HOFFMANN et al., 2014).

Weight gain may be associated with better quality forage, as it benefits from the residual fertilization of tillage and the chemical condition of the soil, which consequently enables significant gains per animal, thus meeting the nutritional requirements of the slaughter weight is achieved more quickly, and thus decreasing the fattening time, as observed in this study (ALMEIDA et al., 2015).

A genetic group effect (Crossbred x Nelore) was observed in DWG (Table 1). This effect may be associated with the productive potential resulting from the high level of heterosis and complementarity between breeds that originated from crossbreeding between the *Bos taurus* and *Bos indicus* groups (TOFFANI et al., 2010).

Table 1. Daily weight gain (kg/animal/day) of cattle on off-season pasture in the period from 05/13 to 11/13/2017 of crossbred steers (½ Angus & ½ Nelore) and Nelores.

Iten	Breed		P-value
	Crossed	Nelore	
Average	0.800^{a}	0.717^{b}	0.043
Standard deviation	0.171	0.150	
Iten	**Forrage**		**P-value**
	Piatã	Paiaguás	
Average	0.764^{a}	0.666^{b}	0.041
Standard deviation	0.188	0.187	

[a] Averages in the row followed by the same letter do not differ statistically.

Dias et al. (2015) when comparing pre-weaning performance between genetic groups: Nelore and ½ blood Angus-Nelore (F1) also found significant differences in DWG (0.683 ± 0.08 and 0.821 ± 0.14, respectively).

Regarding the productivity of kg of carcass per hectare, higher production was observed in cv Piatã when compared to cv Paiaguás (97.98 kg/ha and 73.53 kg/ha, respectively), this result can be justified by the contents of CP and TDN that were higher in cv Piatã (Table 2). Sekiya (2019) working with the same cultivars in SILC found no significant differences for animal performance as well as in the chemical composition of the cultivars.

Table 2. Livestock production, gross values in reais per area and nutritional value of off-season pastures with cvs. Piatã and Paiaguás between May and November 2017.

Item	**Forrage**				**P-value**
	Piatã		**Paiaguás**		
Kg body weight per hectare	188.42^{a}		141.41^{b}		0.038
Kg carcass per hectare[1]	97.98^{a}		73.53^{b}		
@ per hectare	6.53^{a}		4.90^{b}		0.041
R$ per hectare[2]	1,959.60		1,470.60		
	Nutritional Value				
Crude protein[3]	19.0	10.7	14.6	9.2	
Total digestible nutrients[3]	58.4	55.4	55.9	54.1	
Neutral detergent fiber[3]	61.0	68.2	66.8	71.3	
Dry Matter (ton/hectare)	7,83	1,74	6,95	2,38	

[a] Averages in the row followed by the same letter do not differ statistically; [1] Yield considered to be 52%; [2] Considering current @ values of R$ 300.00; [3] Values based on dry matter (%).

Off-season pasture decreases fattening time and increases productivity in kg of carcass per hectare. Other advantages have been observed, such as the decrease in methane emission in the cycle due to the better nutritional value of the forage and consequent weight gain. The animal gaining weight faster and earlier will reach its slaughter weight and thus less food will be consumed throughout the cycle, consequently reducing the emission of enteric methane, resulting in less CH_4 per kg of meat produced (BERCHIELLI et al., 2012).

CONCLUSIONS

The use of off-seson pasture has increased the production capacity of the system, providing higher meat production and lower impacts on forests and deforestation, consequently improving sustainability.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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FORAGE CANOPY STRUCTURE IN PASTURE SYSTEMS COMPOSED OF DIFFERENT TYPES OF PROTEIN SUPPLEMENTATION

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ABSTRACT

The use of forage grass and legume grass-based pastures and the use of protein supplementation can contribute to the sustainability of animal production systems and ensure innovation of management methods with greenhouse gas mitigation potential. The objective of this work was to evaluate the structure of the pasture forage canopy with different types of supplementations in continuous stocking in summer and winter 2020.The study was conducted in an experimental area belonging to the Institute of Animal Science, located in the Nova Odessa/SP. The treatments were composed of pasture systems with three different types of protein supplementation: 1) exclusively marandu grass pasture (*Urochloa brizantha* cv. Marandu) (without supplementation (G); 2) marandu grass pasture plus protein supplementation (G + P); and 3) pasture with legume (*Macrotyloma axillare*) (G + L). The canopy structure was evaluated by determining the vertical distribution of morphological components using the "inclined point" method at each evaluation week. The treatment G + L showed a higher percentage of leaves and branches of the macrotiloma legume composing the canopy structure in the summer. The different treatments and times of the year influenced the proportion and percentage of each morphological component that composes the structure of the forage canopy.

Key words: Consorcised pasture; inclined point; *Macrotiloma axilar*

INTRODUCTION

The use of forage grass and leguminous grass-based pastures and the use of protein supplementation can contribute to the sustainability of animal production systems and ensure innovation of management methods. The variable growth of tropical grasses throughout the year varies widely in their quality and amount of forage mass produced and during the rainy season, these plants grow rapidly; in the dry season, they grow more slowly, among these and other factors, the management of the pasture structure is determinant for the pastoral ecosystem, since it determines the dynamics in the plant community (growth and botanical and morphological composition) in the grazing process of the animals.

In this context, the evaluation of the structure of the forage canopy in response to grazing management can contribute to the understanding of the adaptive responses of the plants since they determine the evolution and modification of the spatial arrangement and distribution of morphological components (leaf, stem, dead material) in the canopy profile. In view of the above, the objective of this work was to evaluate the structure of the forage canopy and the vertical distribution of its components in marandu grass pastures associated with macrotiloma legumes, supplemented pastures and exclusive pastures of marandu grass in two seasons (summer and winter), maintained in continuous stocking with cattle.

MATERIAL AND METHODS

The experiment was carried out at the Animal Nutrition and Pasture Research Center of the Institute of Animal Science, belonging to the São Paulo Agency for Agribusiness Technology (APTA), of the Department of Agriculture and Supply of the State of São Paulo.

Twelve Jersey heifers submitted to the continuous grazing system were used in each collection, which were randomly distributed in six grazing units, two animals per picket, composed of 0.5 ha each submitted to three different treatments: 1) pasture with legume intercropping (*Macrotyloma axillare* access NO 279) and grass (*Brachiaria brizantha* cv. Marandu) (G+L), 2) grass pasture (*Brachiaria brizantha* cv. Marandu) with protein supplementation (G+P) and 3) grass pasture (*Brachiaria brizantha* cv. Marandu) without supplementation (G), each treatment was distributed in a randomized complete block design.

The experimental period lasted one year and data were collected within each season of the year: Summer (Period I): 14/01/2020 to 14/02/2020 and Winter (Period II): 17/08/2020 to 23/09/2020.

The structure of the forage canopy was evaluated by the vertical distribution of the botanical and morphological components of the forage mass using the "inclined point" method (Warren-Wilson, 1960) during the weeks of the experimental period. he height of occurrence of each touch was recorded from readings performed on the graduated rod of the device, and the components were classified into leaves/folíolos, stems/branches and dead material of each of the two species under study (grass and legume) and invasive plants (any plant that was not marandu grass and legume-macrotiloma), until the tip of the stem touched the soil, and this last reading was used as a reference for the adjustment of the other readings. At least 50 touches were performed per experimental unit.

The data obtained were expressed in percentages of the different morphological components in the different vertical strata for each pasture condition and based on these data, graphs were generated to describe the structure of the forage canopy.

RESULTS AND DISCUSSIONS

It is observed that in the pastures of marandu grass treatment conorded with the legume-macrotiloma (G + L) in the summer season, water period, there was a greater distribution of legume leaves by the upper and intermediate stratum of the forage canopy. In the lower stratum, the fractions of dead material of marandu grass and legumes predominated (Figure 1). The legume-macrotiloma integrating the upper stratum of the forage canopy is explained by presenting a habit of fickle growth for the search for light and conditioned in summer (CASAGRANDE et al., 2014). Therefore, its presence composing the structure of this treatment (G + L), favors the system of sustainable animal production to pasture, as it has been shown as a good option for the integration of consortia with tropical grasses due to the biological fixation capacity of atmospheric nitrogen of this family, from the symbiotic associations with N_2-fixing bacteria present in the soil and that result in the contribution of expressive amounts of this nutrient in the soil-plant system. In addition, there are studies that prove its effect in reducing enteric methane emissions and increasing the production of forage mass in intercropping with tropical grasses (SOUZA et al., 2016; FIORELLI et al., 2018; LIMA et al., 2018; TERRA et al., 2019).

Pastures of marandu grass and protein supplement treatments (G + P) and exclusive pastures of marandu grass (G) showed a higher proportion of morphological components slides, stems and dead material of marandu grass distributed along the stratum of the forage canopy, as shown in Figure 1 – water season – summer and Figure 2 – winter drought season.

According to Reis et al. (2009), by supplementing the diet of grazing animals (in the period of water or droughts), there is no reduction in the population density of tillers, maintaining the formation of the pasture structure and thus avoiding a future degradation of the pasture, contributing as a form of sustainable management.

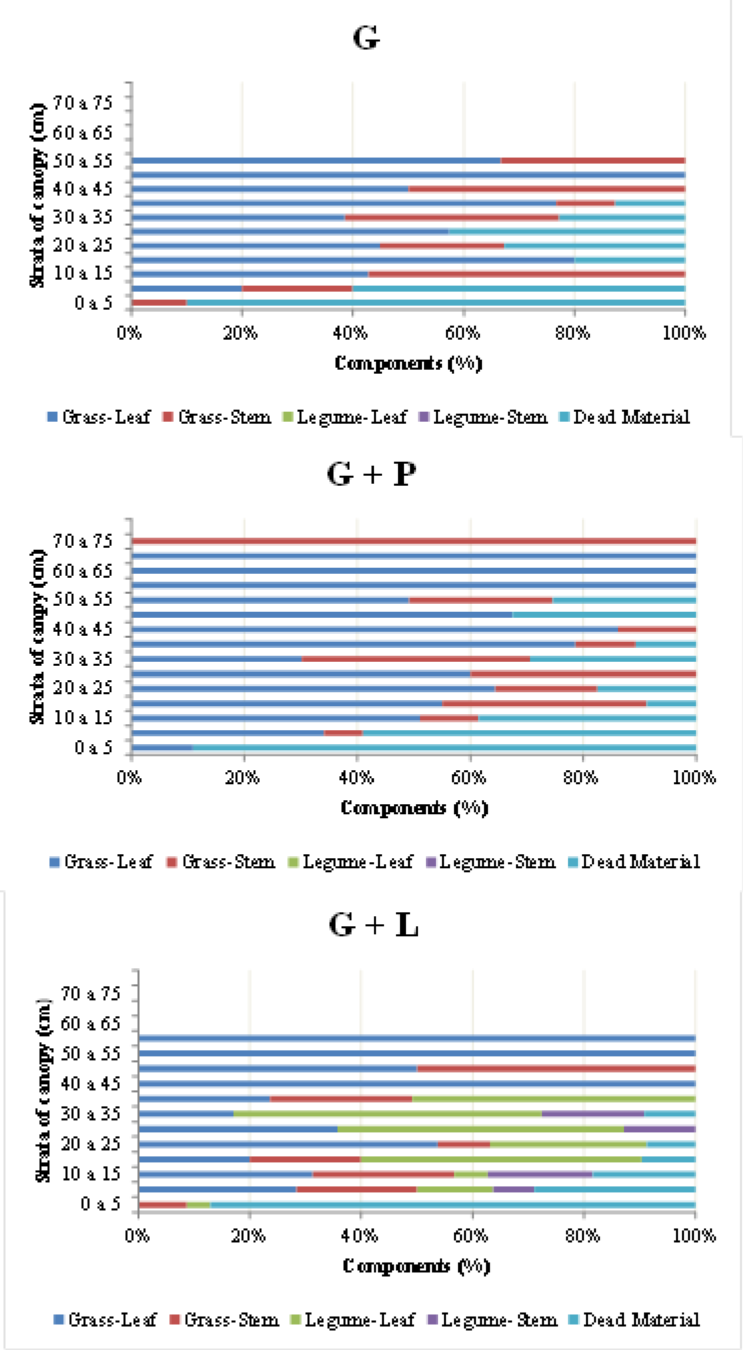

Figure 1. Vertical distribution of the proportion of touches of the morphological components: Grass-Leaf, Grass-Stem, Legume-Leaf, Legume-Stem and Dead material, in every 5 cm in pastures of exclusive pastures of marandu grass (G), pastures of Marandu protein grass (G + P) and marandu grass and legume-macrotiloma (G + L), subjected to continuous stocking in the summer of 2020.

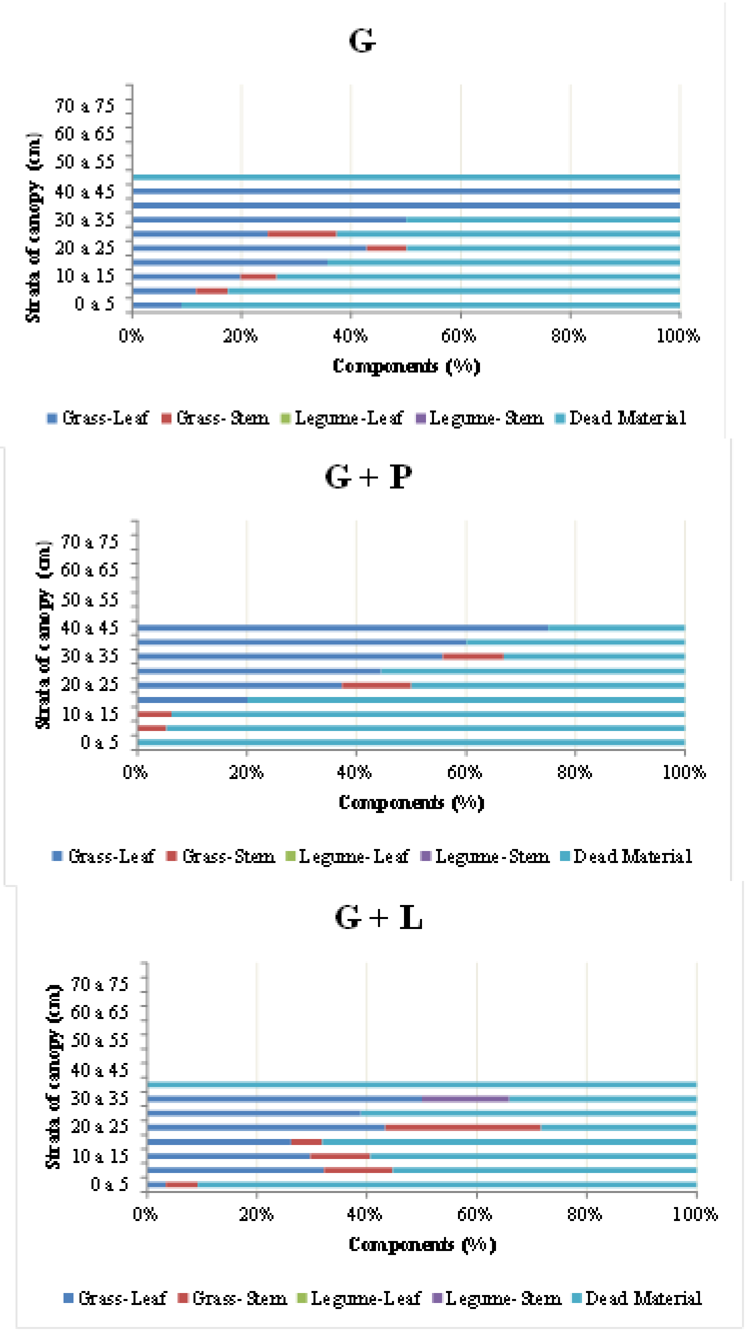

Figure 2. Vertical distribution of the proportion of touches of the morphological components: Grass-Leaf, Grass-Stem, Legume-Leaf, Legume-Stem and Dead material, in every 5 cm in pastures of exclusive pastures of marandu grass (G), pastures of Marandu protein grass (G + P) and marandu grass and legume-macrotiloma (G + L), subjected to continuous stocking in the winter of 2020.

CONCLUSIONS

The structure of the canopy is influenced by grazing management and stational factors modify its spatial arrangement.

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SOYBEAN YIELD AND NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) IN NO-TILL SEEDING AFTER CORN INTERCROPPED WITH DIFFERENT FORAGE SPECIES

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ABSTRACT

One of the challenges to direct seeding system (DSS) is to obtain good amount of soil cover residue during the offseason. Soybean seeding over forage species as cover crops has been highlighted as a strategy to increase the nutrient cycling and efficiency. The aim of this study was to evaluate the soybean yield and normalized difference vegetation index (NDVI) on soybean cultivated in succession to different forage species. The treatments were: (1) Corn in monoculture, (2) Corn intercropped with *U. ruziziensis*, (3) *U. ruziziensis* in monoculture, (4) Corn intercropped with *U. brizantha* cv. Marandu, (5) *U. brizantha* cv. Marandu in monoculture, (6) Corn intercropped with *U. brizantha* cv. BRS. Paiaguás, (7) *U. brizantha* cv. BRS. Paiaguás in monoculture and (8) fallow (no cover crops). NDVI had statistical difference only for treatment in fallow. Thus, the absence of cover crops affected soybean NDVI and consequently the soybean yield. Higher soybean yield was seen on mulch of corn with *U. ruziziensis* (5.988 kg ha^{-1}) and corn with *U. brizantha* cv. BRS Paiaguás (5.681 kg ha^{-1}) and the lowest yield was on mulch of *U. brizantha* cv. Marandu in monoculture (4.810 kg ha^{-1}). This can be related to higher biomass production and consequently higher nutrient cycling in intercropping systems than monoculture.

Key words: Cover crops; GreenSeeker; Direct seeding system

INTRODUCTION

One of the challenges for direct seeding system (DSS) is having a good soil covering during the offseason, mainly due the edaphoclimatic conditions of Brazilian savannah (PACHECO et al., 2008). Different species of cover crops are an alternative to surplus this demand. Thus, cover crop traits as nutrient releasing dynamic and residue permanence on soil affects directly the system success (KLIEMANN et al., 2006).

Soybean seeding over forage cover crops is highlighted as an important management strategy, as these plants absorb nutrients from deep soil layers and release lately in soil superficial layer by residue decomposition enhancing DSS efficiency (DUDA et al., 2003). Calonego (2017), comparing soil chiseling and cover crops, observed higher soybean yield on cover crops after the second year of cultivation. Fialho (2020) showed higher yield already at first year, demonstrating that cover crops benefits depend on management and species used.

Food production by conservation agriculture can reduce soil degradation and increase production in a sustainable way, as showed by Brown et al. (2018), the conventional tillage reduced soybean and corn yield compared to no-till system. Ribeiro et al. (2020) observed higher soybean yield in direct seeding over *U. ruziziensis* mulch, besides the positive effect of cover crops on soil base saturation, organic matter and nutrient content in deep soil layers.

Normalized Difference Vegetation Index (NDVI) is a tool to monitor soybean crop (RISSO et al., 2012), which can identify color intensity emitted by plants. This index can indicate a response to fertilization (ARANGUREN; CASTELLÓN; AIZPURUA, 2018), growth stage (YUN et al., 2015) and yield estimates (YUN et al., 2015). Thus, the objective of this study was to evaluate the soybean yield and NDVI values on soybean cultivated in no-till system with mulch of previous corn crop and different forage species.

MATERIAL AND METHODS

The trial was conducted in Rio Verde – GO in experimental field of Grupo Associado de Pesquisa do Sudoeste Goiano - GAPES (17°52'12.83"S, 50°55'38.99"O) (Figure 1) during the second crop season of 2020 (cover crops) and first crop season of 2021 (soybean). Soybean was sown in October 17 of 2020 and harvested in February 19 of 2021.

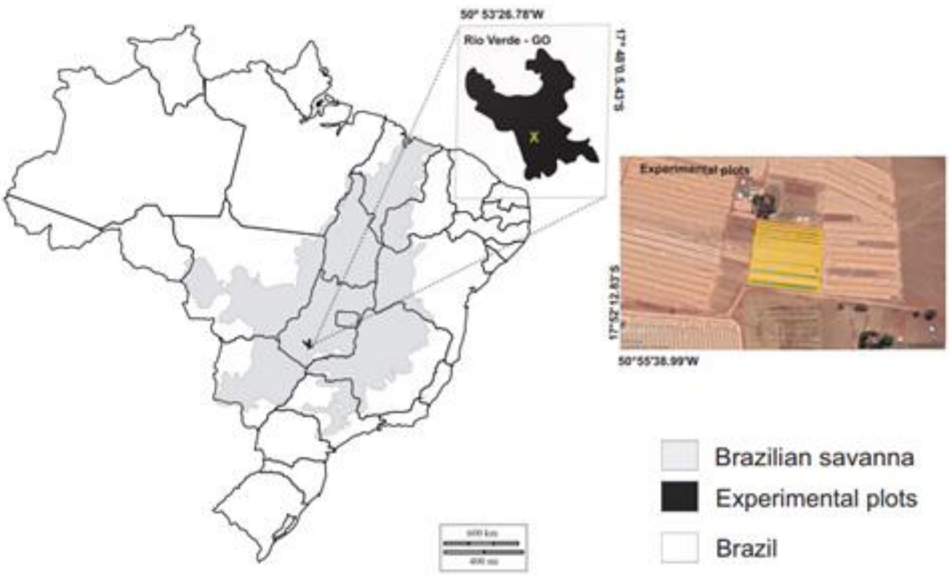

Figure 1. Experimental field localized at Experimental Station of GAPES (Grupo Associado de Pesquisa do Sudoeste Goiano). Rio Verde, GO, Brazil.

Cover crops were sown in March 17th of 2020. Forage species were sown at the same time of corn sowing, using a fine seeding coupled at front of the tractor and a seed drill with 0.5 m spaced rows. The corn seeding rate was 50,000 seeds per hectare and forage species seeding rate was five kilograms of pure viable seeds per hectare (PVS ha^{-1}). The seeding rate for forage species in monoculture was 10 kg PVS ha^{-1}.

The treatments were allocated in ranges of 30 m x 50 m (1500 m^{2}) randomized in the field. The treatments were the cover crops as following: (1) Corn in monoculture, (2) Corn intercropped with *U. ruziziensis* (*Syn. Brachiaria ruziziensis*), (3) *U. ruziziensis* in monoculture, (4) Corn intercropped with *U. brizantha* cv. Marandu (*Syn. Brachiaria brizantha*), (5) *U. brizantha* cv. Marandu in monoculture, (6) Corn intercropped with *U. brizantha* cv. BRS Paiaguás, (7) *U. brizantha* cv. BRS Paiaguás in monoculture and (8) fallow (no cover crops). Corn was harvested in June of 2020. Seventy-four days before soybean seeding, cover crops were desiccated to mulch formation.

Soybean yield were estimated collecting 12 samples of 3 m² per treatment. NDVI values were measured with GreenSeeker® in three soybean growth stages (R2, R3 and R5), with 12 repetitions in each stage and each treatment. The NDVI measurements were done always at same time of the day (CRUSIOL et al., 2013). The results were evaluated using software R (R CORE TEAM, 2020), using *car* (FOX & WEISBERG, 2019) and *emmeans* packages (LENTH et al., 2020). Least square means were compared by Tukey test ($p<0.05$).

RESULTS AND DISCUSSIONS

Corn with *U. ruziziensis* (5,988 kg ha^{-1}) and corn with *U. brizantha* cv. BRS Paiaguás (5,681 kg ha^{-1}) proportionated higher soybean yield compared to *U. brizantha* cv. Marandu in monoculture (4,810 kg ha^{-1}) (Table 1). Monoculture led to lower soil covering, therefore the DSS benefits as nutrient cyling and erosion control are diminished (GRANDO & CAMPO, 2019). Almeida et al. (2020) also found higher soybean yield (3,400 kg ha^{-1}) in succession to corn and *U. ruziziensis* intercropping compared to treatments with only corn straw and *U. ruziziensis* in monoculture.

Even the lowest yield observed here was higher than average productivity in Goias State (3,322 kg ha $^{-1}$) (CONAB, 2019), highlighting the benefits of cover crops.

The fallow treatment had lower NDVI values in all soybean stages (R2, R3 and R4) (Table 1). Therefore, the absence of soil covering impaired soybean growth up to reproduction stages. Fialho (2020) stated that without cover crops, there is space to weed growth, which did not cover soil efficiently and impaired soybean sowing and establishment. High NDVI values suggest a good initial establishment of soybean leading to uniform stand (SOUZA, 2017). Silva et al. (2015), also comparing different cover crops, identified lower NDVI values for fallow treatment, agreeing with these results.

Table 1. Normalized difference vegetation index (NDVI) at different soybean reproductive stages (R2, R3 and R5) and soybean yield (kg ha^{-1}) in no-till system with mulch of different forage species.

Treatments	R2	R3	R5	Yield (kg ha $^{-1}$)
Corn in monoculture	0.764 a	0.867 a	0.899 a	5,198 bc
Corn + *U. ruziziensis*	0.769 a	0.873 a	0.903 a	5,988 a
U. ruziziensis in monoculture	0.717 c	0.872 a	0.902 a	5,228 bc
Corn + *U. brizantha* cv. Marandu	0.725 bc	0.859 a	0.906 a	5,059 bc
U. brizantha cv. Marandu in monoculture	0.722 bc	0.863 a	0.901 a	4,810 c
Corn + *U. brizantha* cv. BRS Paiaguás	0.843 a	0.870 a	0.900 a	5,681 ab
U. brizantha cv. BRS Paiaguás in monoculture	0.722 bc	0.863 a	0.899 a	5,230 bc
Fallow (no cover crops)	0.622 d	0.794 b	0.845 b	5,096 bc
SEM*	0.00841	0.00841	0.00841	161

a,b,c: Means followed by different letters at the same column differs by Tukey test ($p<0.05$). R2, R3, R5: NDVI measurement at different soybean reproductive stages. *SEM: standard error of the mean.

CONCLUSIONS

Soybean had higher yield in corn with *U. ruziziensis* mulch. Thefore, this intercropping system is a good alternative for corn production in the second crop season and mulch formation for soybean seeding in the following crop season.

Normalized difference vegetation index was a good parameter to identify plant responses to mulch conditions, being necessary more studies measuring NDVI at different soybean stages.

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WCCLF 2021

II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

May 4th and 5th, 2021 - 100% Digital

FORAGE NUTRITIVE VALUE IN CROP–LIVESTOCK–FORESTINTEGRATED SYSTEMS UNDER TREE MANAGEMENT

Willian Lucas BONANI [1]; Eduardo Lopes Fernandes da ROCHA [2]; Rolando Pasquini NETO [3]; Cristiam BOSI [4]; José Ricardo Macedo PEZZOPANE [5]; Alberto Carlos de Campos BERNARDI [6]; André de Faria PEDROSO [7]; Patricia Perondi Anchão OLIVEIRA [8]

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ABSTRACT

The objective of this study was to evaluate the nutritive value of pastures in agroforestry systems after trees thinning. The experiment was carried out from October 2016 to March 2018 at Embrapa Southeastern Livestock, in São Carlos, SP, Brazil. The experiment was composed by pastures of palisade grass (Urochloa brizantha “BRS Piatã”), under rotational stocking, in four systems: intensive (INT); crop-livestock (iCL), in which pasture was renewed annually with corn sowed simultaneously with palisade grass; livestock-forest (iLF); and crop-livestock-forest (iCLF). In the iLF and iCLF systems, eucalyptus trees (Eucalyptus urograndis clone GG100) were planted in April 2011, in single rows, with 15×2m spacing. In 2016, the trees were thinned, and the spacing was changed to 15×4m. Forage samples were obtained during six grazing cycles and crude protein (CP) and in vitro digestibility (IVDMD) were determined. The data were submitted to analysis of variance and comparison of means by the Tukey test (5%). The results showed the highest levels of CP for iLF and iCL (12.37, and 10.96%, respectively); for IVDMD there was no significant difference. It can be concluded that the pastures in the systems with trees showed higher nutritional value after the tree thinning.

Key words: crop-livestock-forest; crude protein; eucalyptus

INTRODUCTION

Brazilian cattle breeding is based on the use of areas composed by degraded pastures, characterized by low production and nutritional value, which need management techniques to promote the recovery of pastures and promote the improvement of productive capacity (CARVALHO et al., 2017). Several techniques can be used to promote the recovery of pastures, among them, several types of integrated systems, such as integrated crop-livestock (iCL), livestock-forest (iLF), agroforestry systems (SAF's) and crop-livestock-forest (iCLF) are good options (RODRIGUES, GIULIATTI & JÚNIOR, 2020).

According to Balbino et al. (2011), CLF systems can be defined as sustainable production strategies that integrate agricultural, livestock and forestry activities in the same area, through intercropping, succession or rotation, reducing the impact of agriculture on the environment. These systems consist of associations among grain crops, pastures, and native or planted trees, aiming to produce grains, fibers, wood, meat, milk and bioenergy (KLUTHCOUSKI & YOKOYAMA, 2003).

In established systems, depending on tree population density, excessive shading promoted by trees can impair the development of crops and pastures (PEZZOPANE et al., 2017). According to Almeida et al. (2011), pastures under shade present changes in their structure, such as: lower canopy height and forage mass, however, they present higher CP and IVDMD.

According to Luz (2019), the analysis of pasture dynamics within each season and during the dry and rainy seasons, can, for example, reveal what differences exist between the systems in each season, with grazing being a determining factor to decrease both the supply and the quality of forage in pastures over time, even if the conditions are not limiting for plant growth. It can also indicate if the grazing intensity in a specific period is leading the pasture to degradation in the studied systems. The absorption of mineral elements by plants has no direct relationship with light, however, the shading of trees over crops affects biological processes that can alter their mineral composition, such as photosynthesis, transpiration, and respiration, among others (CLARK, 1981; MENDES, 2013), which can have a negative impact on productive potential (competition for light).

For a balanced production between the constituents of the production system, trees management practices, as pruning and thinning, are necessary. Trees thinning is employed to improve the development of the remaining trees and provide higher light transmission to the understory pastures, increasing their productivity (PACIULLO et al., 2007; NICODEMO et al., 2016).

The objective of this study was to evaluate the effects of thinning eucalyptus trees on nutritive value of palisade grass in agroforestry systems.

MATERIAL AND METHODS

The study was carried out in crop–livestock–forest integrated systems at Embrapa Southeastern Livestock, São Carlos, São Paulo, Brazil (21°57'S, 47°50'W, 860 m a.s.l.), from October 2016 to March 2018. The local climate is classified as highland tropical (Köppen’s classification: Cwa), with two well-defined seasons, a dry season from April to September, with average temperature of 19.9 °C and 250 mm of accumulated rainfall; and a rainy season from October to March, with average temperature of 23 °C and 1100 mm of accumulated rainfall. The soil of the experimental area is a Dystrophic Red Latosol, with a sandy loam texture (FAO Classification: Hapludox, US Soil Taxonomy), according to Calderano Filho et al. (1998).

The experiment was conducted with four treatments with two repetitions (8 experimental units), presented in Figure 1. The four treatments consisted in four production systems: intensive (INT); crop-livestock (iCL), livestock-forest (iLF); and crop-livestock-forest (iCLF).

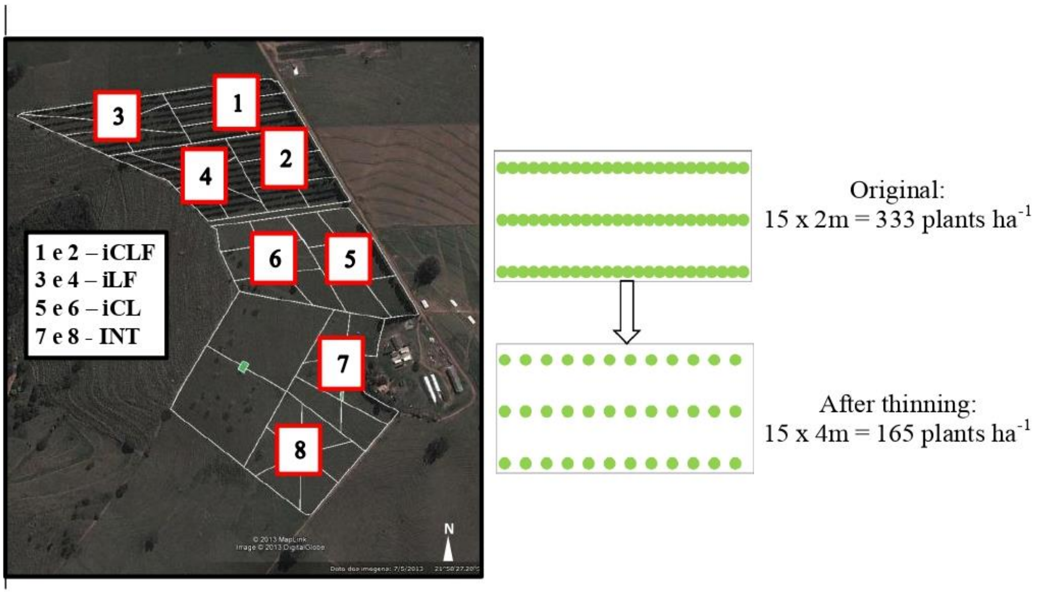


Figure 1. Image of the experimental area with the production systems used in the study (left) and representation of the distribution of trees in the iLF and iCLF systems (right). Intensive (INT); crop-livestock integration system (iCL); livestock-forest integration system (iLF); and crop-livestock-forest integration system (iCLF).

The pastures in the evaluated systems were established in 2011 and composed by *Urochloa brizantha* "BRS Piatã". In the iLF and iCLF systems, eucalyptus trees (*Eucalyptus urograndis* clone GG100) were planted in April 2011, in single rows, with a near east-west orientation and a 15 × 2m spacing (15m between rows and 2m between trees in the rows), which resulted in a population density of 333 trees ha^{-1}. In July 2016, trees were thinned, which consisted in cutting 50% of the trees in each row and spacing changed to 15 × 4m (165 trees ha^{-1}).

The experimental units of the systems were composed of 6 hectares, divided into six paddocks managed under rotational stocking, with cycles of 6 days of occupation and 30 days of rest. Annually, in the iCL and iCLF systems, pasture renovation was performed in two paddocks per integrated system. For this, corn (*Zea mays* L. hybrid AG 8690 PRO 3) was sown first, and palisade grass was sown after the corn was harvested for ensilage. The fertilization used for sowing and covering was calculated based on soil analysis and the expected productivity, after the crop was harvested, the pasture remained for later grazing of the animals. Grazing was performed by Nelore and Canchim (3/8 Nelore+5/8 Charolais) bulls, which were 11 months old and weighed 200 kg on average when put in the systems.

Pasture assessments were carried out in six growth cycles, representative of the seasons of the year, by cutting all the grass at ground level, in four sampling sites of 0.25 m^2 per repetition, with a metallic 0.5 × 0.5m square frame, randomly positioned for each treatment. Subsamples of 200 g were taken to determine dry matter content by drying in an air forced dry oven (60 °C, 72 h) and to determine nutritive value. For this, the subsamples were ground in a Wiley mill with a 0.5mm sieve and determined crude protein (CP) content and in vitro dry matter digestibility (IVDMD). The samples were analyzed by the Fourier transform-near infrared (NIR) technique using a spectrometer model NIRFlex N-500 with polarization interferometer (Büchi, Flawil, Switzerland). These measurements were performed using a calibration model developed and validated by Embrapa Southeastern Livestock ($R^2 = 0.944$ for CP, and $R^2 = 0.923$ for IVDMD) specifically for species and cultivars of *Urochloa spp*. The data were subjected to analysis of variance with the PROC ANOVA of SAS and comparison of means by the Tukey test at 5%.

RESULTS AND DISCUSSIONS

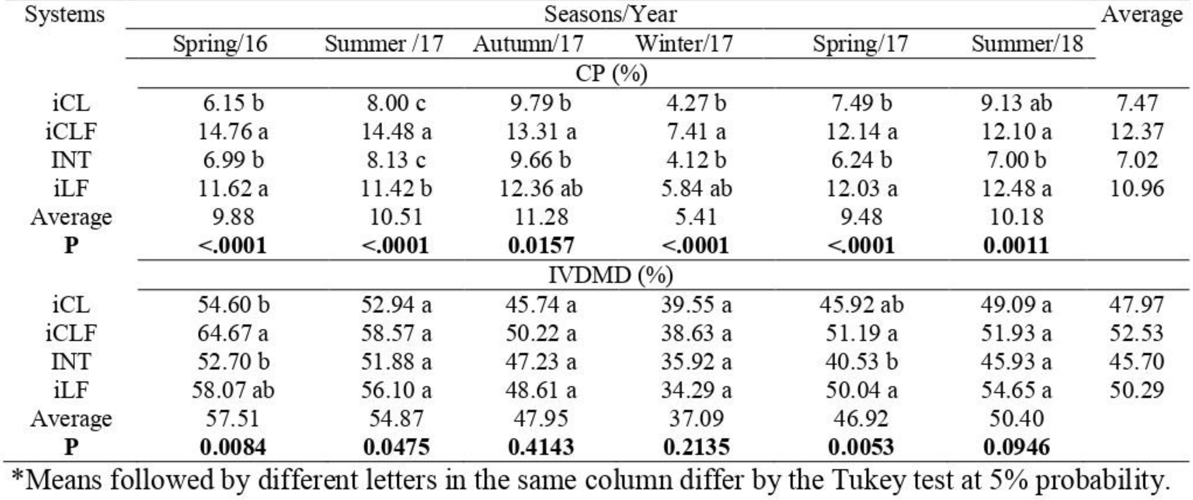
In the general average, the CP levels of the treatments showed significant differences, the iCLF system presented 12.37% of CP, followed by the iLF system (10.96%), iCL (7.47%) and INT (7.02%). Only in the winter of 2017 the CP content of the iLF treatment did not differ from the iCL and INT treatments, and in the summer of 2018 the iCL treatment was similar to the systems with trees (iCLF and iLF).

Regarding the IVDMD of pastures, in the general average, the systems with trees showed higher values during the evaluated cycles (52.52 and 50.29%, for iCLF and iLF, respectively), however, there were no significant differences during the seasons. Differences between treatments were limited only to spring cycles in 2016 and 2017.

The results obtained showed that for most of the evaluated cycles, the pastures of the iCLF and iLF systems (shaded systems) showed higher levels of CP and IVDMD (Table 1), in addition to the thinning providing satisfactory forage production, while the other treatments have shown no beneficial values.

Nicodemo et al. (2016) and Pezzopane et al. (2017), also obtained better nutritive value for pastures cultivated in the shaded environment of systems with trees and concluded that trees management practices, such as pruning and thinning, may decrease, even for a short time, the competition for light in these systems. In general, these authors attribute the highest levels of CP in plants grown under shade over those grown in full sun.

Table 1. Crude protein content (CP) and in vitro digestibility (IVDMD) of forage in iCL, iCLF, INT and iLF in the 2016/2017 and 2017/2018 growing seasons in São Carlos, SP.



Systems	Seasons/Year						Average
	Spring/16	Summer /17	Autumn/17	Winter/17	Spring/17	Summer/18	
	CP (%)						
iCL	6.15 b	8.00 c	9.79 b	4.27 b	7.49 b	9.13 ab	7.47
iCLF	14.76 a	14.48 a	13.31 a	7.41 a	12.14 a	12.10 a	12.37
INT	6.99 b	8.13 c	9.66 b	4.12 b	6.24 b	7.00 b	7.02
iLF	11.62 a	11.42 b	12.36 ab	5.84 ab	12.03 a	12.48 a	10.96
Average	9.88	10.51	11.28	5.41	9.48	10.18	
P	**<.0001**	**<.0001**	**0.0157**	**<.0001**	**<.0001**	**0.0011**	
	IVDMD (%)						
iCL	54.60 b	52.94 a	45.74 a	39.55 a	45.92 ab	49.09 a	47.97
iCLF	64.67 a	58.57 a	50.22 a	38.63 a	51.19 a	51.93 a	52.53
INT	52.70 b	51.88 a	47.23 a	35.92 a	40.53 b	45.93 a	45.70
iLF	58.07 ab	56.10 a	48.61 a	34.29 a	50.04 a	54.65 a	50.29
Average	57.51	54.87	47.95	37.09	46.92	50.40	
P	**0.0084**	**0.0475**	**0.4143**	**0.2135**	**0.0053**	**0.0946**	

*Means followed by different letters in the same column differ by the Tukey test at 5% probability.

CONCLUSIONS

The pastures within the agroforestry systems presented higher nutritive value than the systems without trees, after the management of the tree component.

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4. Impact of integrated systems on the efficiency of nutrient use and water

CORN AND GRASS INTEGRATED SYSTEM FERTILIZED WITH MULTIPLE NUTRIENTS SOURCE

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ABSTRACT

Providing an adequate nutrients supply is important for high yields in crop-livestock integrated systems (CLIS). This research aims to evaluate K sources fertilizer's effect on corn Piatã grass yield and nutritional status in the CLFIS. A two-growing season field experiment was carried out in a Typic Hapludox. The CLFIS was sown with corn together with Piatã grass. Treatments comprised two K sources: polyhalite (14%-K_2O, 19%-S, 3.6%-Mg, and 12.1%-Ca), and KCl (60% K_2O) and five ratios of polyhalite: KCl (0:100%; 12.5:87.5%; 50:50%; 87.5:12.5%; 100%) and a control. The treatments were applied in the sowing and topdressing fertilization of corn. Piatã grass used residual soil fertilization for growth. The best results of corn dry matter yield and Piatã grass were obtained with polyhalite ratios. These values were significantly ($p<0.05$) higher than the best yield obtained in control (without fertilization). The treatments were also efficient in increasing S in soil and exporting K, Mg, and S by corn. This study showed polyhalite as an alternative source of K, Ca, Mg, and S and can meet the nutritional requirements of annual crops and pastures in a CLIFS.
Key words: *Zea mays*; *Urochloa brizantha*; Polyhalite

INTRODUCTION

Crop-livestock integrated systems (CLIS) have been used as a sustainable agricultural intensification strategy, integrating annual crops and livestock activities in the same area and the same season. Providing an adequate supply of nutrients is essential for high yields and is necessary to maintain high quality and profitable returns in integrated systems (BALBINO et al., 2011).

The knowledge of the dynamics of nutrients in the soil in ILPF systems is essential to establish adjustments in the recommendation of lime and fertilizers. The nutrients balance in the soil-plant system can be considered an indicator of agricultural land use sustainability (HANÁČKOVÁ et al., 2008). The difference between the amount of nutrient exported with the harvest and applied with the fertilizer indicates the degree of increase or reduction of the nutrient content in the soil and, when the nutrient output is higher than the input in the crop, the condition is unsustainability (OENEMA et al., 2003).

The study of alternative sources and cultivation techniques such as no-till, crop rotation, and integrated systems is essential to make the use of nutrients K, Ca, Mg more efficient (BENITES et al., 2010).

Potassium chloride (58 to 62% of K_2O) is the most used potash fertilizer in Brazil (ANDA, 2016). However, other sulfates-minerals may be considered. Polyhalite ($K_2MgCa_2(SO_4)4.2H_2O$) is a natural occurrence multi-nutrient mineral (11.7%-K, 19%-S, 3.6%-Mg, and 12.1%-Ca), as a fertilizer for crop production (BARBARICK, 1991; PRUD'HOMME & KRUKOWSKI, 2006; VALE & SÉRIO, 2017).

Supplying nutrients at balanced and adequate levels is a critical factor for high quality and efficient yields crop. However, low information is available for the forage and annual crops' response to polyhalite. Acid, low-fertile, high-weathered soils are expected to be benefited from the addition of

K, Ca, Mg, and S nutrients. So polyhalite may provide an alternative to KCl, with the advantage of offering a slow-release fertilizer source of other nutrients like Ca, Mg, and S (BARBARICK, 1991; VALE & SÉRIO, 2017). This research aims to evaluate K sources fertilizer's effect on corn Piatã grass yield and nutritional status in the CLFIS.

MATERIAL AND METHODS

The study area is located at Embrapa Pecuária Sudeste in São Carlos, Brazil (21°57'S, 47°50'W, 860 m alt). The crop-livestock integrated systems (CLFIS) are growing on a Red-yellow Latosol, i.e., Haplortox. The climate is tropical of altitude (Cwa), with minimum and maximum temperature, respectively, of 16.3°C (July) and 23°C (February) and 1502 mm annual rainfall.

Soil chemical analysis (0-0.2m depth), before experiment establishment: pH_{CaCl2} = 5,6; M.O. = 46 g dm^{-3}; P_{resina} = 11 mg dm^{-3}; K = 1.5 $mmol_c$ dm^{-3}; Ca = 36 $mmol_c$ dm^{-3}; Mg = 14 $mmol_c$ dm^{-3}; H+Al = 19 $mmol_c$ dm^{-3}; CTC = 72 $mmol_c$ dm^{-3}; V = 73%; and sand = 550 g kg^{-1}; clay = 386 g kg^{-1}; and silt = 64 g kg^{-1}.

Corn for silage (*Zea mays* cv. AG 8690-Pro3) and Piatã grass (*Urochloa brizantha*) were sowed together in a CLIFS in two crop seasons (2016–17, and 2017-18). The experiment was carried out in 12.8-m^2 plots, formed by planting four 4-m-long rows, with a 0.8 X 0.2 m spacing. Piatã grass was simultaneously sowed with the corn in a 0.4 m spacing at a rate of 10 kg of seeds per ha.

Treatments comprised two K sources: polyhalite (14%-K_2O, 19%-S, 3,6%-Mg, and 12,1%-Ca.) and KCl (60% K_2O), five ratios (polyhalite: KCl) with 4 replications: i) Control (no K, S, Mg or Ca); ii) KCl 100%; iii) KCl 87.5% + Polyhalite 12.5%; iv) KCl 50% + Polyhalite 50%; v) KCl 12.5% + Polyhalite 87.5%; vi) Polyhalite 100%. The treatments were applied in the sowing and topdressing fertilization of corn.

Due to high V (73%), liming was not necessary. Experimental plots were fertilized uniformly at planting with N, 40 kg ha^{-1}; P_2O_5, 140 kg ha^{-1}; K_2O, 80 kg ha^{-1}; and Zn, 4 kg ha^{-1}. Topdressing fertilizer was broadcast applied 45 days after planting in100 kg ha^{-1}; P_2O_5, 25 kg ha^{-1}; K_2O, 100 kg ha^{-1}.

Corn leaf sampling for nutrient analysis was done when 50% of the plants were in the whole flowering stage, randomized sampling five plants per plot. Silage corn was harvested in March 2017 and March 2018, when whole-plant water concentration was between 600 and 700 mg kg^{-1}. Two 2-m length rows were harvested per plot. After corn silage harvesting, the grass developed, and the pasture was formed. The biomass evaluation of Piatã grass has begun in June 2017 and June 2018 and was periodically repeated for seven cuts. To that end, a metallic 0.5×0.5 m square frame was used at each experimental plot, and the grass inside the frame was cut in three different points at 0.15 m-aboveground level and weighed. Aliquots of corn and grass biomass samples were dried at 65 ºC for 72 h for dry matter yield (DMY) determination. Afterward, corn and grass DM samples were used to determine total K, Ca, Mg, and S concentrations, according to Nogueira et al. (2005). Macronutrient exportation was obtained using the silage corn and grass DMY and macronutrient concentration tissue data. Soil testing for samples collected at 0-20 and 20-40cm depths was conducted following Primavesi et al. (2005). The data collected were evaluated by variance analysis of, and when the Duncan test separated significant means of the treatments at 0.05 probability test considering the different K sources.

RESULTS AND DISCUSSIONS

Table 1 presents the dry matter yield (DMY) of corn harvested for silage and Piatã grass due to the nutrient sources. The maximum corn DMY result agrees with those that are commonly observed with hybrid corn in Brazil. The best results for corn were obtained with the different polyhalite ratios mixed with KCl. These values were 17 to 22% higher than the best production achieved in control, without the addition of multiple nutrient fertilizers. For Piatã grass, the differences between sources and relationships were more striking and followed the same trend of corn. The DMY values were 30 to 45% higher than the control.

The leaf diagnosis principle compares the concentration of nutrients in the leaves with standard values, corresponding to the varieties or species with high productivity and appropriate vegetative development. Thus, the relevant content ranges for macronutrients in the corn leaf proposed by Cantarella & Camargo (1997) are K, from 17 to 35 g kg^{-1}; Ca, 2.5 to 8.0 g kg^{-1}; Mg, 1.5 to 5.0 g kg^{-1}; S, 1.5 to 3.0 g kg^{-1}. For the Piatã grass, the values considered adequate (WERNER et al., 1997) are K, 12 to 30 g kg^{-1}; Ca, 3 to 6 g kg^{-1}; Mg, 1.5 to 4.0 g kg^{-1}; S, 0.8 to 2.5 g kg^{-1}. Based on these interpretation ranges, K, Ca, Mg, and S levels observed in this experiment can be classified as adequate.

Potassium is an essential element for plants. However, K is not a constituent of any organic molecule in the plant; however, it contributes to various biochemical activities, activates many enzymes, and regulates osmotic pressure (water entering and leaving the cell), opening and closure of stomata. Potassium is essential in photosynthesis, fruit formation, resistance to cold, and diseases (MALAVOLTA et al., 1997). Considering the treatments, there were no significant differences in the contents of K in corn leaves. For the Piatã grass, significant differences were observed between control and the treatments with nutrient supplying.

In the plant, Ca participates in enzymatic functions, is a constituent of pectates (giving resistance to cell walls), an activator of several enzymes (MALAVOLTA et al., 1997). Magnesium is a constituent of the chlorophyll molecule necessary for various enzymatic reactions (MALAVOLTA ET AL., 1997). The were no significant differences between treatments and Ca levels, just between the control and the treatments. Concerning Mg levels in corn leaves, the significant differences were between the higher level of polyhalite and KCl. The exception was in the control treatment with significantly higher levels of these nutrients, and the explanation lies in the competitive inhibition between these cations (MALAVOLTA et al., 1997) because as there was no K supply, it facilitated the absorption of Ca and Mg in the treatment control for both corn and Piatã grass (Table 1). Sulfur (S) is required to form amino acids and proteins and photosynthesis (MALAVOLTA et al., 1997). Despite S importance for the proper plant nutrition, there were slight differences in corn leaves, and there were no differences for Piatã grass foliar diagnosis.

The extraction of nutrients was obtained from corn samples at harvest, which was analyzed for the total contents of K, Ca, Mg, and S in the material collected for silage. The extraction by Piatã grass was the sum of extractions at the seven cuts. There were significant differences in the extraction of K by the corn biomass produced according to the treatments used. The most significant extractions of K were obtained in the treatments and the control in silage corn. For the K extraction by Piatã grass, there were significant differences between treatments, and the trend indicates higher K uptake as more polyhalite was used (Table 1).

There were no differences for Ca or Mg extractions by corn depending on the treatments (Table 1). Regarding the extracted Ca by the grass, there was a significant trend to extract higher amounts with the highest polyhalite ratios, with the largest removals obtained in polyhalite treatments in the proportions of 100%, 87.5%, and 50%. Mg extraction by grass, the most remarkable significant difference was between the polyhalite and KCl sources. There were also significantly higher values for S extraction with the highest polyhalite ratios for both corn and Piatã grass. With the reduction in S (present in polyhalite) supply, there was significantly less extraction of this vital macronutrient (Table 1).

Table 1. Dry matter yield (DMY), leaf levels, and extraction of K Ca, Mg and S by corn and Piatã grass fertilized with K sources in a CLIS in São Carlos – SP, Brazil.

Treatments	**DMY**	**Leaf analysis (g kg^{-1})**				**Nutrient extraction (kg ha^{-1})**			
	kg ha^{-1}	**K**	**Ca**	**Mg**	**S**	**K**	**Ca**	**Mg**	**S**
					Corn				
Polh100%	13,846.7 a	21.09	3.11 b	2.01 b	2.12 ab	140.3 a	20.9 -	15.6 -	16.3 a
KCl12.5% + Polh87.5%	13,215.8 a	21.33	3.00 b	1.94 bc	2.19 a	137.9 a	20.2 -	15.9 -	15.0 ab
KCl50% + Polh50%	12,679.7 ab	21.38	2.92 b	1.79 bc	1.94 ab	132.7 a	19.5 -	16.0 -	14.4 ab
KCl87.5% + Polh12.5%	12,983.1 ab	21.14	2.85 b	1.81 bc	1.67 b	132,6 a	19.4 -	14.4 -	13.3 ab
KCl100%	12,805.1 ab	21.07	2.85 b	1.73 c	1.64 b	132.2 a	18.3 -	14.8 -	12.6 b
Control	11,343.4 b	18.63	3.59 a	2.48 a	2.03 ab	86.2 b	20.2 -	15.2 -	12.4 b
					Piatã grass				
Polh100%	6,049.3 a	20.31 ab	4.13 ab	3.10 b	1.72 -	182.4 a	39.7 a	27.9 a	15.9 a
KCl12.5% + Polh87.5%	5,513.8 ab	21.25 a	3.64 b	2.87 b	1.61 -	165.2 ab	33.8 abc	25.2 ab	13.7 ab
KCl50% + Polh50%	5,419.3 ab	18.18 bc	4.25 ab	3.09 b	1.62 -	155.7 bc	36.6 ab	24.4 ab	13.2 ab
KCl87.5% + Polh12.5%	5,147.9 abc	20.71 ab	3.84 b	2.94 b	1.52 -	155.3 bc	32.2 abc	22.5 ab	11.8 bc
KCl100%	4,650.5 bc	20.87 ab	3.78 b	2.97 b	1.47 -	133.7 c	28.5 bc	19.5 b	10.1 c
Control	4,168.4 c	16.44 c	4.79 a	4.11 a	1.62 -	98.9 d	27.6 c	23.3 ab	9.6 c

Different letters indicate statistical differences by Duncan's test ($p<0.05$).

Soil colloids retain K^+, Ca^{2+}, and Mg^{2+} through the negative charges of soil colloids (RAIJ, 1991), so there were significantly more K and Mg in the 0-20cm layer in the 20-40cm layer (Table 2). Ca levels did not vary, probably due to the liming historical of the area. Comparing the nutrient sources, the results indicated no differences between the K, Ca, and Mg contents between sources. From the limits established for the interpretation of soil fertility levels by Raij et al. (1997), the soil's K content can be considered low for all treatments, including the control, which did not receive potassium fertilization.

In Table 2, the levels of Ca^{2+} and Mg^{2+} are considered high in all treatments, with all samples of depth 0-20cm being in the classes considered high (ALVARES VENEGAS et al., 1999). In the depth of 20-40cm, Ca was also regarded as high. The Mg content was classified as medium (5 to 10 $mmol_c$ dm^{3-}). The results also indicate no differences in Ca and Mg levels due to the sources of K tested, even though polyhalite has these elements in its composition. Possibly, this effect occurred due to the previous liming done on this soil before planting the experiment establishment, indicating that this input probably supplied Ca in sufficient quantities so that there were no differences between treatments at both depths studied. The movement of cations like calcium in the profile is influenced by limestone application (RHEINHEIMER et al., 2000). This is also due to the soil correction and fertilization program used in the area, which has made it possible to correct and maintain soil fertility, as previously described by Bernardi et al. (2019).

In the soil, the sulfur leaching process in the form of sulfate is quite intense, resulting in the accumulation of sulfate in the subsurface layers, where the $S\text{-}SO_4^{2-}$ content is higher than in the surface layer (RAIJ, 1991). The results in Table 2 confirmed a significant increase in the S- SO_4^{2-} concentration in the deepest layer of the soil (20-40cm) with polyhalite. The interpretation of results for the content of $S\text{-}SO_4^{2-}$ in the soil proposed by Raij et al. (1997) indicates the classes: low from 0 to 4 mmol$_c$ dm^{3-}; an average of 4 to 10 mmol$_c$ dm^{3-}; and high> 10 mmol$_c$ dm^{3-}. Thus, the values are considered average in the 0-20 cm layer and top in the 20-40 cm layer. After applying the tested nutrients' sources, the content of S- SO_4^{2-} in the soil was higher for the polyhalite treatments at 100%, 87.5%, and 50% ratios, indicating that this fertilizer is an efficient source macronutrient.

Table 2. Soil levels of K^+, Ca^{2+}, Mg^{2+}, and SO_4^{2-} due to K sources in a CLIS in São Carlos – SP, Brazil.

Treatments	K				Ca		Mg				S-SO$_4$			
	------------------------------------ mmol$_c$ dm^{-3} -----------------------------										------------ mg dm^{-3} ---------			
	0-20		20-40		0-20	20-40	0-20		20-40		0-20		20-40	
Polh100%	1.25	A	1.0	B	31.0	27.0	11.8	A	7.5	B	9.0	Ba	24.5	Aab
KCl12.5% + Polh87.5%	1.08	A	0.9	B	37.5	41.3	10.3	A	7.3	B	9.0	Ba	31.0	Aa
KCl50% + Polh50%	1.15	A	0.7	B	27.8	31.3	8.8	A	6.0	B	8.0	Bab	25.0	Aab
KCl87.5% + Polh12.5%	1.18	A	0.88	B	40.0	29.0	11.0	A	7.0	B	5.3	Bb	19.0	Abc
KCl100%	1.50	A	0.93	B	26.3	28.5	10.8	A	7.5	B	6.3	Bab	16.3	Ac
Control	0.98	A	0.95	A	31.3	27.0	10.8	A	7.8	B	7.0	Bab	18.5	Abc

Different letters indicate statistical differences by Duncan's test ($p<0.05$). Uppercase letters indicate differences between depths, and lowercase letters indicate differences between nutrients sources.

CONCLUSIONS

The best results of corn dry matter yield and Piatã grass were obtained with polyhalite ratios. These values were significantly ($p<0.05$) higher than the best yield obtained in control (without fertilization). The treatments were also efficient in increasing S in soil and exporting K, Mg, and S by corn. This study showed polyhalite as an alternative source of K, Ca, Mg, and S and can meet the nutritional requirements of annual crops and pastures in a CLIFS.

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EVOLUTION OF SOIL FERTILITY OVER TIME OF ADOPTION OF CROP-LIVETOCK INTEGRATION

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ABSTRACT

The soil fertility evolution was monitored in a Red Latosol, very clayey texture, under intensive management in a crop-livestock integration system, conducted for 15 years. The indicators of soil productivity potential and “bioavailability” of macro and micronutrients were monitored in different glebes, cultivated with grain crops, forage, and pasture, in rotation, succession and intercropping systems. In general, it was possible to maintain satisfactory conditions of chemical soil fertility over time, especially considering that it is a realistic management/production scheme, analogous to a small rural property. Nevertheless, there were possibilities for improvements in nutritional monitoring and management of correction and fertilization of the glebes. The results of the soil fertility indicators reveal some interesting results that serve as a basis for decision making in this area and, mainly, in future works to be developed with intensive production systems. The first aspect is related to the planning for carrying out soil sampling, considering the need to obtain more consistent and standardized results. Another aspect refers to establishing fertilization programs using the concept of fertilization of production systems according to the requirements of the crops and export of nutrients, taking into account the purpose of exploration, whether for the production of grains, silage, or forage.

Key words: Soil productivity; soil fertility; crop systems

INTRODUCTION

Crop-livestock integration has been identified as a land use strategy that makes it possible to combine gains in plant and animal productivity, with greater efficiency in the use of available resources, including nutrients, in addition to greater sustainability by improving the quality of the land ground. However, alternatives for intensifying agricultural production systems, such as crop rotation, succession, and intercropping, require more frequent monitoring (2 to 3 years) of the chemical, physical and biological attributes of soils, in order to maintain their productive potential and, consequently, its sustainability. This is due to the fact that the different types of crops and their production purposes (grains and forage) present different nutritional requirements and, consequently, nutrient exports and cycling, which can cause imbalance in the nutrient contents of the soils, thus limiting their productive potential. In this type of exploration, the balance of nutrients (applied quantity less exported in the harvested products) assumes fundamental importance, as an auxiliary tool, in the recommendation of liming and fertilization for production systems. This research aims to evaluate the evolution and variations in soil fertility indicators of an intensive production system, involving different crops in rotation, succession, and intercropping, in a pilot project for the integration of livestock farming, conducted from 2005 to 2018.

MATERIAL AND METHODS

The pilot project, in a crop-livestock integration system has been carried out in the experimental area of Embrapa Maize e Sorghum in Sete Lagoas, MG, since 2005. The project area comprises about 24 ha and was divided into four glebes of 5.5 ha each. The soil is classified as Yellow Red Latosol, very clayey texture, managed under no-tillage system since 2006.

Soil sampling and laboratory analysis

The sampling in each glebe was carried out at random points, in the traditional system, taking 25 simple samples from each glebe (5.5 ha) to compose a composite sample. The sampling depths were different for each year, and in 2005 sampling was carried out at depths of 0-20 cm and 20-40 cm. In 2006 and 2012 at depths of 0-10 cm, 10-20 cm, and 20-40 cm. In 2014, sampling was carried out at depths of 0-5 cm, 5-10 cm, 10-20 cm, 20-40 cm, and 40-60 cm. In 2017 and 2018, sampling was performed at depths of 0-10 cm, 10-20 cm, 20-40 cm, and 40-60 cm.

Due to these differences in the sampling depths, for the presentation of the results, we opted for uniformity for the depths of 0-20 cm (weighted average values of the sampled depths up to 20 cm) and 20-40 cm, for which it was possible obtain results for a greater number of years of sampling. The weighted averages for the 0 to 20 cm layer were calculated using the equation: $\{(P_{0\text{-}5} \times 5) + (P_{5\text{-}10} \times 5) + (P_{10\text{-}20} \times 10)\}/20$.

These differences in the sampling depths performed, without an adequate systematization of methods, such as standardization in the depths and sampling periods, make it difficult to use statistical tools to analyze this type of result. Thus, in studies of this nature, it is necessary to have an initial planning for carrying out soil sampling, defining the form of collection, randomized or systematized, the depth and timing of sampling (COELHO, 2005a). However, the need to compare non-standardized data also occurs in many agricultural properties that wish to obtain a history of the evolution of soil fertility in their glebes.

The chemical and physical analyzes were carried out in the chemical and physical analysis laboratories of Embrapa Maize and Sorghum, being determined: the pH in water, the potential acidity (H + Al) extracted with calcium acetate solution pH 7.0; exchangeable acidity (Al), Ca and Mg extracted in 1N KCl solution; K, P, Zn, Cu, Mn and Fe extracted by the Mehlich1 extractor, B extracted in hot water, organic carbon in a carbon analyzer at 800 ºC, and the organic matter contents being obtained by multiplying the organic carbon contents by the 1.72. Based on these results, the CEC-pH7 (T), effective CEC (t), saturation by Al of the effective CEC (m), sum of bases (SB) and base saturation (V) were calculated. The granulometric analysis (sand, silt, and clay) was performed using the pipette method.

The results were analyzed statistically through the classic descriptive analysis in SAS software version 8.2 and the figures (graphs) elaborated in Origin75 software. The results of these analyzes were organized into three groups: (a) indicators of the productive potential of the soil, which includes data on organic matter (OM), cation exchange capacity (CEC-pH7), pH-water, saturation by aluminum of the effective CEC (m) and base saturation of the CEC-pH7 (V) and clay content; (b) indicators of the "bioavailability" of macronutrients (Ca, Mg, K and P) and (c) indicators of the "bioavailability" of micronutrients (Zn, Cu, Mn, Fe and B).

Soil amendment and fertilization history

The application of correctives and fertilizers according to the results of the soil analysis for each glebe. The limestone doses were calculated by the base saturation method, aiming to increase to a value of 60%, with dolomitic limestone. Gypsum in the doses of 1.0 Mg ha^{-1} and 2.0 Mg ha^{-1} was applied to the soil surface in 2005 and 2014, respectively. In 2018, as a source of magnesium, 1.0 Mg ha^{-1} of serpentinite rock powder (MgO - 38%) was applied to each glebe.

At sowing time, fertilizers formulated N, P, K and Zn were used for corn, sorghum and brachiaria pastures (300 to 400 kg ha^{-1} of formula 08-30-15 of N, P_2O_5 and K_20, respectively). For soybeans, formulated fertilizers containing P, K and Zn were used (300 kg ha^{-1} of the formula 00-30-15 of N, P_2O_5 and K_2O, respectively). In the top dress fertilizations for corn and sorghum, doses ranging from 90 to 130 kg ha^{-1} of N in the form of urea were applied in the stage of 5 to 6 leaves. When maize and sorghum crops were used for the production of forage, potassium was also applied top dressing, together with N (200 kg ha^{-1} of the formula 20-00-20 of N, P_2O_5 and K_2O, respectively). In pasture glebes, 200 kg ha^{-1} of N were applied in the top dressing, divided into three applications.

RESULTS AND DISCUSSIONS

In the implementation of the crop-livestock integration project in 2005, the initial results of the chemical soil analyze showed a marked variation in the soil fertility indicators among the glebes (Table 1), thus suggesting a different management for the correction of acidity and fertilization.

Table 1. Chemical and physical attributes of soil samples collected in 2005, before the implementation of the component areas of the pilot project.

Glebes	**Glebe 01**		**Glebe 02**		**Glebe 03**		**Glebe 04**	
Depth - cm	**0-20**	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**
Indicators of the productive potential of the soil								
O.M.[1] (%)	3.98	3.31	3.55	2.98	3.25	2.84	4.28	3.50
pH (water)	5.40	5.40	5.20	5.40	5.60	5.30	5.10	5.00
CEC[2] ($\text{cmol}_c\ \text{dm}^{-3}$)	11.57	11.19	11.07	9.90	9.88	8.92	10.76	10.43
Al Sat.[3] (%)	3.0	6.0	12.0	7.0	2.0	8.0	20.0	32.0
Base Sat.[4] (%)	48.0	44.0	38.0	43.0	51.0	38.0	29.0	20.0
Clay (%)	62	69	69	71	62	71	69	62
Indicators of the "bioavailability" of macronutrients								
Ca ($\text{cmol}_c\ \text{dm}^{-3}$)	4.49	1.06	3.50	3.64	4.29	2.85	2.69	1.87
Mg ($\text{cmol}_c\ \text{dm}^{-3}$)	0.72	0.61	0.48	0.44	0.61	0.37	0.29	0.18
K (mg dm^{-3})	140	89	92	52	64	48	45	23
P (mg dm^{-3})	20	14	39	11	9	5	11	6
Indicators of the "bioavailability" of micronutrients								
Zn (mg dm^{-3})	4.5	2.5	7.0	14.5	2.5	4.0	12.5	1.5
Cu (mg dm^{-3})	1.2	1.1	1.4	1.5	1.2	1.4	0.8	4.1
Mn (mg dm^{-3})	134	121	85	81	61	50	19	31
Fe (mg dm^{-3})	43	45	52	71	43	47	47	51

[1]O.M.-organic matter, [2]CEC-pH7-cation exchange capacity, [3]Al Sat.-aluminum saturation, [4]Base Sat.-base saturation.

For example, if we consider the need for limestone to raise the base saturation (V) to a theoretical value of 60%, the calculated quantities, would indicate doses of 1.38; 2.43; 0.89 and 3.33 Mg ha^{-1} of a limestone with 100% effective calcium carbonate equivalent, respectively, for glebes 01, 02, 03 and 04, to be incorporated into the soil in the 20 cm layer. However, due to the high buffer capacity of the soil, associated with the reaction speed of the granulometry fractions of the limestones, the expected value of 60% of base saturation is hardly reached, thus requiring adjustments in the doses and in the application of the limestone, mainly in soils with higher levels of CEC-pH7 and organic matter. The average pH-water values of 5.0 to 5.5, aluminum saturation of 5 to 20% and base saturation of 25 to 35%, verified in the analyzed period, support these considerations.

Within this focus, it is important to mention that in experiments conducted by Coelho (1994) in a Red Latosol, very clay texture, the limestone dose calculated by the base saturation method (2.5 Mg ha^{-1}), was not enough to raise base saturation to the target value of 60%. In order to reach this value, it was necessary to apply 6.0 Mg ha^{-1}, as revealed by the results of soil analysis of samples collected 11 months after the application of lime and successive crops of corn and beans.

According to CFSEMG (1999), the maximum values of saturation by aluminum in the superficial layer (20 cm) tolerated by the crops are 15% for corn and sorghum and 20% for soybeans. For brachiaria these values are 20% to 30%. However, in an intensive system of grain and forage production like the one used in this work, the objective must be to completely neutralize Al in the surface layer, which can be obtained by applying lime in an appropriate dose and incorporated into the soil at depth maximum possible. This management becomes more important when the objective is to implement the no-till system, where the subsequent application of lime will be carried out on the soil surface and, therefore, without possibilities of incorporation.

In the present work, although gypsum applications were carried out in 2005 (1.0 Mg ha^{-1}) and 2014 (2.0 Mg ha^{-1}), the presence of exchangeable Al^{3+} was also found in the 20 to 40 cm layer, whose values represented 6 to 21% of saturation by aluminum of the effective CEC. The existing recommendations for applying gypsum on Brazilian soils for the cultivation of grain crops are based on the following critical limits in the subsurface layer (20 - 40 cm): $\geq$ 20% for Al saturation (m), and or ≥ 0.5 $cmol_c$ dm^{-3} for exchangeable Al^{3+} and/or ≤ 0.5 $cmol_c$ dm^{-3} for exchangeable Ca^{2+} (SOUZA and LOBATO, 2004; PAULETTI and MOTTA, 2017). Considering these criteria, only for glebe 04, it would be recommended to apply gypsum. Considering that the main recommendations for gypsum doses for Brazilian soils are based on clay content, the following equation has been suggested: Gypsum dose (Mg ha^{-1}) = 0.05 × clay content (%) (SOUZA and LOBATO, 2004). Therefore, based on this equation, the recommended gypsum dose for glebe 04 is 3.10 Mg ha^{-1}.

According to Pias et al. (2020), cereals (corn, wheat, white oats, barley, and rice) had a high probability (77-97%) that their grain yields would be increased by the application of gypsum on soils with Al saturation greater than 5% in the 20 to 40 cm layer. The average increase in grain production was 14 and 7% in crops that developed in the presence and absence of water deficit, respectively. A positive response of soybeans to gypsum was observed in soils deficient in water and with an Al saturation greater than 10%. Under these conditions, the probability of a positive response from soybeans was 88% and the average increase in grain production was 12%.

Regarding the levels of P and K revealed by soil analysis of samples collected during the period of conduction of the crop-livestock integration system, there were variations over the years and among glebes (Figure 1), also indicating that different management could be used in fertilization of crops, in order to balance the reserves of these nutrients among the glebes.

For P, the available levels (Mehlich1), presented themselves during the conduction period of the crop-livestock integration system, with small increases (Figure 1), but with values always above the critical level of 8 to 10 mg of P dm^{-3}, previously established for the soil of the area managed under conventional tillage (COELHO and FRANÇA, 1994) and 6.0 mg dm^{-3} for this same type of soil managed under no-tillage already established (SOUSA et al., 2019). This probably occurred due to the application to the crops of doses of P greater than the amount exported in the crops, thus creating a reserve of P in the soil that could be better used, adjusting the doses of P to be applied according to the expectation of crop yields and the respective exports of P by harvests.

For K, there was an inverse situation in relation to P (Figure 1), that is, the levels available in the soil, in the period from 2005 to 2014, decreased to values well below the critical level of 100 mg dm^{-3} of K in the soil (COELHO, 2005b), reflecting a greater export of the nutrient in the harvests in relation to the applied doses. However, after that period, the K content in the soil increased considerably to values above the critical level, reflecting a better adjustment in the applied doses, as occurred in 2014, with the application of 200 kg ha^{-1} KCl (120 kg ha^{-1} of K_2O).

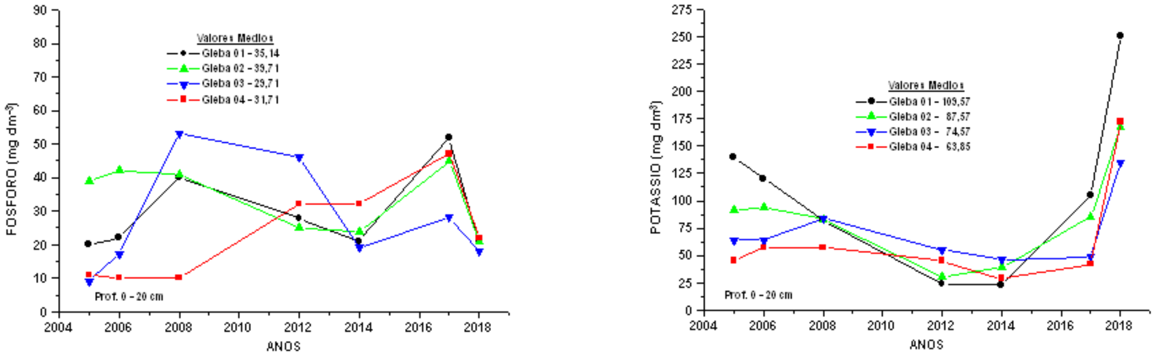

Figure 1. Phosphorus and potassium contents in the soil at a depth of 0-20 cm in the different glebes, over the period of conduction of the crop-livestock integration system.

With regard to micronutrients, it was found that in the period of conduction of the crop-livestock integration system, the levels in the soil have always remained close to or above the established critical levels of: 1.5 mg dm^{-3} of Zn; 1.2 mg dm^{-3} of Cu; 8 mg dm^{-3} of Mn; 30 mg dm^{-3} of Fe (Mehlich1) and 0.6 mg dm^{-3} of B (hot water) (CFSEMG, 1999), thus not constituting limitations for the development and productivity of crops.

CONCLUSIONS

In general, the crop-livestock integration system conducted in the pilot project, made it possible to maintain satisfactory conditions of chemical soil fertility over time, especially considering that it is a realistic management/production scheme, analogous to a small rural property, associated with the dynamics of alternating crops, and animal purposes in the glebes. Nevertheless, there were possibilities for improvements in nutritional monitoring and management of correction and fertilization of the glebes.

The results of the soil fertility indicators in the glebes, evaluated in the period from 2005 to 2018, reveal some interesting results that serve as a basis for decision making in this area and, mainly, in future works to be developed with intensive production systems. involving intercropping, rotation, and succession of crops for different purposes, such as grain production, forage, and pasture.

The first aspect is related to the planning for carrying out soil sampling, considering the need to obtain more consistent and standardized results. In this respect, the system of systematic sampling, in grids and georeferenced, with repetitions, would make it possible to obtain more consistent results and statistical analysis using appropriate models.

Another aspect refers to establishing fertilization programs using the concept of fertilization of production systems according to the requirements of crops and export of nutrients, taking into account the purpose of exploration, whether for the production of grains, silage, or forage.

This information is essential for establishing a balance of nutrients that, associated with the results of soil analysis, allows the elaboration of a more adequate program for soil correction and fertilization of the system, thus avoiding excessive or insufficient applications of correctives and fertilizers and providing greater sustainability of the production system. Management based on the balance of nutrients would certainly allow for a better adjustment in the supply of phosphorus and potassium, increasing the efficiency of utilization of the P reserves already existing in the soil and avoiding deficit levels of K will limit the productive potential of the glebes.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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MAIZE AND BRACHIARIA INTERCROPING SYSTEM EFFICIENCY IN THE USE OF SOIL PHOSPHORUS RESERVES AND FRESH FERTILIZER

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ABSTRACT

The potential for using soil P reserves has been evaluated since 2014, in experiments with maize in monoculture and intercropped with brachiaria and in rotation with soybean. In order to evaluate the residual effect of these P reserves in the soil when compared to recent P applications, treatments with rates of P (0, 22 and 44 kg of P ha^{-1}) were included as maintenance. Also, the effect of inoculation with arbuscular-mycorrhiza was evaluated. Results showed that, in this specific case and after four years of P “draw down” by the corn grain, legacy P in soil alone (without addition P fertilization) led to a significantly lower cumulative grain yield than with P fertilization, when other nutrients in the soil were at adequate levels. In this research there is no evidence that the use of brachiaria intercropping with corn associated with mycorrhiza can optimize the use of residual phosphorus. In general, the brachiaria intercropped with corn reduced grain yield, due mainly brachiaria management. The potential and the time for utilization of P reserves in the soil is closely related to the bioavailability of P evaluated by extractor (Mehlich1), whose values must be above the critical levels pre-established that provide economic productivity for farmers.

Key words: : legacy-P; maintenance-P; mycorrhiza

INTRODUCTION

Currently, the role of the scientist in increasing the life span of world P reserves lies in increasing the efficiency of use of P in agriculture. This may be P applied in mineral fertilizers, in organic manures (animal manures, composts and biosolids), but also soil P reserves accumulated as residues from past applications of fertilizers and manures (HEFFER et al., 2006). New strategies need to be implemented in order to improve the P efficiency of crop systems, including readjusting fertilizer recommendations, adoption of best management practices, use of crop rotations including P-mobilizing species. Moreover, the reengineering of plant, fertilizer, and microorganism processes are needed, as the development of P-efficient cultivars, novel fertilizers with enhanced efficiency, and stimulating beneficial associations between plants and microorganisms can all extend the root system or mobilize P in the rhizosphere. All these strategies can increase the use of legacy-P from soil and contribute to the reduction of inputs of phosphate fertilizers, therefore leading to a better use of phosphorus in agriculture. The present research is part of a series of experiments conducted in the same area, in the period from 2008 to 2013, and whose partial results obtained previously, were published by Coelho (2014a, 2015b, 2015c). In this context, the objective of this study is to contribute to a more systematic assessment of the effect of soil phosphorus. If the recovery of added P is of interest not only in the year of application but in subsequent years as well, this raises the following questions: (a) can the residual P produce yields that are economically viable for the farmer, (b) what is the effect of the crop system, brachiaria intercropping with corn, in to optimize the use of soil phosphorus reserves and (c) what is the potential of the introduction of mycorrhiza into soil for improving the availability of soil P reserves?

MATERIAL AND METHODS

The research was conducted at the agronomic research station of the Embrapa, located in Sete Lagoas, MG, Brazil (19° 28’ S, 44° 15’ W and 732 m above sea level). The soil classified as Red Latosol, very clayey texture. The soil chemical attributes were determined in 2014, getting the following results in the 0-20 cm layer: 40 g dm^{-3} organic matter; 5.95 pH (water); K, Ca, Mg, H + Al and Al = 0.32; 3.45; 0.84; 6.23 and 0.01 cmol$_c$ dm^{-3}, respectively; Cu, Fe, Mn, Zn (Mehlich 1) = 1.46; 31.64; 34.77 and 3.18 mg dm^{-3}, respectively, and 50% base saturation. The experiments were conducted in the summer seasons of 2014-15, 2016-17, 2018-19 and 2019-20 in the system corn in rotation with soybean. The experiments were in random blocks using a split-split plot design, consisting of three treatments factors, with four replications. The main plots were levels of P (0, 218 and 436 kg ha^{-1}) applied in 2003, and classified as low, medium, and high. The split plot factor consisted of crop system (corn and corn intercropping with brachiaria) and the split-split plot factor consisted of doses of P (0, 22 and 44 kg P ha^{-1}) as maintenance and, arbuscular-mycorrhiza inoculum, annually applied by hand, banded in the furrows. Corn single hybrids DKB390 (20014-15), AG8088 (2016-17, 2019-20) and SHS4080 (2018-19) were sowed mechanically at 0.70 m between rows and density of five seeds per meter (plant density 70,000 ha^{-1}), in the first fortnight of November in each season. The brachiaria brizantha, cv. Xaraes, was sowed intra and inter-row of maize at a rate of 10 kg of seeds ha^{-1} and was used as cover crop. At sowing time N and K were applied at rate of 45 and 75 kg ha^{-1}, respectively, as ureia and KCl. Micronutrients, as FTE BR12, at rate of 50 kg ha^{-1} was applied mixed with urea and KCl only in one year. At 35 days after planting (V5-V6 stage with five to six leaves),150 kg of N ha^{-1}(70% ureia plus 30% ammonium sulfate) and 75 kg K ha^{-1} (KCl) were applied, spread on the soil surface, following by irrigation. In all growing seasons, except 2018-19, irrigations were provided, as necessary, to supply water during drought periods, a phenomenon of common occurrence in the region. In the growing season of 2018-19, the irrigation was not possible to be provide, and a drought period of 30 days occurred during grain filing stage and the grain yield was very lower, less than 1.50 Mg ha^{-1} and the results will not be considered. At harvest time, number of plants and ears, weight of biomass and grain were determined by hand harvesting four adjacent 4-m long rows. Grain yields were obtained after threshing the ears in a mechanical machine and reported at 130 g kg^{-1} grain moisture. After crop harvest, soil samples of 0 - 20 cm depth, were taken from sub-sub plots in 2014 and 2017. Soil samples were taken between and in the row, collecting five single samples from each sub-subplot. Composted soil samples were mixed, air dry and crushed to pass a 2-mm sieve and analyzed for soil fertility indicator at the Embrapa Maize and Sorghum laboratory of soil analyzes. The biomass of brachiaria was harvest two months after corn has been harvest. The yield of biomass was determined by harvesting two sub-sample of 1 square meter inside of each sub-subplot of the treatments. The weight of biomass was recorded, and subsamples were taken for determination of dry matter (65ºC). All data were analyzed by conventional analysis of variance procedures for split-split plot design (SAS Inst., Cary, NC). When significant factors or interactions were observed ($P \leq 0.10$), Tukey’s Studentized Range (HSD) test was used for means separation within each treatment. Statistical significance was assessed at the 0.10 level.

RESULTS AND DISCUSSIONS

Soil phosphorus “bioavailability”

In the Table 1, are showing the results of “bioavailability” of soil P, extracted by Mehlich1. The applications of high rates of P in 2003, were necessary to reach 20 and 40 mg of P dm^{-3} (Table 1). Thereafter, the balance of phosphorus obtained in the time period of 2003 to 2014 (data not showed), indicated that of total P fertilizer applied in 2003 (218 and 436 kg ha^{-1}), the total P removed in the grains of the crops (corn and soybean) were 117 and 136 kg ha^{-1}, respectively, representing 53 % and 31 % of the total P fertilizer applied, indicating thus, a positive balance in which significant amounts of P fertilizer (100 and 300 kg ha^{-1}) remained as reserves (legacy P) in the soil. However, the results of analyzes of the “bioavailability” of P in soil, measured by extractor Mehlich1, in soil samples taking at 20 cm depth, in 2014 and 2017, represented in the average, only a small fraction of 6.4% and 4.1%, respectively, of these reserves (Table 1).

Table 1. Soil P “bioavailable” analyses (0 - 20 cm depth).

P-level[1]	**P-residual[2]**	**Crop**	**Bioavailable P-Mehlich1**		
kg ha^{-1}	**kg ha^{-1}**	**System**	**2003[3]**	**2014**	**2017**
			--------------------- mg dm^{-3} soil --------------------		
0 (Low)	0 (Low)	Corn	5.33 ± 0.85[4]	6.31 ± 2.55	7.00 ± 4.75
		Corn+ brachiaria		3.97 ± 1.02	5.98 ± 3.55
218 (Medium)	100 (Medium)	Corn	20.50 ± 7.87	5.54 ± 1.34	6.65 ± 3.04
		Corn + braquiaria		6.72 ± 4.13	6.77 ± 2.60
436 (High)	300 (High)	Corn	39.70 ± 14.98	13.48 ± 3.84	10.05 ± 4.58
		Corn + brachiaria		13.64 ± 4.80	11.93 ± 6.71
Average			31.84	8.28	8.06
CV %			20	47	41

[1]Total P added via inorganic P fertilizers (TSP) after 11 years (2003–2014). [2]P fertilizer residual left in soil in 2014. [3]P initial in 2003 determined in soil samples taken four months after triple superphosphate has been applied. [4]Numbers followed by signal ± is the stander deviation.

As far as the critical level is concerned, the bioavailability of P extracted by Mehlich1, previously established for this soil, under conventional tillage, is in the range of 8.0 to 10.0 mg of P dm^{-3} of soil (COELHO & ALVES, 2004). However, as verified by Ciotta et al. (2002), for a Latossolo clayey texture, managed under no-tillage for several years (>20 years), the “bioavailability” of P, in the layer of 0-20 cm, measured by Mehlich1 extractor was higher (10,85 mg kg^{-1}) as compared with the same soil under conventional management (4,04 mg kg^{-1}), and the recommended critical level is lower, with value of 6.0 mg dm^{-3} of P in the soil (SOUZA et al., 2016). Thus, as showed in the Table 1, in the period of time analyzed, only the application of a high dose of P (436 kg ha^{-1}) in 2003, maintain in the soil, values of “bioavailability” of P above the critical level. For the control and application of a medium dose of P (218 kg ha^{-1}) in 2003, the values of “bioavailability” of P are similar and close or below of the critical level considered for soils managed under no till system (Table 1).

Although the bioavailability of P increases with increasing levels of residual P, the values are similar within cropping systems, except for the soil samples taking in 2014, when the bioavailability of P was lower for the treatment with low P residual and the crop system was corn intercropped with brachiaria (Table 1). Almeida et al. (2019), in experiment with bachiaria ruziziensis, cultivated as cover crop in the soybean off-season, observed decreases in the soil P bioavailability by fundamentally to reduce P mobility and P resupply from soil solid phase into soil solution.

Grain yield potential and corn responses to P-reserves, P-fresh and mycorrhiza

Independent of applied treatments (level of P residual and maintenance, mycorrhiza, and crop system), the annual corn grain yields to three cultivated crops, range from 5.50 to 11.10 Mg ha^{-1} with average of 8.64 Mg ha^{-1} (data not shown). In irrigated corn, the yield potential obtained by farmers in the region, range from 8.0 to 10.0 Mg ha^{-1} against 4.50 to 6.50 Mg ha^{-1} in rainfed corn conditions.

In the Table 2, are presented the grain yield of corn in each growing season. For all experiments the isolated effect of levels of P residual (legacy P) and maintenance (fresh P) were statistic significant ($p \leq 0.10$), with the higher yields obtained with the high level of P residual associated to P maintenance (Table 2). If we take in count only the effect of P residual, without P maintenance or mycorrhiza application, it was obtained gain of 30 % (2.15 Mg ha^{-1}), 27 % (2.07 Mg ha^{-1}) and 3.2 % (0.26 Mg ha^{-1}) in the grain yield in the plots with high P residual (300 kg ha^{-1}) as compared with control, indicating that is important to maintain in the soil values of "bioavailability" of P above the critical level (Table 1), to reach economic yields of corn.

Table 2. Effect of P residual (legacy), P maintenance, mycorrhizae, and crop system in the grain yield of corn cultivated in rotation with soybean in four growing seasons.

Mycorrhizae (M)/ P-Maintenance (kg ha^{-1})	**P - Residual (kg ha^{-1})**			**Average**	**Crop system**	
	0 (Low)	**100 (Medium)**	**300 (High)**		**Corn**	**Corn + Brachiaria**
Growing Season 2014-15, Grain Yield (Mg ha^{-1})						
M	7.17b	7.00c	9.52b	7.90c	8.87b	6.92c
0	7.07b	6.63c	9.22b	7.64c	7.81c	7.44c
22	7.78b	7.89b	10.05ab	8.57b	9.05b	8.10b
44	8.90a	9.54a	10.39a	9.60a	9.79a	9.42a
Average	7.72B	7.77B	9.80A		8.88A	7.98B
Growing Season 2016-17, Grain Yield (Mg ha^{-1})						
M	6.88b	6.81c	9.90ab	7.86c	8.58bc	7.14c
0	7.58b	6.82c	9.65b	8.02c	7.96c	8.08b
22	8.90a	8.53b	10.56a	9.33b	9.28b	9.38a
44	9.41a	9.95a	10.73a	10.03a	10.09a	9.97a
Average	8.19B	8.02B	10.21A		8.98A	8.64A
Growing Season 2019-20, Grain Yield (Mg ha^{-1})						
M	8.12	6.88	8.76	7.92b	8.88b	6.96b
0	8.06	7.66	8.32	8.01b	8.35b	7.67b
22	9.35	8.88	9.86	9.36a	9.70a	9.03a
44	9.25	9.14	9.78	9.39a	9.96a	8.83a
Average	8.69A	8.14B	9.18A		9.22A	8.12B

Medias in the same column following by same letters are not statistically different by tukey test at 0.10 level. Small letters compare effect of P levels maintenance and capital letters compare P levels residual and crop system.

On the other hand, independent of crop system used, the grain yields obtained in the control treatment (Table 2) during the period analyzed (6.0 to 8.0 Mg ha^{-1}), were an indicator to the potential of this soil to supply P for the crop, although the "bioavailability" of P (Mehlich1) is around the critic level

(Table 1), an indicator that other sources of P in soil are releasing P for corn. As mentioned by Soltangheisi et al. (2020), without P fertilization, organic P contribution to supply P for plant uptake is higher than inorganic P. These actors, verifying in long-term field experiment, that under nil-P, the organic fractions of P (Po labile and moderate labile), was depleted by 31% (from 51% in 2009 to 20% in 2017), which indicates that these organic P fractions are acting as a source of available P over the time. Another aspect to be considered is that the Melich1 extractor do not measure the potential of P bioavailability of soil. As verified by Gatiboni et al. (2002), a single Mehlich1 extraction, extracted only 29% of the potentially available phosphorus and to extract the potentially available phosphorus, four successive extractions were necessary.

The effect of crop system in the corn grain yield was not consistent, with variations among the growing seasons (Table 2). Only in the growing season of 2016-17, the corn grain yield was similar between the crop system, in the others growing season, the system brachiaria intercrop with corn reduced corn grain yield. Apparently, this effect could be not attributed to soil P bioavailability and probably due to the management of development of brachiaria. Lower yields of cash crops have been observed after growing ruzigrass compared with those in fallowed soil. Almeida et al. (2019) observed a lower soybean [*Glycine* max (L.) Merrill] grain yield and leaf P concentration after ruzigrass than fallow in four consecutive years.

Although, the soil used in the present research has a high reserve of phosphorus in the soil, from natural and the addition of phosphate fertilizer over the period (Table 1), corn responded to doses of this nutrient applied as maintenance (Table 2), especially when the “bioavailability” of soil revealed by the Mehlich1 extractor was below the critical level (6.0 mg dm^{-3}). However, as reported by Owen et al. (2015), the exploitation of soil P reserves is hindered by the fact that the forms, distribution, and accessibility of legacy P are complex and diverse, and often not in a form that is readily available for plant uptake. Thus, in the absence of a pool of readily-available P provide by inorganic fertilizers, plant must utilize numerous strategies to acquire soil inorganic (Pi) and organic (Po) quickly and efficiently to ensure an adequate supply of P during the growing seasons.

CONCLUSIONS

Results showed that, in this specific case and after four years of P “draw down” by the corn grain, legacy P in soil alone (without addition P fertilization) led to a significantly lower cumulative grain yield than with P fertilization, when other nutrients in the soil were at adequate levels. In general, the cultivation of brachiaria intercropped with corn reduced the productivity of corn grains when compared to corn cultivated alone. However, this reduction was not associated with the availability of P in the soil, but probably with an inadequate management of the brachiaria, resulting in a marked competitive effect. Thus, in this research, there was no evidence that the use of brachiaria intercropped with corn associated with mycorrhiza can optimize the use of soil P reserves. The potential and time for utilization of P reserves in the soil is closely related to the bioavailability of P, evaluated by extractor (Mehlich1), whose values must be above the pre-established critical levels, that provide economic productivity for farmers.

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DECOMPOSITION OF OAT STRAW IN DIFFERENT MANAGEMENTS OF SUMMER CROP SOWING AND SOIL ACIDITY CORRECTION IN THE CROP-LIVESTOCK INTEGRATION SYSTEM

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ABSTRACT

The decomposition of plant residues is closely linked to its structural composition, being influenced by the management carried out in the crop and which conditions the release of nutrients. The objective of this work was to evaluate the dry matter decomposition rate of oats in an oxisol, when subjected to different combinations between soil acidity corrective / conditioner and sowing methods of grain culture, in grazed area and in non-grazed area. The experiments were carried out in the municipality of Vitorino in Paraná. Two experiments were conducted, one in an area of black oats grazed in winter and another in an area of not grazed black oats, organized in a bifactorial scheme (2x4) with subdivided plots, in a randomized block design with four replications. In the main plots, two managements of the sowing of the summer crop were allocated (sowing with mismatched double discs and sowing with furrow rods); the subplots were composed of four forms of soil acidity correction / conditioning [without correction; recommended dose of limestone (2000kg acre^{-1}); recommended dose of plaster (1000kg acre^{-1}) and the mixture of limestone + plaster], totaling 32 experimental units per experiment (2x4x4). Grazed black oats showed a lower dry matter decomposition speed compared to not grazed black oats, regardless of the treatment. The decomposition rate of the remaining dry matter of grazed black oats does not differ significantly between treatments. In general, the use of mismatched double discs resulted in a shorter half-life of ungrazed black oats than the use of furrow rods.

Key words: Dry matter; Limestone; Plaster

INTRODUCTION

The growing demand for food, animal and vegetable raw material, poses a major challenge to Brazilian agriculture, increasing production with less environmental impact (GASPARINI et al., 2017), integrated agricultural production systems, are a bet to meet this need, which makes it possible to diversify production on the property, extra income in the off-season and cattle food in winter with the implantation of black oats (*Avena strigosa*), also used as a vegetable cover (ZANELLA, 2019; FLORES et al., 2007).

The use of nylon *litter bags* is the main way of accounting for the speed of decomposition of dry oat matter and the release of nutrients for the summer crop, this knowledge being indispensable to enable integrated agricultural production systems, in which there are no results in the literature regarding the influence that the superficial application of soil acidity corrective and conditioner and sowing methods have on the decomposition and release of nutrients from the oat straw to the successor crop, in grazed and not grazed areas.

MATERIAL AND METHODS

The experiment described below was carried out in an area belonging to a private property in the municipality of Vitorino-PR (26°17’38.3” S, 52°40’23.7” W), since May 2018.

Two experiments were carried out in a contiguous area. One on an area of black oats grazed in winter and another on an area not grazed, both were organized in a bifactorial scheme (2 x 4) in plots subdivided in a randomized block design with four replications. The main plots consisted of two management systems for the sowing of the summer crop (sowing with mismatched double discs and sowing with furrow rods).

In the subplots, four different forms of soil acidity correction / conditioning were allocated [without correction; recommended dose of limestone (2000 kg acre^{-1}); recommended dose of plaster (1000 kg acre^{-1}); limestone mixture (2000 kg acre^{-1}) + plaster (1000 kg acre^{-1})], totaling 32 experimental units (2 x 2 x 4), in each experiment. The application of treatments (2 sowing managements x 4 forms of soil acidity correction / conditioning) started on October 29, 2018 with the sowing of the soybean crop, succeeding the black oat crop sown in April 2018. The oats used in this work were implemented in April 2019.

To assess the speed of decomposition of the matter, vegetable residues were collected randomly in each plot, being dried in an oven at 60 ° C for 72 hours, then weighed 20g of dry matter and placed in nylon bags with 2 mm mesh, size 20 x 20 cm. With that, the litter bags were identified, sealed and distributed in the experiment area, where they were collected after 30, 62, 96, 120 and 132 days, afterwards they were weighed and the weight difference based on the total amount of dry matter (20g) was carried out, less the remaining number of evaluation days.

The dry matter decomposition rates (DM) of the oat residues were estimated by adjusting the non-linear regression model, as proposed by Wieder and Lang (1982) (Equation 1) and, in case of lack of adjustment, it will be by the linear model simple (Equation 2). The two fitted models have the following mathematical equations:

Equation 1: RDM = Ae-kat + (100-A)

Equation 2: RDM = a + bx

In which the RDM = percentage of DM remaining at time t (days); ka = constant decomposition rates of DM; t = time (in days after the deposition of dry matter in the soil).

In the asymptotic model (Equation 1), only the DM remaining in the most easily decomposable compartment is transformed, decreasing over time at constant rates (Ka).

The criteria for choosing the model were the significance of the model ($p \leq 0.05$) and the highest adjusted determination coefficient.

With the adjusted model and the DM decomposition values, the half-life time ($t_{1/2}$) was calculated, the time required for 50% of the DM of that compartment to be decomposed, using the following formula (PAUL & CLARK, 1996):

$T_{1/2} = 0.693 / (a)$

To adjust the equations, the SigmaPlot® statistical computational application, version 12.5 (SYSTAT SOFTWARE, SAN JOSE, CA) was used.

RESULTS AND DISCUSSIONS

The rate of decomposition of plant residues is linked to its structural composition, which is influenced by the management of the crop and which conditions the release of nutrients to the system, which will be made available to the successor crop.

All adjusted models had a high adjusted coefficient of determination (R^2adj.) Indicating that they are adequate to represent the functional relationship between the percentage of remaining dry matter of black oats and the days after straw deposition (Figures 1 and 2). The values of R^2adj. ranged from 84% (in the treatment using lime as a soil acidity corrector and sowing soybeans with mismatched double discs, in an area of grazed black oats, (Figure 1B) to 98% (in the treatment with lime + plaster and soybean sowing with furrower stems, (Figure 2D).

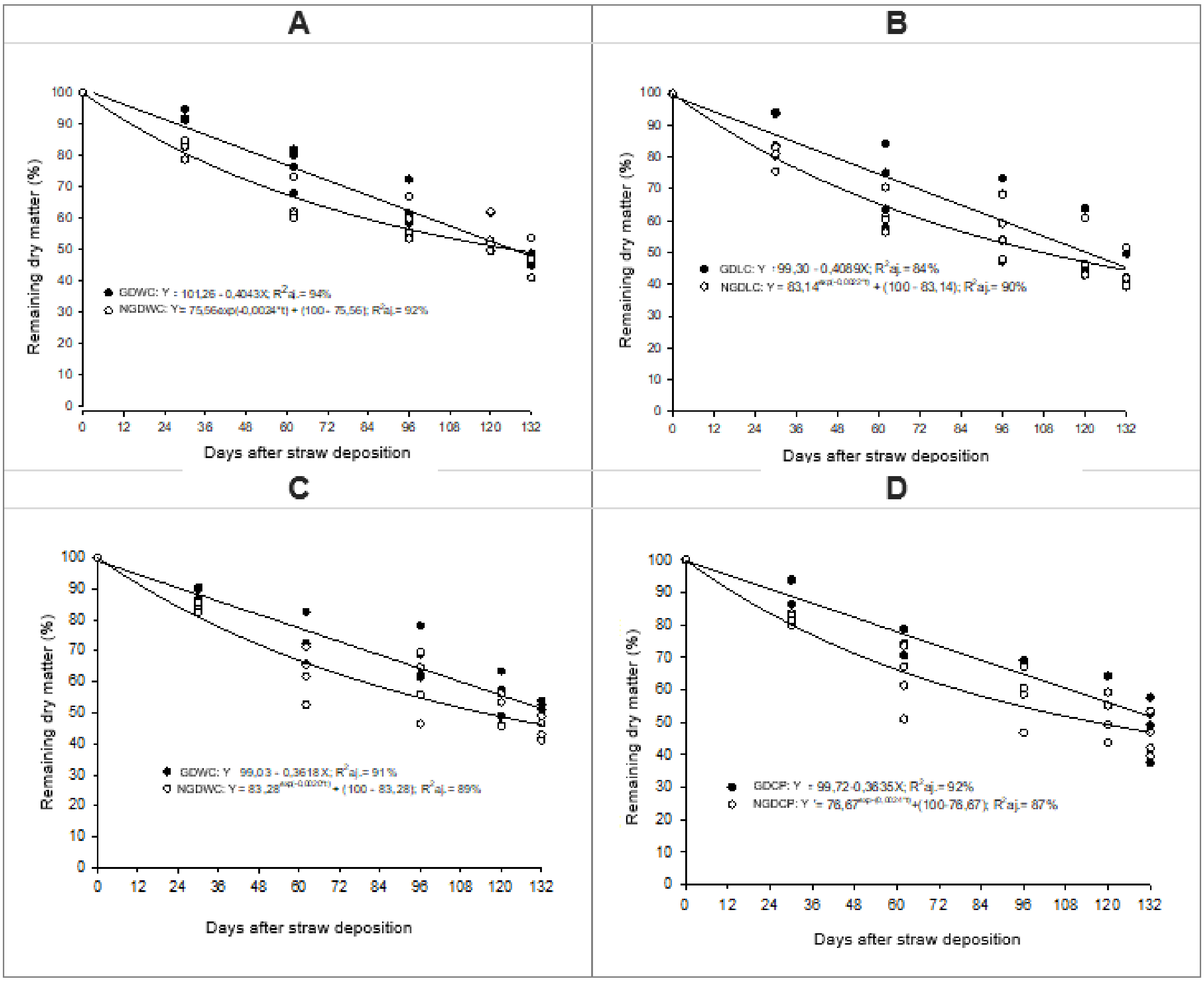

Figure 1A. GDWC: grazed oats double discs found without correction of soil acidity; NGDWC: not grazed oat double discs found without correction of soil acidity. Figure 1B: GDCL: grazed oats double discs mismatched with correction using limestone; NGDCL: double disc not grazed oats matched with correction using limestone. Figure 1C: GDWC: grazed oats, double discs found without correction of soil acidity; NGDWC: not grazed oat double discs found without correction of soil acidity. Figure 1D: GDCP: grazed oats double discs mismatched with soil acidity correction using plaster; NGDCP: not grazed oat double discs mismatched with soil acidity correction using plaster. Source: Own authorship (2020).

Figure 1. Remaining dry matter (RDM) in % of the oat culture as a function of days after straw deposition: 0, 30, 62, 96, 120 and 132 days; cultivated in two experiments: experiment 1 (grazed black oats - G) and experiment 2 (black oats for cover = not grazed - NG). Each of the experiments

had sowing of the summer crop with mismatched double discs (Figure 1) and furrower (Figure 2) associated with different soil correction methods: witness without applying soil acidity corrective (A), recommended dose of limestone (B), recommended dose of plaster (C) and, recommended dose of limestone + recommended dose of plaster (D); in a randomized block design in subdivided plots (main plot = summer crop sowing method; subplot; soil correction methods) with four replications. Vitorino-PR, 2019.

The models that best represent the behavior of dry matter remaining over time, for grazed black oats, are all linear (Figure 1A to 1D), indicating that there is a constant decrease in MSR over time, with daily decreases in MSR (decomposition speed) ranging from -0.3618% (sowing with double discs and conditioning with plaster) to -0.4111% (sowing with furrowing stems and without correction).

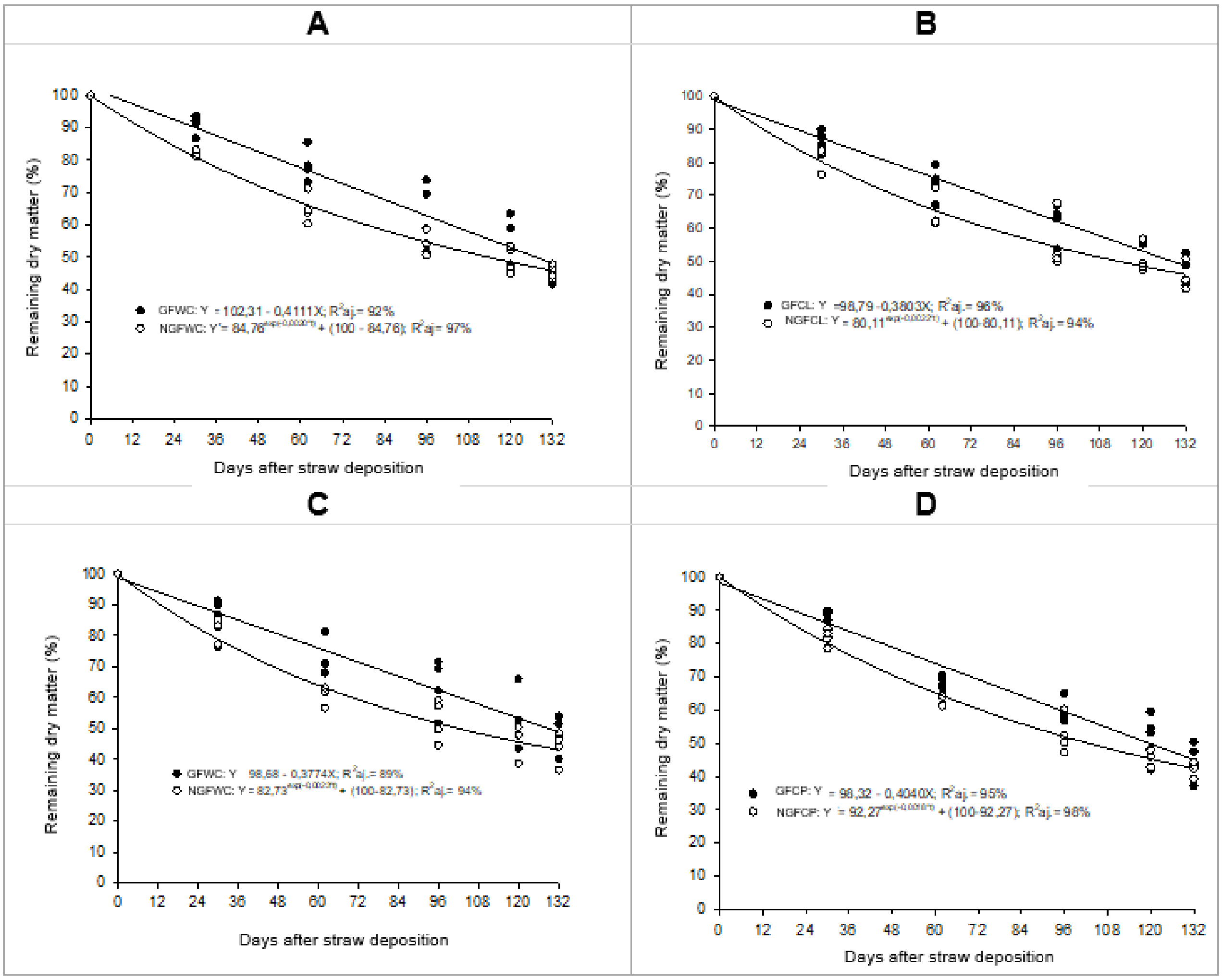

Figure 2A. GFWC = grazed oat furrower without correction of soil acidity; NGFWC = not grazed oat furrower without correction of soil acidity. Figure 2B: GFCL: grazed oat furrower with correction using limestone; NGFCL: not grazed oat furrower with limestone soil acidity correction. Figure 2C: GFWC: grazed oat furrower without soil acidity correction; NGFC: not grazed oat furrower without soil acidity correction. 2D figure: GFCP: grazed oat furrower with plaster soil acidity correction; NGFCP: not grazed oat furrower with plaster soil acidity correction. Source: Own authorship (2020).

Figure 2. Remaining dry matter (RDM) in % of the oat culture as a function of days after straw deposition: 0, 30, 62, 96, 120 and 132 days; cultivated in two experiments: experiment 1 (grazed black oats - G) and experiment 2 (black oats for cover = not grazed - NG). Each of the experiments had sowing of the summer crop with mismatched double discs (Figure 1) and furrower (Figure 2) associated with different soil correction methods: witness without applying soil acidity corrective (A), recommended dose of limestone (B), recommended dose of plaster (C) and, recommended dose

of limestone + recommended dose of plaster (D); in a randomized block design in subdivided plots (main plot = summer crop sowing method; subplot: soil correction methods) with four replications. Vitorino-PR, 2019.

For not grazed black oats, regardless of the treatment used, the percentage of dry matter remaining of black oats over time was adjusted to the simple exponential model, in which only the most easily decomposable compartment reduces to constant rates over the evaluation period (Figure 2A to 2D). All equations had a high adjusted coefficient of determination (R^2adj.), Between 89 and 98%, indicating that the mathematical models adjusted for each situation satisfactorily explain the relationship between the RMD and the straw deposition time.

The linear models adjusted for the relationship between RMD and the days after straw deposition, for grazed black oats show that under grazing and animal trampling in the area, the decomposition of black oat straw was slower than in an area with absence of animals (black oats for ground cover), regardless of the treatment studied. This result contradicts those already existing on the subject, as it can be explained by the lower leaf / stem ratio present in the grazed area. However, it was reported by several authors, among them Bortolli (2016), that for black oats at high grazing height, that is, a situation with little grazing intensity, similar to the ungrazed area, observed a lower leaf / stem ratio and higher levels of cellulose and lignin, which reduced the speed of decomposition of the straw in relation to the low grazing height, in which leaves predominated, originating from regrowth of the pasture.

This contrast observed in the present study can be explained by the water deficit at the stage when the material under study was collected. Under normal conditions, the grazed area has a lower C: N ratio due to the greater presence of new and better nourished leaves, as a result of the frequent deposition of feces and urine on the soil surface (MCNAUGHTON, 1992); However, at the time of straw collection for the study, a moment of water deficit was recorded in the region, which negatively influenced the emission of new leaves and grazing, which, in turn, led to the formation of a compound pasture, mostly by more fibrous material and slower decomposition.

For grazed black oats, values close to decomposition speed are observed in all treatments and especially in treatments without correction (-0.4043% day^{-1}, Figure 1A) and correction with recommended dose of limestone (-0.4089 % day^{-1}, Figure 2B), when double discs were used when sowing soybeans; which are also similar to those observed for treatments without correction (-0.4111% day^{-1}, Figure 2A) and correction / conditioning with limestone + plaster (-0.4040% day^{-1}, Figure 2D), when sowing was performed with furrating rods. These results show that the correction / conditioning of soil acidity associated with the use of double discs or furrowing rods in grazed area did not influence the straw decomposition speed. A similar situation was reported with the use of limestone by Caires et al. (2006), who observed that when applying it on a surface with or without grazing, there was no interference in the decomposition of oat straw.

The most easily decomposable compartment (A) of the adjusted exponential model for ungrazed black oats is indicative of the decomposition speed that varies from 0 to 100.00; in the adjusted equations, this parameter ranged from 75.56 (use of double discs in soybean sowing associated with the absence of soil acidity correction, Figure 1A) to 92.27 (use of furrower stems and soil correction / conditioning with lime plaster; Figure 2D), demonstrating that most of the remaining dry matter of the oats was in the compartment of easy decomposition. Bortolli (2016) found values of (A) between 78 and 85 for black oats managed at low and high grazing height, respectively.

The half-life times of ungrazed black oat straw ranged from 289 days (double discs without correction of soil acidity and correction / conditioning with limestone + plaster) to 385 days (furrowing stems and limestone + plaster). Equal values (315 days) were observed in treatments with double disc sowing and sowing with furrow rods when soil acidity correction using limestone (315 days) was carried out. This can be explained by the greater soil disturbance caused by the furrowing rod that leads the limestone and plaster to a greater depth, making more calcium available, which is present in the cell wall of plants, which increases the rigidity of the tissues (FAQUIN, 2005).

Working in the same area, with soy litter bags, in the previous year (2018) Pavan (2019), considering only the area not grazed in winter, also found that when using furrower rods the remaining dry matter half-life was longer. According to the author, this is due to the greater turning and unpacking of the soil by the furrower stems, which results in a better distribution of the roots and greater growth and development of the plants, which, in a condition of water stress (event that occurred during the cultivation of the oats in 2019), stand out from the rest, producing a stiffer and slower decomposition dry matter.

In summary, it was found that the main aspect that should be observed by producers in relation to the speed of decomposition of the dry matter of black oats is the type of management to which it was subjected, that is, whether for grazing or covering the soil.

CONCLUSIONS

Grazed black oats showed a lower dry matter decomposition speed compared to non-grazed black oats, regardless of the treatment.

The decomposition rate of the remaining dry matter of grazed black oats does not differ significantly between treatments.

In general, the use of mismatched double discs resulted in a shorter half-life of not grazed black oats than the use of furrow rods.

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LIGHT USE EFFICIENCY OF EUCALYPTUS CLONES IN AN INTEGRATED CROP-LIVESTOCK SYSTEM IN THE NORTH REGION OF BRAZIL

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ABSTRACT

A good part of the world's wood supply is provided by forest plantations, which reduce the pressure on the exploitation of native forests. Normally, forest plantations are made on soils of low natural fertility, depending on the supply of nutrients for good development of the crop. Understanding the functioning of the stand in relation to efficiency in the use of resources is of paramount importance for its economic and environmental sustainability. The objective of this work was to analyze the light use efficiency of contrasting clones of *Eucalyptus* sp. cultivated in an integrated crop-livestock system in the northern region of Brazil. To determine the light use efficiency - LUE, five diametric classes were determined and two trees per diametric class of each clone were felled at 30 months after planting. For the density of 344 trees ha^{-1}, the LUE (in a period of six months) varied between 0.34 and 0.61 g MJ^{-1}. The genotypes presented contrasting values for the parameters leaf area index, wood biomass and LUE. For the studied clones, the light use efficiency and the accumulation of biomass in the wood had a positive correlation with the leaf area index.

Key words: biomass; resource use; genotypes

INTRODUCTION

Brazil has about 9 million hectares of forest plantations, which are mainly composed of species of the genera *Eucalyptus* and *Pinus*, which account for 91% of all wood produced for industrial purposes in the country. This area corresponds to 0.84% of the country's area and 1.55% of the total area of forests (IBÁ, 2020). Forests have a key role in capturing and storing large amounts of carbon from the atmosphere (MONTAGNINI; PORRAS, 1998).

The assimilated carbon can be used for growth and establishment of reserves, while the magnitude of the net assimilation rate depends on the physiomorphological constitution of the plant species, such as photosynthetic capacity, leaf area and proportion of photosynthesizing tissues in the foliage (LARCHER, 2000). Furthermore, environmental factors such as water, light and nutrients, for example, can affect the production of dry matter and, consequently, interfere in the carbon balance.

Tropical forests provide an increasing portion of the global wood supply and the competition with other land uses in the future will require sustained yields to meet demand. In the 1990s, eucalypt selection programs in Brazil also began to consider resource use efficiency (RUE) as a criterion for choosing superior genotypes, in addition to productivity, wood quality, tree form and resistance to diseases (SANTANA; BARROS; NEVES, 2002). RUE can vary within a plant species due to the genotypic differences that can occur and the genotype-environment interaction. These differences can alter the capacity of plants to absorb, transport and utilize nutrients (STEENBJERG & JAKOBSEN, 1963; MARSCHNER, 1997).

Also, about the environmental factors that can affect the production of dry matter, greater light radiation (intensity and/or exposure) is able to promote increases in biomass increment, since species with high relative growth rates need more light to reach their metabolic optimum (TAIZ & ZEIGER, 2009). The objective of this work was to evaluate the efficiency in the use of light by three Eucalyptus sp. clones planted in an integrated crop-livestock system in the southern of Rondônia.

MATERIAL AND METHODS

Study area

The work was carried out at Federal Institute of Rondônia, Colorado do Oeste-RO, Brazil (13°07'53"S and 60°28'57"W). The soil of the region is of type eutrophic Oxisol (EMBRAPA, 2006) and according to the Köppen classification the climate of the region is of type Am, tropical hot and humid, with two well-defined seasons (ALVARES et al., 2013).

This experiment is part of an integrated crop-livestock-forest system, implemented in December 2015. The area where the system is implemented presents slope varying from 2.0 to 6.0%. being previously used for more than 15 years with the cultivation of corn for silage production in conventional soil preparation system.

In 2015, the soil was prepared with subsoiling and harrowing and terraces were built. After soil preparation, seedlings of six clones of *Eucalyptus* sp. were planted, which were purchased from a commercial nursery in the region. The planting rows were spaced 2.0 meters apart and 3.0 meters between rows. The space between rows was 26.0 meters, with 344 trees per hectare. The clones were equally distributed throughout the experimental area.

Determination of Dendrometric Variables

At 30 months after planting, an inventory of the plantation was made to determine the dendrometric variables and through these five intervals of diametric classes were determined. Two trees were felled for each class. Three contrasting clones were evaluated, which were considered the treatments. In each plot, the diameter at breast height (DBH cm) and total height (Ht m) of all individuals were measured.

Leaf Area

After felling the trees, all the leaves were removed and weighed, and a sample of 100 leaves collected randomly along the crown was weighed separately. Once in the laboratory environment, the 100 leaves from the sample had the areas of their limbs measured by means of an optical planimetry apparatus and were then taken to the oven at 60º C until their weight stabilized. With the values of the sample dry weight and leaf area, it was possible to determine the Specific Leaf Area (SLA) of the individual, which relates the amount of leaf area per dry mass ($m^2\ kg^{-1}$). From the ratio dry mass/wet mass of the sample, it was possible to estimate the total dry weight of the leaves of the harvested tree and, multiplying this by the SLA, the total leaf area of the harvested tree was estimated. Thus, the calculation of the leaf area index (LAI) was given by the ratio between the sum of the leaf area of all trees (m^2 of leaf/m^2 of soil) and the area of the plot (m^2).

Light Use Efficiency

The light use efficiency (LUE) was calculated for each clone by dividing the dry matter of the trunk (data from dendrometric analyses) by the photosynthetically active radiation intercepted (PAR), according to the methodology proposed by Pangle et al. (2009). The observed period was six months, between 24 and 30 months after planting.

LUE = NPPw/PARi

where,

LUE = light use efficiency (g MJ^{-1}), NPPw= net primary wood productivity (Mg ha^{-1} $period^{-1}$), PARi = intercepted photosynthetically active radiation (MJ m^{-2} $month^{-1}$).

The NPPw of a period was calculated by subtracting the biomass at the end and the beginning of the period. The net primary wood production was evaluated by the equation:

$NPPw_{i,j} = W_{B\ ij} - W_{B\ i(j-1)}/(j-1)$

where,

NPPw: net primary wood productivity (Mg ha^{-1} $period^{-1}$);

W_B: wood biomass (Mg ha^{-1});

i: plot;

j: time (semester or year)

The intercepted photosynthetically active radiation was calculated using Lambert Beer's Law, following the equation (SANDS; LANDSBERG, 2002) (LANDSBERG AND SANDS, 2011):

$PARi = APAR * (1-exp^{-k.IAF})$

where,

APAR = absorbed photosynthetically active radiation (MJ m^{-2} $month^{-1}$); k = light coefficient extinction (data obtained in literature); LAI = leaf area index (m^2 of leaf m^{-2} of soil).

APAR = 0.5 * Qg (global solar radiation). The Qg values were obtained from the nearest weather station of the National Institute of Meteorology (INMET). In case of failure, the data were then obtained by the Nasa Power.

RESULTS AND DISCUSSIONS

The biomass values presented refer only to the stem. For the clones studied, light use efficiency showed a positive correlation with the leaf area index (Figure 1). In a study developed by Le Maire et al (2019), the authors observed that genotypes with high growth efficiency did not necessarily show high LUE, these differences resulted from the non-proportionality between the LAI and the fraction of absorbed photosynthetically active radiation.

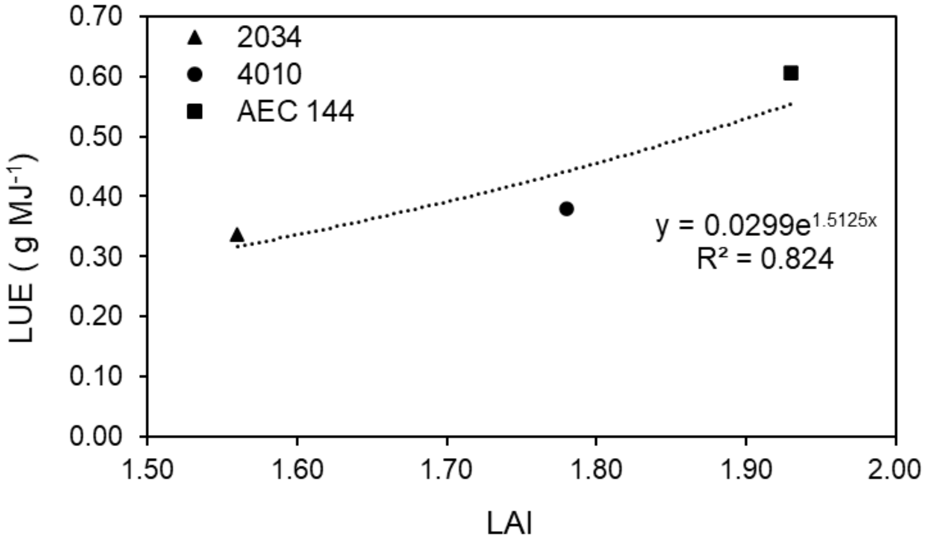

Figure 1. Allometric relationship between leaf area index and light use efficiency of the studied clones.

The biannual LUE ranged between 0.34 and 0.61 g MJ^{-1} (Table 1). The values found in the literature represent the LUE in conventional plantations (pure and with a density of 1666 trees ha^{-1}). Making the conversions to this, the values observed in our study resemble those found by Stape et al. (2008) and Mattos (2015).

Table 1. Mean values of growth, wood biomass and light use efficiency (LUE) of eucalyptus clones at 30 months of age in an integrated crop-livestock system in the southern cone of Rondônia, Brazil.

Clone	DBH (cm)	H (m)	Biomass (Mg ha^{-1})	LAI	LUE (g MJ^{-1})
2034	9.50	10.91	18.02	1.74	0.34
4010	11.10	10.96	23.15	2.26	0.38
AEC 144	11.66	12.67	27.78	2.72	0.61
Average	10.72	11.49	22.83	2.23	0.44

DBH = diameter at breast height; H = total height; LAI = leaf area index; LUE = light use efficiency.

CONCLUSIONS

The genotypes showed contrasting values for the parameters LAI, woody biomass and LUE. For the clones studied, the light use efficiency and the accumulation of biomass in the woody had a positive correlation with the leaf area index.

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YIELD COMPONENTS AND CORN PRODUCTIVITY IN THE INTERCROP WITH BRACHIARIA RUZIZIENSIS AND PIGEON PEA AT THE SOUTHERN BRAZIL

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ABSTRACT

The objective of this work was to evaluate the yield components and morphological traits of Corn intercropped with *Brachiaria ruziziensis* and Pigeon Pea (*Cajanus cajan*). The experiment was developed in the Instituto Federal Catarinense – Campus Concordia, Western region of Santa Catarina State – Brazil. Randomized block design with four replications was used. Treatments were composed by intercrop and single crop plant arrangements as follows: *(1)* Corn; *(2)* Corn + *Brachiaria ruziziensis*; *(3)* Corn + Pigeon Pea; *(4)* Corn + *Brachiaria ruziziensis* + Pigeon Pea. The evaluations were developed at the end of the Corn cycle, during the grains harvest. The presence of *Brachiaria ruziziensis* did not influence the Corn grain yield. When the intercrop used *Brachiaria ruizizensis* and Pigeon pea it was observed increases in the ear diameter and Grain depth in the cob. The treatments that intercropped all plants did not influence de number of grains per row, and presented lower percentages of lodging and rickety plants.

Key words: *Zea mays*; *Cajanus cajan*; Crop Livestock Systems

INTRODUCTION

The Western region of Santa Catarina State is located in the Brazilian subtropical zone. Climate in the area presents good rainfall levels, well determined warm and cold seasons, further soils with high presence of clay and good fertility. This territory is notable by the dairy production, farms of small size and family workforce as main mechanism for the activities management. One of the bottlenecks in the development of the region, however, is the production of forage for the herd in the transition of the seasons, this is promoted by factors as the climate itself but also by size of the cropped areas and the hilly terrain. The system used follows the guideline of producing corn for silage during the summer and annual winter forages as Oat and Ryegrass for grazing in the winter. In this Crop-Livestock system the Corn became so a fundamental crop as it produces high amounts of dry mass and good bromatological quality conserved feeds.

Over the last years some problems started to take form in this system. The excessive nutrient extraction and the intense degradation of the soil structure by the machinery traffic brought to the light the necessity to look for some techniques to recover the environment capacity and improve the sustainability. Intercropped systems could be an interesting alternative to manage this situation since it allows the production of corn with forages concomitantly, those last ones which can be used as soil cover or animal feed in the period after the grain harvest (OLIVEIRA, 2013). These systems are well known in the tropical region of Brazil, being noticed by the better use of agricultural inputs, increasing in soil organic matter and improvement in the nutrient cycling (SOARES et al., 2014).

Besides the adoption in several areas of the country it still needs some investigation about the viability in regions of higher latitudes as the Southern Brazil. Some results can change according to the environment, the presence of different biotic (diseases, pests) and abiotic (water availability, fertility, temperature ranges) drivers could control the expression of the yield potential. In intercrops these factors became even more complex once competition can result in a lower development of the species involved and consequently threaten the system viability (VIDAL, 2010).

In Corn part of the yield are defined in the early stages. In V5 and V4, as example, the plant originates the primordia of the tassel and the ear, and also define the number of leaves the adult plant will have (RITCHIE et al., 1993). In V8 some of the yield components as the row number per ear and the number of grains per row begin to be defined (MAGALHÃES; DURÃES, 2016). These stages can be known as critical competition periods, and appears in several other moments of the cycle as well, including the flowering, pollination and grain filling. If some resource limitation occurs in these phases the plant may reduce the productivity (BRITO et al., 2011).

The species which compose a intercrop with corn must be selected and arranged then in a way the competition is reduced, avoiding effects in the crop yields. *Brachiaria ruziziensis* is one of the species commonly used in these systems in Brazil, it has high capacity to produce forage, good bromotological quality and seed available in the market, besides being one of the easiest species in *Brachiaria* genus to eliminate spraying herbicides as glyphosate (RICHART et al., 2010). Nonetheless, the use of legumes in the arrangement could be recommended since it promotes biological nitrogen fixation and soil improvements. Nunes et al. (2006) indicates the Pigeon Pea (*Cajanus cajan*) as a good plant to that, the author relates the legume as capable of improving the soil fertility or the quality of the feed when the sward is harvested for silage. On this basis if it is known the influence of the plants present in the intercrop it could be possible to avoid yield reductions, and also understand which corn yield component may be affected by the competition. The objective of this work was to evaluate the yield components and morphological traits of Corn in an intercrop with *Brachiaria ruziziensis* and Pigeon Pea in the Southern Brazil.

MATERIAL AND METHODS

The experiment was developed in the Instituto Federal Catarinense (IFC) Farm, Concordia – SC – Brazil (640 a.s.l.; 27°13'55" S e 52°00'26" W). Climate is Subtropical humid (Cfa) according to Köppen classification. Average air temperature is 19.6 ºC and rainfall rates are near 1900 mm year^{-1} (Embrapa, 2019). Soil is classified as Red Nitosol, with strong presence of clay (Santos et al., 2018).

Randomized block design with four replications were used. Treatments were composed by plant combinations to form single and intercropped arrangements as follows: *(1)* Corn (‘C’); *(2)* Corn + *Brachiaria ruziziensis* (‘CB’); *(3)* Corn + Pigeon Pea (‘CP’); *(4)* Corn + *Brachiaria ruziziensis* + Pigeon Pea (‘CBP’). Experiment was sowed after a pasture of Oat + Ryegrass grazed by dairy cows. It was used for desiccation of the pasture Glyphosate (480 g.a.i ha^{-1}). The area was divided into experimental plots of 48 m^2. For the single corn cropping rows were spaced 0.8 m (six rows per plot), with a sowing density of 75,000 seeds ha^{-1}. Intercropped systems that used Corn + Pigeon Pea were arranged in a 0.8 m row spacing and the species were interspersed (three rows of corn and three rows of Pigeon Pea), it was then used 37,500 seeds ha^{-1} for corn and 1.75 kg of pigeon pea seeds ha^{-1}. In all plant arrangements with *Brachiaria ruziziensis* it was used 40 kg seeds ha^{-1} in a 0.4 row spacing, and these seeds were mixed with the fertilizer in the moment of the seeding. 300 kg ha^{-1} of N-P_2O_5-K_2O (9-33-12) were delivered in the row at the sowing moment, and 150 kg ha^{-1} of Urea (45% N) was top-dressed in the corn V3 stage.

Sampling was developed in the moment of the harvest (May 16; 6.4 m^2 - 2 x 3.2 m) just in the central part of the plot, avoiding the 2 external rows and 0.5 m longitudinally at the end of the rows. Variables evaluated were Corn yield (kg ha^{-1}); Number of rows in the ear; Number of grains in the ear row; Thousand grain weight (g); Ears per hectare; Grain moisture; Ear diameter; Grain depth and; Plant stand (plants ha^{-1}). Morphological variables were evaluated as well: plant height; ear height (counting from the ground); percentage of lodging (collapse below the second node), broken plants (collapse above the second node) and rickety plants (plants with low development). Statistical analysis was performed using Genes software (CRUZ, 2006) and regression curves were generated according to significance of the model. All analysis used 5% significance level.

RESULTS AND DISCUSSIONS

There were no water shortages neither substantial influence of pests or diseases during the corn cycle. Considering this situation pesticides were not applied looking to preserve the plants form influences of the chemical products. It was observed the presence of spontaneous Alexandergrass (*Brachiaria syn. Urochloa plantaginea*) in the intercrops, this plant is very common in Southern Brazil, developing from the soil seed bank in crops during the warm season. This occurrence however is not a problem and can be also a contributor to the forage production given the good bormotological quality and high mass production of this plant.

Results obtained in the evaluations are presented in the Table 1. There was no difference in the Corn yield between the treatments ‘C’ and ‘CB’ (9,011 kg ha^{-1} and 10,112 kg ha^{-1}, respectively). These values are also higher than the average of the Santa Catarina State for Corn productivity (7,997 kg ha^{-1}; Conab, 2018). *Brachiaria ruziziensis,* then, did not affect the productivity of Corn, a behavior observed also by Freitas et al. (2013) and Oliveira et al. (2010). These authors indicate yet the fertilization in proper levels as fundamental for these results. The yield was reduced when Pigeon Pea was included in the intercrop (‘CP’ and ‘CPB’; Table 1). It is important to point that this difference is probably a result of the lower corn plant population in the arrangement that used Pigeon Pea. It is also confirmed by the differences in the ear number per area.

Analysis of the variables grains per row, row per ear and grain moisture did not present statistical difference among the treatments. Yield components are important characteristics to define the grain yield, in corn the row number it is usually defined near the stage V8 and the grain per row is defined in the stage V12, those are then considered critical periods in the development of the plant. In these moments stresses as water shortage, nutrient deficit or competition will probably influence negatively the ear size and consequently the grain productivity (MAGALHÃES; DURÃES, 2016). Considering the results obtained it is possible to say that the species involved in the intercrop do not influence this yield components in the ear.

The number of grains per ear, however, was higher in the treatment ‘CBP’ in comparison to ‘C’ and ‘CB’, and presented no differences in comparison to ‘CB’. In this case the changes in plant population could be positive to the increase of the grain number in a single plant. The average of the treatments indicates good numbers (more than five hundred grains per ear) which is product of a good development of the plant and the good environmental conditions in the experiment (Bergamaschi et al., 2004). Grain depth and ear diameter where higher in the treatments ‘CB’ and ‘CBP’ in comparison to ‘CP’, and did not differ from ‘C’. This variable has strong correlation with the grain filling and consequently the grain weight (OHLAND et al., 2005), being fundamental to the productive potential of the crop. The results indicate that the presence of *Brachiaria ruziziensis* did not influence this yield component.

Higher lodging was found in the treatment ‘C’ in comparison to the treatments ‘CP’ an ‘CPB’, there were no statistical difference between ‘C’ and ‘CB’. These results can be related at least in part to the ear height from the ground, which differed among these treatments as well. Higher sowing densities and populations in the plant community could intensify competition and reduce stem diameter, decrease the relation plant height/ear height and so make the plant more prone to lodging (BRACHTVOGEL et al., 2009). Lower occurrence of rickety in corn plants were observed in the ‘CBP’ treatment, also indicating the role of the plant arrangement and the plant number in the morphological characteristics of the intercrop sward.

Table 1. Corn yield components and morphological characteristics according to intercrop arrangements with Corn, *Brachiaria ruziziensis* and Pigeon Pea. Santa Catarina, Brazil.

Variable	C^1	CP^2	CB^3	CBP^4	CV (%)
Corn yield (kg ha^{-1})	9,011 A*	5,394 B	10,112 A	6,112 B	15.2
Thousand grain weight (g)	412 ^{ns}	402	399	409	4.3
Grains per row (un)	31.5 ^{ns}	32.6	33.4	34.8	5.3
Rows per ear (un)	15.4 ^{ns}	15.2	15.9	16.0	2.7
Grains per ear (un)	488 B	497 B	531 AB	559 A	5.0
Ears per hectare (un)	54,687 A	34,375 B	59,375 A	32,031 B	11.3
Grain moisture (%)	24.6 ^{ns}	23.6	24.3	24.5	4.1
Grain depth (cm)	2.25 AB	2.07 B	2.31 A	2.35 A	3.8
Ear diameter (cm)	4.91 AB	4.72 B	5.02 A	5.07 A	1.8
Cob diameter (cm)	2.66 ^{ns}	2.65	2.71	2.72	2.5
Plant stand (un ha^{-1})	66,718 A	37,812 B	64,062 A	35,468 B	6.6
Corn breaking (%)	0.6 ^{ns}	0	0.7	0.0	0.9
Corn lodging (%)	17.7 B	6.3 A	9.1 AB	2.2 A	4.7
Corn rickety (%)	41.8 B	26.2 AB	22.1 AB	9.1 A	19.1
Plant height (m)	2.76 ^{ns}	2.67	2.76	2.61	3.0
Ear height (m)	1.65 A	1.54 B	1.62 AB	1.55 AB	3.1

^{1}C = Corn; ^{2}CP = Corn + Pigeon Pea; ^{3}CB = Corn + *Brachiaria ruziziensis*; ^{4}CBP = Corn + *Brachiaria ruziziensis* + Pigeon Pea; ^{ns}Means do not differ; *Means followed by the same letter in the row compose statistical homogeneous group by Tukey test ($P < 0,05$).

CONCLUSIONS

1. The use of *Brachiaria ruziziensis* in an intercrop arrangement with corn do not affect the grain yield, neither the number of rows per ear and grains per row in the corn ear.

2. The intercrop of Corn and Pigeon Pea reduced the height of the ear in the plant and also the lodging in corn plants.3. The plants population and the plant arrangement play a key role in the performance of the intercrop among Corn + *Brachiaria ruziziensis* and Pigeon Pea.

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DESICCATION EFFICIENCY, PRODUCTION AND BIOMASS DECOMPOSITION OF SORGHUM AND FORAGE AN INTEGRATED CROP-LIVESTOCK SYSTEM

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ABSTRACT

The correct choice of cover crop used for biomass production is directly related to the success of the no-till farming system. In this context, the objective was to evaluate the desiccation efficiency, production and biomass decomposition of sorghum and forage an integrated crop-livestock. The experiment was conducted in randomized block design with four repetitions. The treatments consisted of the biomass obtained after intercropping sorghum with forages of the *Brachiaria* genus (*Brachiaria ruziziensis*, *Brachiaria brizantha* cv. Marandu, *Brachiaria brizantha* cv. Xaraés, *Brachiaria brizantha* cv. BRS Piatã, *Brachiaria brizantha* cv. BRS Paiaguás, *Brachiaria* cv. BRS Ipyporã), plus an additional treatment referring to sorghum in monoculture, which after cutting for grain production, remained fallow. The results showed that Paiaguas palisadegrass and Congo grass showed higher desiccation efficiency in all evaluation periods, showing more susceptibility to glyphosate. One of the greatest benefits of Paiaguas palisadegrass in crop-livestock integration is its high biomass production and efficiency of desiccation. Xaraes palisadegrass, on the other hand, should be adopted with caution, although it has the highest potential for biomass production with slower decomposition, it presents the lowest desiccation efficiency among the forages studied.

Key words: *Brachiaria brizantha*; *Brachiaria ruziziensis*; integrated systems

INTRODUCTION

The socioeconomic and environmental impacts of food production and consumption in the world have already been measured and evaluated by many countries that are concerned about the future of the food chain (ALLAOUI et al., 2018). Thus, meeting the market demands with products that are sustainable has been the great challenge of the agricultural sectors (KAMBLE et al., 2020). Thus, integrated crop-livestock systems have become an efficient option for global food production ensuring sustainability and conservation of natural resources (REIS et al., 2021).

This system is characterized by the cultivation of annual crops and animal breeding in the same area, using pastures as a source of food for animals and later as a cover plant for the no-till farming system, thus promoting efficiency in land use and also of agricultural ecosystems (SEKARAN et al., 2021).

Biomass from forage plants promotes many benefits to the soil such as contributing to nitrogen and carbon stocks (DIAS et al., 2020), improving microbiological properties (MAZZUCHELLI et al., 2020), increasing nutrient and organic matter cycling (SEKARAN et al., 2021). In addition, the synergism between the components collaborates to decrease the use of chemical fertilizers in the soil, reducing costs and impacts to ecosystems (LAROCA et al., 2018).

Therefore, the correct choice of forage plant used for biomass production is directly related to the success of the system, since the species used will serve as food for the animals and cover for the no-till system (DIAS et al., 2020). Among the various species of forage plants, those of the genus Brachiaria stand out, for presenting high biomass production, with accumulation and release of nutrients for the next crops (FLÁVIO NETO et al., 2015; COSTA et al., 2017, DIAS et al., 2020). On the other hand, sorghum also shows good biomass production mainly due to its ability to resist drought, with high photosynthetic efficiency which collaborates to ease regrowth (CHEN et al., 2020).

Another important factor that should be taken into consideration is the efficiency of desiccation. Desiccation of forages should preferably be carried out with systemic products, such as glyphosate (CECON et al., 2014). However, little is known about the desiccation efficiency of new forage species of the genus Brachiaria. Thus, due to the need to generate more information about the biomass of soil cover from integrated systems, we aimed to evaluate the efficiency of desiccation, production and decomposition of biomass of sorghum and forages an integrated crop-livestock system.

MATERIAL AND METHODS

This field experiment was conducted at an experimental site belonging to the Federal Institute of Goiano, located in the municipality of Rio Verde, Goiás State, on a typic Acriferric Red Latosol, according to the Brazilian soil classification (SANTOS et al., 2018).

Soil samples were collected to determine the physical-chemical characteristics of the soil in the experimental area at a 0-20-cm depth before the establishment of cultures with the following results: clay: 562 g kg^{-1}; silt: 94 g kg^{-1}; sand: 344 g kg^{-1}; pH in $CaCl_2$: 5.0; Ca: 1.7; Mg: 1.1; Al: 0.0; Al+H: 3.6; K_2O: 0.38; CEC: 6.78 cmol$_c$ dm^{-3}; P (Mehlich): 2.4; Cu: 2.8; Zn: 0.5; Fe: 16.1 in mg dm^{-3} and OM: 23.7 g kg$^{-1.}$

The site was prepared by desiccation of the previous crop with the application of herbicide (Transorb 3.5 L ha^{-1}) at a dose of 2,058 g ai ha^{-1} at a spray volume of 150 L ha^{-1}. Thirty days after desiccation, harrowing was performed with a harrow at 0.20 m depth to eliminate weeds not controlled by the herbicide, followed by a subsoiling and levelling.

One week before sowing, 1 ton of lime filler was applied by broadcasting and was incorporated into the soil to increase the base saturation to 60%. The forage systems were sown manually on February 4th, 2019, with the application of 200 kg ha^{-1} of P_2O_5 and 20 kg ha^{-1} of FTE BR 12 fertilizer (9% Zn, 1.8% B, 0.8% Cu, 2% Mn, 3.5% Fe, and 0.1% Mo), using simple superphosphate and fritted trace elements as sources, respectively.

In the monoculture and intercropping, sorghum was sown at 2 cm depth and the forage plants of the genus *Brachiaria* at 6 cm depth in the same sowing row. Each plot consisted of six 3.0-m-long rows spaced 0.50 m apart. The used area was only the three central rows, excluding 0.5 m from each end.

The sorghum sowing density was calculated to achieve an average population of 240,000 plants ha^{-1}. For forages of the genus *Brachiaria*, the equivalent of 5.0 kg of pure viable seeds per hectare. When the sorghum plants were at the three and six fully expanded leaf stages, two top-dressing fertilizations were performed, applying a total of 120 and 80 kg ha^{-1} of nitrogen and K_2O with urea and potassium chloride as sources, respectively.

Sorghum was harvested on May 20th 2019 at 120 DAS. Subsequently, the forages were evaluated for one year through successive cuts, simulating grazing. After the last cut in August 2020, the forage plants were left to rest for re-growth, for subsequent desiccation for biomass formation.

The experiment was conducted in a randomized block design with four replicates. The treatments consisted of the intercropping of sorghum with forage plants of the genus *Brachiaria* (*Brachiaria ruziziensis*, *Brachiaria brizantha* cv. Marandu, *Brachiaria brizantha* cv. Xaraés, *Brachiaria brizantha* cv. BRS Piatã, *Brachiaria brizantha* cv. BRS Paiaguás, *Brachiaria* cv. BRS I*pyporã),* in addition to an extra treatment comprising sorghum in monoculture which, after being cut for grain production, remained fallow for one year.

The desiccation of forage plants was performed with the application of glyphosate herbicide at a dose of 960 g ha^{-1} acid equivalent (a.e.). Herbicide efficacy was measured by visual control evaluations at 7, 14, 21 and 28 days after herbicide application using a visual scale, 0-100%, where 0% corresponds to no damage and 100% to plant death, based on the criteria of the Brazilian Weed Science Society - SBCPD (1995).

To quantify biomass production, three biomass samples were collected from 1 m2 square randomly distributed within each plot. The cut of the plant material was made flush with the ground. The cut material was weighed and the samples were placed in a forced air ventilation oven at 55ºC until constant mass, and the quantities were extrapolated to kg ha^{-1}.

The decomposition of biomass was evaluated after the desiccation of sorghum and forage crops, in decomposition bags made of nylon (*Litter bags*) with a 2 mm mesh opening and dimensions of 25 x 30 cm (THOMAS & ASAKAWA, 1993). Four bags containing residues of the species in an amount proportional to the dry biomass produced per hectare were deposited in direct contact with the soil.

At 30, 60, 90 and 120 days after management, a "litter bag" was removed from each plot in order to evaluate the remaining biomass and determine the decomposition of biomass during the 120-day period. Subsequently, at each evaluation, the material was sent to the laboratory for removal of soil adhered with running water until removing all residue and dried in an oven at 55°C until constant weight to obtain the dry biomass (COSTA et al., 2017). Based on the data of initial biomass production (kg ha^{-1}) of the systems, the percentage decompositions were calculated, by the ratio between the mass of litter bags in kg ha^{-1} and the initial biomass production.

The results of the desiccation efficiency were fitted with regression equations, with standard error. To describe the decomposition of biomass, the data were fitted together with the standard error to an exponential mathematical model via Sigma Plot software. To calculate the half-life (t1/2), i.e., the time required for 50% of the remaining biomass to be decomposed, the equation proposed by Paul and Clark (1989) was used, namely, $t1/2 = 0.693/k$, where t1/2 is the half-life of the dry biomass and k is a constant of the dry biomass decomposition. The graphics were made using the SigmaPlot software.

RESULTS AND DISCUSSIONS

Desiccation efficiency, yield and remaining biomass were influenced ($p<0.05$) by the different ground covers (Figure 1a, b).

Paiaguas palisadegrass and Congo grass showed higher desiccation efficiency at all times of evaluation, showing more susceptibility to glyphosate. At 7, 14, 21 and 28 days, the efficiency was 51.6, 72.7, 92.3 and 97.0% for Congo grass and 54.3, 74.6, 93.0 and 99.0% for Paiaguas palisadegrass. The high desiccation efficiency of these forages can be explained by the large amount of leaves that these forages have. These results were similar to those obtained by Machado et al. (2017) who, evaluating the susceptibility of tropical forages to glyphosate in integrated systems at 7, 14, 21 and 28 days after application, found that Congo grass and Paiaguas palisadegrass showed great sensitivity to glyphosate, with greater efficiency mainly at the highest dose and at short desiccation interval, and that they contribute to the diversification of forages used in integrated agricultural production systems.

The lowest efficiency among tropical forages was seen in Xaraes palisadegrass, which at 21 and 28 days showed efficiencies of 67.6 and 78.3%, respectively. This lower efficiency can be explained by the morphology of this forage that presents greater clumping (COSTA et al. 2014). In a study evaluating the mass yield and desiccation efficiency of nine perennial forages, Ceccon and Concenço (2014) classified the forages into three groups: easy to desiccate, moderately easy and difficult to desiccate, and found that Congo grass were easy to desiccate with excellent results, while Xaraes and Marandu palisadegrass were moderately easy to desiccate, but Xaraes palisadegrass showed the highest mass yield.

On the other hand, sorghum was more difficult to dry out, especially in the first days. This result may be related to the fallow time, where after the crop regrowth, it remained alive and growing freely for a year. On the other hand, the forage plants were in the regrowth stage after cutting, in full early growth. Under these conditions, the plant metabolism is more active due to the need for growth, which increases the efficiency of desiccation and reduces the percentage of regrowth of the plants.

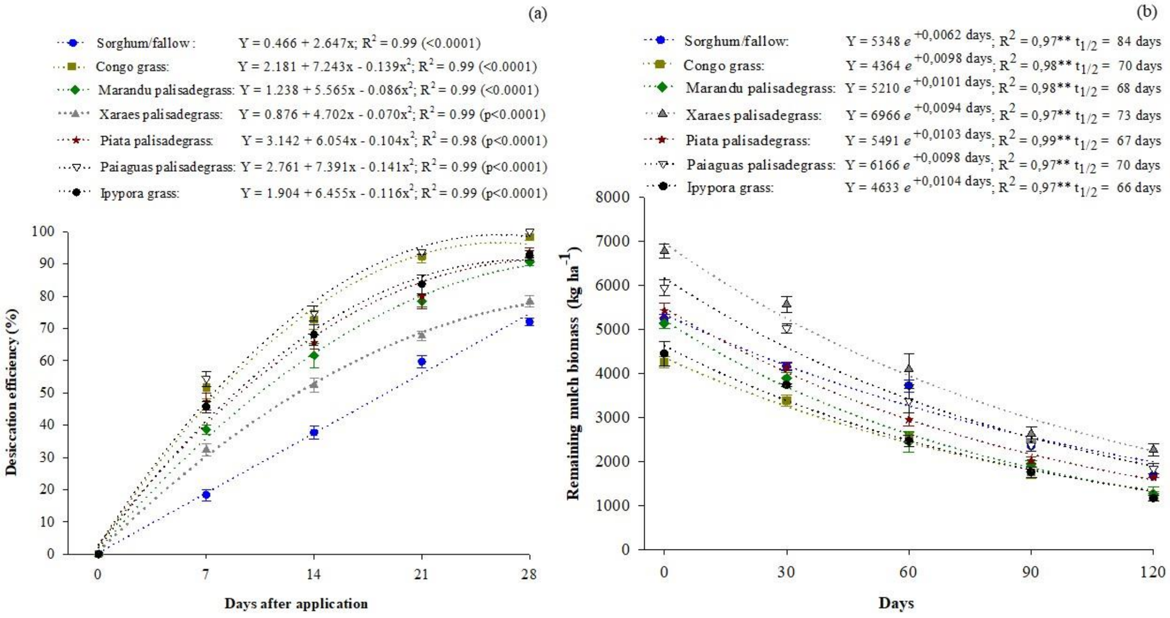

Figure 1. Desiccation efficiency (a) and remaining biomass (b) from 0 to 120 days.

The highest biomass production was obtained in Xaraes palisadegrass (6779 kg ha^{-1}), followed by Paiaguas palisadegrass (5952 kg ha^{-1}). This same behavior is verified for remaining biomass up to 120 days (Figure 1b). The higher biomass production of Xaraes and Paiaguas palisadegrass can be explained by the higher regrowth speed of these forages even with the low rainfall that occurred in September and October of 2020. Xaraes palisadegrass is tall, with thick canes and a larger leaf blade, with vigorous and rapid regrowth (COSTA et al., 2014). On the other hand, Paiaguas palisadegrass has thin canes and high productivity (EPIFANIO et al., 2019), which provides excellent soil coverage (COSTA et al., 2017).

In studies that evaluated the production and biomass decomposition of different forages in crop-livestock integration systems, Dias et al. (2020) and Muniz (2020) found that the Xaraes and Paiaguas palisadegrass, respectively, obtained higher production throughout the soybean development cycle. Several studies have already proven that Paiaguas palisadegrass is one of the most suitable forages for crop-livestock integration, with satisfactory results in productivity, especially in the period of water scarcity (SANTOS et al., 2016; GUARNIERI et al., 2019), making it an interesting option for biomass production (COSTA et al., 2016b) and nutrient accumulation (COSTA et al., 2017), for the no-till soybean system (SANTOS et al., 2020).

At the end of the evaluations, the total remaining biomass was 2265; 1839; 1645; 1271 1210 and 1168 kg ha^{-1} for Xaraes, Paiaguas, Sorghum, Piata, Marandu, Congo and Ipypora, respectively, with biomass losses of 65.0; 65.6; 67.7; 67.9; 71.2; 72.3 and 80.4% at the final 120-day management.

Congo and Ipypora grasses showed less remaining biomass in all evaluations. This fact is due to the morphological characteristics of these species, which have lower height and stoloniferous growth. One of the prerequisites for a successful no-till system is the amount of biomass on the soil surface, because organic matter improves soil properties and is a source of nutrients and energy for microorganisms (MALHI et al., 2018). Therefore, the correct choice of plant species for soil cover is extremely important, since the characteristic climatic factors of each region and soil type must be considered (COSTA et al., 2015).

In the Cerrado region of Central Brazil, there are frequent veranicos, even during the wet season, which affects the development of the crop. In addition, the high temperatures during the year accelerate the decomposition of the material, which makes it difficult for the biomass to remain on the soil surface (ZAGATO et al., 2018). With the soil protected by biomass, there is a reduction in moisture loss, ensuring more peace of mind for the producer. In this context, it is worth noting the biomass production potential of Xaraes and Paiaguas palisadegrass that even in the final management of 120 days, provided greater biomass and duration time on the soil surface, ensuring greater coverage for a prolonged period.

The sorghum biomass had the longest half-life, being 84 days. This can be explained by the fact that sorghum has thicker stalks with higher lignin content in its composition and higher C:N ratio, when compared to forages, which have a large proportion of leaves, accelerating the speed of decomposition of plant residues (COSTA et al., 2015).

CONCLUSIONS

Paiaguas palisadegrass and Congo grass showed higher desiccation efficiency in all evaluation periods, showing more susceptibility to glyphosate.

One of the greatest benefits of Paiaguas palisadegrass in crop-livestock integration is its high biomass production and efficiency of desiccation. Xaraes palisadegrass, on the other hand, should be adopted with caution, although it has the highest potential for biomass production with slower decomposition, it presents the lowest desiccation efficiency among the forages studied.

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NUTRIENT CYCLING IN THE BIOMASS OF FORAGE OF THE GENUS BRACHIARIA AND PANICUM MAXIMUM IN AN INTEGRATED CROP-LIVESTOCK SYSTEM AND A SECOND-CROP MAIZE

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ABSTRACT

Owing to contribution of nutrient cycling for subsequent crops, the integrated systems become increasingly important for agricultural conservation. Thus, the objective of this study was to evaluate the nutrient cycling in the biomass of *Brachiaria* and *Panicum maximum* forage crops in crop-livestock integrated and second-maize crop. The treatments consisted of the following cropping systems: Xaraes palisadegrass intercropped with soybean, Congo grass intercropped with soybean, Mombaça guinea grass intercropped with soybean, Tamani guinea grass intercropped with soybean, and a soybean/maize succession system. The forage grasses were established during the soybean R6-R7 stage. The biomass mulch dos Xaraes palisadegrass, Mombaça guinea grass and Tamani guinea grass resulted in greater nutrient cycling, indicating the benefits of these grasses for use as mulch in integrated production systems. The use of an integrated crop-livestock system combined with a forage cropping system provided greater soil nutrient cycling than the maize cropping system did, contributing to the sustainability of agricultural systems.

Key words: Forage biomass; Nutrient content; Nutrient cycling

INTRODUCTION

A current challenge in agricultural systems is to balance increases in productivity and reductions in cultivation area while also preserving the environment and generating profits for farmers (ROESH-MCNALLY et al., 2018). Integrated systems are techniques that provide benefits for both agriculture and livestock production, leading to economic and especially environmental gains (SANTOS et al., 2014).

The biomass of perennial plants used as mulch promotes high levels of organic matter (OM) in the soil, which contributes to nutrient cycling, especially the replenishment of nitrogen (N) and C, and water maintenance and improves soil properties (RYSCHAWY et al., 2017). Furthermore, this soil dynamic helps to reduce the use of fertilizer, thus reducing costs and the impacts on the environment (LAROCA et al., 2018).

Brachiaria species are considered the primary species for the production of mulch biomass, with the potential to accumulate and release nutrients into the soil for subsequent crops (FLÁVIO NETO et al., 2015; COSTA et al., 2017). However, with the emergence of new *Panicum maximum* cultivars, the Mombaça guinea grass (SORATTO et al., 2019) and Tamani guinea grass (MACHADO et al., 2017) have been increasingly used in integrated systems, with positive results.

As such, it is necessary to determine the potential of these forage grasses in integrated production systems for promoting increased soybean yields via biomass production compared with that of maize in succession with soybean as the second crop. Thus, the objective of this study was to evaluate the nutrient cycling in the biomass of *Brachiaria* and *Panicum maximum* forage crops in crop-livestock integrated and second-maize crop.

MATERIAL AND METHODS

This study was conducted at the Institute of Science and Technology Comigo in Rio Verde, state of Goias, Brazil. The experimental design was a randomized block design with four replicates. The treatments consisted of the following cropping systems: Xaraes palisadegrass (*Brachiaria brizantha* cv. Xaraés) intercropped with soybean, Congo grass (*Brachiaria ruziziensis*) intercropped with soybean, Mombaça guinea grass (*Panicum maximum* cv. Mombaça) intercropped with soybean, Tamani guinea grass (*Panicum maximum* cv. BRS Tamani) intercropped with soybean, and a soybean/maize (*Zea mays*) succession. The treatments were randomly distributed throughout the total area. The area of each plot was 2000 m², and each plot was divided by an electric fence, such that there were four plots, each with a separate forage grass, and four plots containing maize.

In October 2016, the first soybean crop was established, and in February 2017, when the soybean plants were at the R6-R7 stage (FEHR and CAVINESS, 1977) and the leaves began to become yellow and fall, the forage grass seed was sown. In total, 5.0 kg/ha of seed of each *Brachiaria* species and 3.5 kg/ha of seed of *Panicum maximum* were sown, which were rated as 60% and 40% of the seed germination and purity, respectively. The seed and monoammonium phosphate (MAP) were mixed together at a dose of 100 kg/ha, after which the mixtures were distributed over their respective areas via a Lancer spreader.

The soybean plants were harvested 34 days after the forage grass seed was sown, and the forage grasses continued to grow until the animals entered the system. AG7098 maize was sown on February 20, 2017, and 300 kg/ha of 2-20-18 fertilizer was applied at sowing. At the V4-V6 phenological stage, topdressing urea fertilizer was applied at a dose of 90 kg/ha of nitrogen.

In April, animals were added to the system; 25 male Nellore cattle with an average weight of 232 kg were used. Each forage system received animals. The stocking rate varied and was adjusted as necessary throughout the experiment. The animals remained in the plots for 141 days (off-season) as part of an intermittent grazing system, with the animals in the paddock for 7 days followed by a 28-day resting period for the forage, with a total of five grazing cycles.

After the off-season (September 2017), the animals were removed from the area, and the forage grasses were allowed to recover and regrow before termination to form mulch for the no-till system. The forage grasses were killed 14 days before soybean planting by an application of glyphosate herbicide at a dose of 960 g of a.i/ha.

One day before soybean sowing, biomass samples of the mulch were collected from a 1-m2 area randomly selected within each plot. The plant material was cut at ground level. The cut material was weighed, the samples were placed in a forced-air oven at 65°C until they reached a constant weight, and the amounts were converted to dry weight (kg/ha).

Mulch decomposition was evaluated for dead forage material collected in 25 x 30 cm litter bags made of a 2-mm mesh (THOMAS and ASAKAWA, 1993). For this, four bags containing biomass samples of each species in amounts proportional to the dry mass produced per hectare were placed in direct contact with the soil. At 30, 60, 90 and 120 days after the bags were placed on the soil, one litter bag was removed from each plot to evaluate the remaining amount of mulch biomass and to determine mulch decomposition throughout the 120-day period.

At each evaluation time point, the material was subsequently sent to the laboratory. The soil debris was removed by washing the material with running water until all the debris was gone, after which the material was dried in an oven at 55°C until it reached a constant weight, according to the methods of Costa et al. (2017). The biomass samples were ground (2 mm) in a mill to determine the carbon (C), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) contents according to the methods of Malavolta et al. (1997). To evaluate the nutrient contents, the macronutrient concentrations were multiplied by the dry mass production, and the results were expressed as kilograms per hectare.

The N, P_2O_5 and K_2O fertilizer equivalents of the mulch biomass of the forage and maize cropping systems were determined considering the atomic mass of the elements according to analytical chemistry conventions and the N, P and K concentrations of the biomass analysed (Santos et al., 2014).

To describe the nutrient contents, the data were fitted together with the standard error to an exponential mathematical model ($y = a + bx$) via Sigma Plot software. To calculate the half-life (t1/2), i.e., the time required for 50% of the remaining biomass to be decomposed, the equation proposed by Paul and Clark (1989) was used, namely, t1/2 = 0.693/k, where t1/2 is the half-life of the dry biomass and k is a constant of the dry biomass decomposition. The data concerning the fertilizer equivalents, were analysed by analysis of variance by the use of R software version 3.1.1 (2014); specifically, the ExpDes package was used (FERREIRA et al., 2014). The means were compared according to Tukey's test at a significance level of 5%.

RESULTS AND DISCUSSIONS

There was a significant effect ($p < 0.05$) of cropping system on nutrient contents (Figure 1). At time point zero and after 30 days of decomposition, the Xaraes palisadegrass and Tamari guinea grass had the greatest values of N content, and the maize presented the lowest N content (Figure 1a). When the initial N content was compared with the values attained during the last evaluation at 120 days, 75.5, 79.3, 80.8, 74.6 and 82.4% N release occurred for the Xaraes palisadegrass, Congo grass, Tamani guinea grass, Mombaça guinea grass and maize, respectively.

The greater nitrogen content in Xaraes palisadegrass and Tamani guinea grass compared with the other forage grasses (Figure 1a) may be attributed to their greater biomass. Furthermore, these results may be related to the increased production of leaves by these grasses, which are the organs in which excess nutrients are concentrated, thus favouring N cycling. Another factor that may have an effect was the relatively stable stocking rate during the 141-day grazing period, which resulted in an improved nutrient return through manure and urine excretion, increasing nutrient recycling and thus resulting in increased concentrations.

A study by Costa et al. (2015) on the nutrient contents and decomposition rate of the biomass of forage plants showed that Xaraes palisadegrass accumulated 81.3 kg/ha of N; which this amount was similar to that obtained in the present study, which was 83.0 kg/ha at time point zero. Soratto et al. (2019) evaluated the nitrogen content of Mombaça guinea grass and reported amounts that surpassed 95.3 kg/ha.

With respect to the phosphorus content (Figure 1b), maize had the lowest content, and Xaraes palisadegrass had the greatest content. When the initial phosphorus values were compared with the values attained at 120 days, 73.7, 84.9, 67.35 and 78.7% phosphorus release levels occurred for the Xaraes palisadegrass, Congo grass, Mombaça guinea grass, Tamani guinea grass and maize, respectively, indicating that, of these grasses, Tamani guinea grass released the most phosphorus.

The greatest content of phosphorus occurring in Xaraes palisadegrass is also due to the relatively high biomass production and, consequently, increased nutrient cycling. According to Jouany et al. (2011), grazing can be considered a regulator of labile phosphorus, and the effects of this process depend on pasture consumption and urine and manure recycling.

In general, tropical forage species are extremely important in production systems because they recycle nutrients from the subsoil, replenish OM and promote soil decompaction because of the abundant volume and aggressiveness of their root systems and the resulting biological activity. This phenomenon was demonstrated in a study by Flávio Neto et al. (2015), who reported that Xaraes palisadegrass had a high potential for soil decompaction, which is essential in areas that have been under no tillage for many years because it increases the water availability of crops in succession and promotes soil conservation in the Cerrado region.

Compared with the other grasses, Xaraes palisadegrass and Mombaça guinea grass had greater initial potassium contents (Figure 1c). At 90 and 120 days, the values were similar between the cropping systems. The potassium release rates were 96.1, 95.5, 91.2, 97.6 and 88.7% for Xaraes palisadegrass, Congo grass, Mombaça guinea grass, Tamani guinea grass and maize, respectively.

Compared with other nutrients, nitrogen and potassium are extracted in greater amounts by forage plants used for biomass production; thus, these nutrients are presents in relatively a greater proportion within the biomass. These two nutrients are also the most easily leached, especially in deep soils, thus hindering access to them by the root system of many crops; this is an advantage for grasses with deep and aggressive root systems and is a benefit to soybean as a subsequent crop species, given that there is a relatively high concentration of these nutrients in the soil.

The greatest potassium content occurring in Xaraes palisadegrass and Mombaça guinea grass is also due to their relatively high biomass production, as these forage grasses are tall and produce both a large amount of leaves and an abundance of roots. Most of the potassium accumulated within the biomass remains in the shoots before being released into the soil and used by the subsequent crop (Miguel et al., 2018).

The release of potassium is very interesting because the potassium suddenly decreased immediately after the grasses were killed; the lowest half-life were 29, 26 and 24 days for Xaraes palisadegrass, Mombaça guinea grass and Tamani guinea grass, respectively. However, Congo grass and maize had relatively long half-life - 36 and 52 days. Thus, notably, the nutrient release rate during decomposition depends on the material and the form of these nutrients in the plant tissues.

In the present study, the amount of potassium released at 30 days reached 45.1, 38.5, 53.9, 52.1 and 53.9% for Xaraes palisadegrass, Congo grass, Mombaça guinea grass, Tamani guinea grass and maize, respectively. The amount that remained within the biomass during the final cycle of soybean development was very small; the average was 6.18% of the total unreleased potassium from all the cropping systems. Taken together, these results show that the biomass presented release rates that exceeded 90% and demonstrate the representativeness of this the return of this nutrient to the soil via the biomass.

When evaluating the release rate of nitrogen, phosphorus and potassium within the mulch biomass of Marandu palisadegrass, Congo grass, Mombaça guinea grass, Tanzania guinea grass and Aries guinea grass, Pereira et al. (2016) reported that the maximum release of these nutrients occurred during the first 30 days. In general, at 120 days after planting, more than 60% of the nutrients had already been released from the mulch, and these results are similar to those found in the present study.

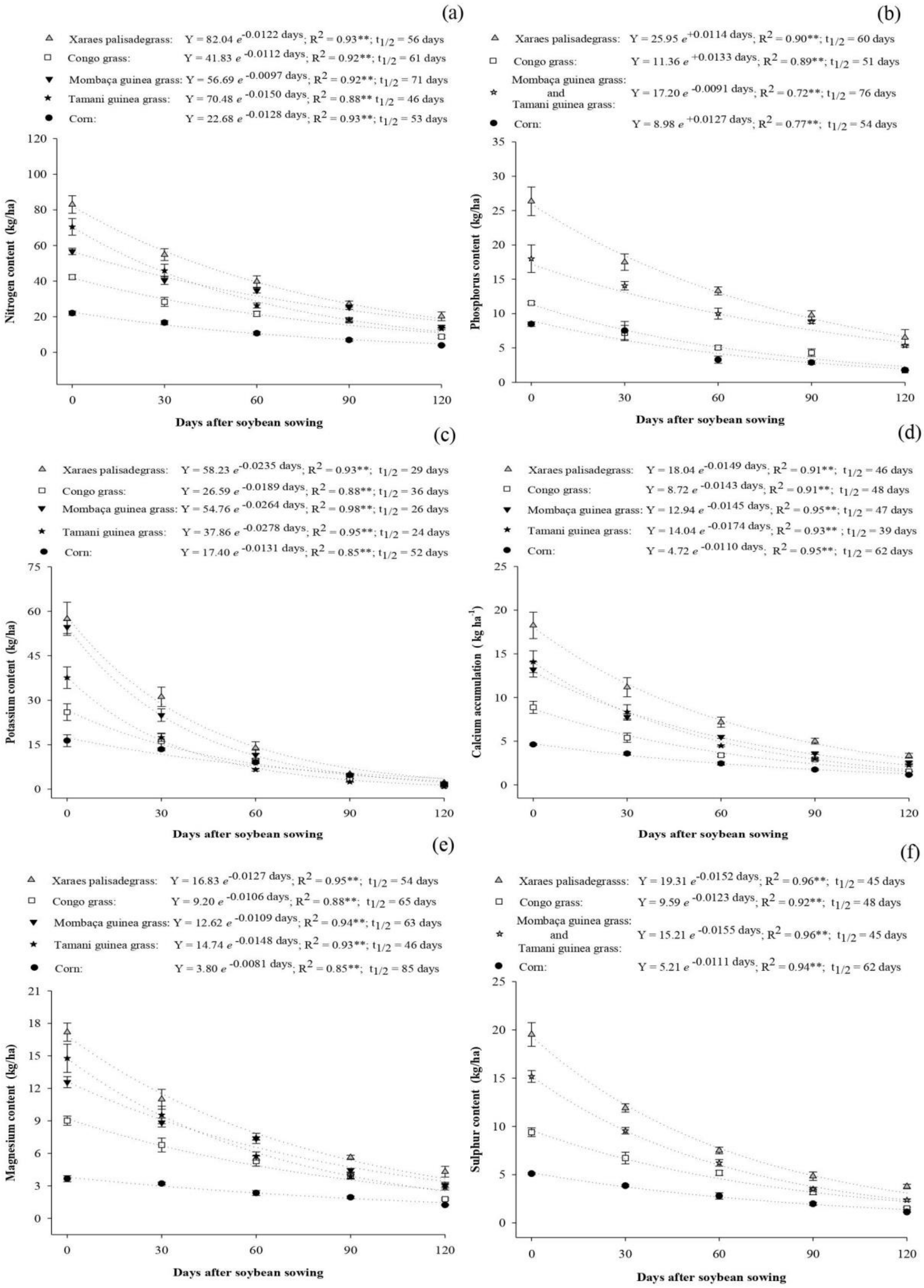

Figure 1. Nitrogen (a), phosphorus (b), potassium (c), calcium (d), magnesium (e) and sulphur (f) content in the biomass of forages in the *Brachiaria* and *Panicum* genera and maize during soybean cultivation (0 to 120 days).

For calcium (Figure 1d), magnesium (Figure 1e) and sulphur (Figure 1f), the greatest initial contents were detected in Xaraes palisadegrass, followed by Tamani guinea grass and Mombaça guinea grass, whereas Congo grass and maize displayed the lowest potential to accumulate these nutrients in the soil. For Xaraes palisadegrass, Congo grass, Mombaça guinea grass, Tamani guinea grass and maize, the respective calcium release rates at 120 days were 81.2, 82.1, 80.1, 83.4 and 75%; for magnesium 74.4, 80.2, 75.7, 79.6 and 65.8%; and for sulphur 80.4, 84.1, 83.7, 84.2% and 77.8%.

Potassium, calcium, magnesium, and sulphur showed longer half-life within the maize biomass, while nitrogen and phosphorus had longer half-life within the Mombaça guinea grass biomass. However, the Tamani guinea grass had the shortest half-life in terms of the release of potassium, calcium, and magnesium the half-life of sulphur was similar to that of Mombaça guinea grass; however, the shortest half-life for phosphorus occurred in Congo grass.

The presence of the relatively low calcium and magnesium contents in maize is due to the early decomposition of the maize biomass until the soybean crop was sown, which is a disadvantage of this cropping system compared with integrated crop-livestock systems because of the relatively low soil cover at the time of soybean sowing. According to Crusciol et al. (2005), calcium and magnesium are easily released because they are components of ionic compounds and soluble molecules in plants and are thus quickly released into the soil by the decomposition process.

The order of nutrient contents in the remaining biomass in all the cropping systems studied as was as follows: N > K > P > Ca > S > Mg. These results highlight the importance of biomass production for soybean no-till systems because these systems involve nutrient cycling. In addition, this production maintains the C stocks in the biomass and in the soil and is considered a greenhouse-mitigating and environmentally friendly soil management practice (COSTA et al., 2017).

The greater amounts of nitrogen, phosphorus and potassium equivalents obtained via Xaraes palisadegrass compared with the other grasses are due to the greater biomass production and subsequent release of nutrients (Table 1). Knowledge of fertilizer equivalents is highly important with respect to fertilizer programmes because the amount released must be considered for fertilizer recommendations for the subsequent crop (SANTOS et al., 2014; ASSMANN et al., 2017).

Table 1. The N, P_2O_5 and K_2O equivalent contents in the biomass of different cropping systems.

Cropping systems	**Equivalent (kg/ha)**		
	N	**P_2O_5**	**K_2O**
Xaraes palisadegrass	83.0 a	60.4 a	69.2 a
Congo grass	42.3 c	26.4 bc	31.3 bc
Mombaça guinea grass	56.7 b	41.2 b	65.9 a
Tamani guinea grass	70.5 ab	34.7 b	45.3 b
Corn	22.0 d	19.4 d	19.7 c
CV (%)	11.79	18.28	18.22
p value	0.0021	0.0001	0.0002

Averages followed by different letters do not differ from each other by Tukey’s test at 5% probability.

Thus, when considering the high cost of fertilizer, it is possible that the continuous use of cover crops in soybean agricultural systems enables the most efficient use of the nutrients available in the soil, with favourable effects on the cost of production, increasing production sustainability.

CONCLUSIONS

The biomass mulch dos Xaraes palisadegrass, Mombaça guinea grass and Tamani guinea grass resulted in greater nutrient cycling, indicating the benefits of these grasses for use as mulch in integrated production systems. The use of an integrated crop-livestock system combined with a forage cropping system provided greater soil nutrient cycling than the maize cropping system did, contributing to the sustainability of agricultural systems.

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PHYSICAL ATTRIBUTES AND CARBON STOCK OF A SOIL CROPED WITH ROTATING SOY ON SORGHUM STRAW CONSORTIUM

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ABSTRACT

The accumulation of carbon (C) based on the stabilization mechanisms in the soil, requires the interaction between mineral and organic surfaces, making this relationship in the soil finite, which indicates the need for maintenance and constant input of plant residues. Sorghum cultivars were evaluated: graniferous, cultivar A9902 (SG); forage, cultivar Volumax (FS), double-aptitude, cultivar Rancheiro (SDA), sown with *Urochloa brizantha* cv. Paiaguás next to the fertilizer with dwarf pigeon in the densities of 0, 6, 12, 18, 24 seeds m-1, between the lines. The experimental design was randomized blocks in a factorial scheme (3 x 5), with 04 repetitions. Soil density (SD) and total porosity (TP) were analyzed using the volumetric ring method; microporosity (MI), using the tension table method with a 60 cm water column; macroporosity (MA), due to the difference between TP and MI. The stocks of C in the soil were calculated from the values obtained for the organic matter content of the soil (organic carbon) and the values of the soil density collected in the plots. Higher carbon stocks were observed in the soil under the consortium with graniferous sorghum; The cultivars of forage sorghum and double aptitude sorghum, provided lower values for soil density and higher values for macroporosity and total porosity in soils.

Key words: Integrated production systems; Crop Rotation; Soil organic matter

INTRODUCTION

The accumulation of carbon (C) based on the stabilization mechanisms of these fractions in the soil, requires the interaction between mineral and organic surfaces, making this relationship in the soil finite, which indicates the need for maintenance and constant input of plant residues (ROSCOE et al., 2001). Thus, the intercropping and rotation of forage crops with legumes can cause significant increases in C content for the productive capacity of soils in the Cerrado. According to the management used in the pastures, the root system of the grasses contributes to the improvement of the physical properties, by the aggregation and aeration of the soil, causing, reduction of the erosion and pollution of bodies of water, (FRANZLUEBBERS, 2007). For Vilela et al. (2011), intercropping and rotating grasses with grains (soy, corn and sorghum) in livestock properties, cause the recovery and maintenance of degraded pastures. Thus, increases in soil density, limited to surface layers, are aggravated by the reduction and removal of vegetation cover. However, they are described as temporary and reversible properties, which can be altered due to the management with rotating crops in these areas (CORSI et al., 2001; CASSOL, 2003). The objective of this work was to evaluate the physical properties and the carbon stock of the soil in the 0.0 to 0.010 m layer of a soil under soybean rotation with intercropped sorghum for silage production.

MATERIAL AND METHODS

The experimental area is located at the Teaching, Research and Extension Farm (FEPE) - Vegetable Production Sector, Faculty of Engineering - UNESP, Ilha Solteira Campus, located in the Cerrado Biome, Selvíria municipality, State of Mato Grosso do Sul. geographic coordinates of latitude 20°20'36.95” S, longitude 51°24'5.96” W and altitude of 356m. The preparation of the area before the sowing of the cultures was carried out with desiccation of the weed with Glyphosate herbicide (1,560 g ha^{-1} of a.i.), and later harvesting of vegetable residues (Triton). Dolomitic limestone (PRNT 85%) was applied on the surface, without incorporation, at the dose of 2.0 t ha^{-1}, in September 2015.

The sorghum sowing took place at a depth of 0.03 m, with 6 seeds per meter, using a 7-row sowing-fertilizer tractor with a furrow-like mechanism (stem), in no-tillage system (NTS), with a spacing of 0.45m, on 04/04/2016 and 04/04/2017, respectively, for the 2017 and 2018 autumn crops. The cultivars used were grain Sorghum, cultivar A 9902 (SG); Forage sorghum, cultivar Volumax (FS) and, Sorghum double aptitude, cultivar Rancheiro (SDA), recommended for the region. The seeds of *Urochloa brizantha* cv. Paiaguás were mixed with the fertilizer, moments before the operation, and placed in the fertilizer compartment of the seeder-fertilizer used for the sorghum, and sown simultaneously with the sorghum culture, in the same implement. Being deposited at a depth of 0.06m, using approximately 10 kg ha^{-1} of pure viable seeds. The seeds of the dwarf pigeon (Caqui cultivar) were deposited at a depth of 0.05 m, just after sowing the sorghum, at densities of 0, 6, 12, 18, 24 seeds m^{-1}, at a spacing of 0.45 m, on the other, a tractor-seeder-fertilizer set with a double disc-type furrower mechanism found for NTS, aligning the seeding devices between the lines of the sorghum seeding. The experimental design used for the two years of conducting the experiment was that of Randomized Blocks in a factorial scheme (3 x 5). Formed by 03 (three) sorghum cultivars (graniferous, forage and double aptitude) cultivated with the paiaguás grass in the sowing line and intercropped between 05 (five) dwarf pigeon sowing densities (0, 6, 12, 18 and 24 seeds m^{-1}), with 04 (four) repetitions, totaling 60 plots. The experimental plots in the field were arranged in sowing strips, formed by 14 lines of sorghum spaced at 0.45 m with paiaguás grass and pigeon pea between the lines spaced at 0.45 m. The dimension of the area of each plot was 6.30 x 8.50 m, totaling 53.55 m^2 per plot.

After the soybean harvest in the 2016/17 and 2017/18 summer harvests, mini trenches were opened and five (05) undisturbed samples with volumetric ring were manually collected with the aid of hoe to assess the physical attributes of the soil, in each of the 60 plots, at depths of 0.00-0.10m. Soil density (SD) and total porosity (TP) were analyzed using the volumetric ring method; microporosity (MI), using the tension table method with a 60 cm water column; macroporosity (MA), due to the difference between TP and MI. The evaluation for all physical attributes was carried out according to the methodology described by Embrapa (1997). The stocks of C in the soil were calculated from the values obtained for the organic matter content of the soil (organic carbon) and the values of the soil density collected in the plots, and, calculated according to the depth of the soil layers, according to the equation (1) by Bernoux et al., (1998):

$$\mathbf{CS = SD \cdot h \cdot C}$$

Em que: CS = Carbon stocks on soil (t ha^{-1});

SD = Soil density (kg dm^{-3});

h = layer height (cm); e,

C = soil carbon content (g dm^{-3}).

RESULTS AND DISCUSSIONS

The use of crop rotation through the cultivation of soybean on straw of consortia of treatments with sorghum with grass and dwarf pigeon pigeons, caused changes in the physical attributes and in the carbon stocks in the soil at the soil surface, for the 0 layer, 00-0.10 m (Table 1). However, no significant effects of dwarf pigeon pea sowing densities have been described, nor have there been interactions between pigeon pea sowing densities and sorghum cultivars on the physical properties evaluated in this layer.

Table 1. Average carbon stocks (CE), soil density (SD), macroporosity (MA), microporosity (MI) and total porosity (TP) of the soil in the 0-0.10 m layer after soybean grown in rotation under straw of sorghum regrowth intercropped with paiaguás grass and dwarf pigeon pea, Selvíria - MS.

Trat.	**CE**		**SD**		**MA**		**MI**		**TP**	
	t ha^{-1}		**kg dm^{-3}**		**-----------------------------m^{-3} m^{-3}---------------------------**					
	2017	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
SG	43.9 a	37.3 a	1.57 a	1.55 a	0.061 a	0.068 b	0.238 b	0.247 a	0.300 b	0.316 b
SF	32.9 b	36.9 a	1.50 b	1.50 a	0.077 a	0.103 a	0.251ab	0.220 b	0.328 a	0.323 ab
SDA	29.2 b	31.4 b	1.46 b	1.42 b	0.058 a	0.107 a	0.263 a	0.235 ab	0.321a	0.342 a
					Dens.					
0	33.9	35.2	1.51	1.46	0.063	0.090	0.254	0.227	0.317	0.326
6	35.1	33.5	1.51	1.48	0.058	0.101	0.256	0.229	0.314	0.330
12	36.2	35.3	1.52	1.50	0.060	0.099	0.258	0.240	0.319	0.340
18	35.7	36.2	1.47	1.51	0.076	0.086	0.243	0.233	0.319	0.320
24	35.7	35.9	1.54	1.52	0.070	0.078	0.243	0.241	0.314	0.319
D.M.S	4.49	4.16	0.06	0.07	0.022	0.027	0.016	0.019	0.012	0.023
F.V						*Teste F*				
Treat.	33.7^{**}	7.16^{**}	10.1^{**}	9.45^{**}	2.39^{ns}	6.48^{**}	6.81^{**}	5.71^{**}	18.03^{**}	3.91^{*}
Dens.	0.27^{ns}	0.47^{ns}	1.25^{ns}	0.61^{ns}	0.81^{ns}	0.92^{ns}	1.35^{ns}	0.72^{ns}	0.33^{ns}	0.99^{ns}
Treat*dens	0.32^{ns}	0.59^{ns}	0.93^{ns}	1.35^{ns}	0.35^{ns}	1.17^{ns}	0.12^{ns}	0.51^{ns}	1.08^{ns}	0.98^{ns}
Mean	35.4	35.2	1.5	1.5	0.065	0.092	25.1	23.4	31.7	32.7
C.V.	16.6	15.4	5.2	6.6	44.0	38.5	8.6	11.1	5.0	9.2

Averages followed by the same letter, lower case in the column and upper case in the line, do not differ statistically from each other, by the Tukey test at 5%. EC: carbon stock; Dens: ensity; Ptotal: total porosity; SG: consortium of graniferous sorghum / Paiaguás grass and dwarf pigeon peas; SF: consortium of forage sorghum / Paiaguás grass and pigeon pea; SDA: consortium of double-capacity sorghum / Paiaguás grass and dwarf pigeonpea. D.M.S.: minimum significant difference; F.V.: sources of variation; Treat.: Treatment; Dens.: Density of sowing of dwarf pigeonpea. **, *, ns: ($P <0.01$), ($P <0.05$) and ($P> 0.05$), respectively.

Higher values for the surface CE were observed in the areas of the consortium with SG, in the first year, and in the consortia of SG and SF in the second (Tabel 1). With regard to treatment in the consortium with SG, there was a reduction in EC from the first to the second year from 43.9 t ha^{-1} to 37.3 t ha^{-1}, respectively. On the other hand, in the treatment with SF, there was an increase in SC from the first to the second year, from 32.9 to 36.9 t ha^{-1}, respectively. Regarding the DS values, these were lower in the area of treatment with SDA for the two years, with a reduction observed in the second year of cultivation in the SG treatment for this attribute.

The data of the present research are similar to those obtained by Nakao (2018), who also found higher values of SD and EC in the first year of the sorghum consortium with Paiaguás grass in the treatment with SG, and, reporting reductions in the DS and EC mainly in the treatments using SDA, attributing this reduction to the greater export of plant material (silage) by this cultivar and due to its cultivation in the areas. Cruz (2016) and Nakao (2018) attribute these changes to the pluviometric indexes that occurred in the experimental period and to the intense machine traffic on the ground. In this work, an inverse behavior was observed, being that for the treatments with SF and SDA with characteristics for forage production, there was an increase in the EC in this layer for the second year of cultivation, respectively, of 36.9 t ha^{-1} and 31.4 t ha^{-1}, and, reductions in DS values in SDA (1.46 to 1.42 kg dm^{-3}).

In the treatments with SF and SDA, the MA values increased, reducing the MI in the second year of evaluation of these attributes. This result can be attributed to the root volume of the grasses, increasing the M.O. added and promoting superficial unpacking, as observed in the works developed by Costa et al. (2015) and Mello (2001). These changes even caused an increase in soil PT due to the development of plants in the consortium for all evaluated treatments, however, differing significantly in treatments with SF and SDA (Table 1).

CONCLUSIONS

1. Higher carbon stocks were observed in the soil under the consortium with graniferous sorghum; and,

2. The cultivars of forage sorghum and double aptitude sorghum, provided lower values for soil density and higher values for macroporosity and total porosity in soils.

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NUTRIENT CYCLING IN THE BIOMASS OF THE PAIAGUAS PALISADEGRASS AND TAMANI GUINEA GRASS IN AN INTEGRATED CROP-LIVESTOCK AND SECOND-CROP MAIZE

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ABSTRACT

Among integrated crop-livestock systems, forage succession is an advantageous strategy for the use of pasture to feed cattle in periods of low rainfall, as well as for the generation of biomass and nutrient cycling for the no-till system for the next crop. Different species have different abilities to accumulate nutrients in their biomass, which are then released into the soil through the decomposition of crop residues. This study was to evaluate the nutriente cycling in the biomass of the Paiaguas palisadegrass and Tamani guinea grass in an integrated crop-livestock and second-crop maize. The experiment had a randomized block design with four replicates. The treatments were three cropping systems: integrated crop–livestock with Paiaguas palisadegrass (Brachiaria brizantha cv. BRS Paiaguas), integrated crop-livestock with Tamani guinea grass (Panicum maximum cv. BRS Tamani), and maize grown in succession to soybean. The results showed that the use of the integrated crop-livestock system in the form of forage succession provided greater nutrient cycling as a result of the better utilization of the animals excreta, than the cropping of maize in succession, thus contributing to agricultural sustainability.

Key words: *Brachiaria brizantha* cv. BRS Paiaguas; *Panicum maximum* cv. BRS Tamani; Sustainability

INTRODUCTION

The integrated crop–livestock system is a production strategy that consists of the diversification and integration of different production, agricultural, and livestock systems within the same area while striving for environmental preservation and meeting the global demand for food. When done under careful management, the integration of crops in no-till systems can benefit from the complex synergism between soil, plants, and animals due to its unique characteristics of diversification of activities and promotion of complex functions of the agroecosystem, which ensure greater productivity in smaller areas, with greater profitability and sustainability (CARVALHO et al., 2018).

The availability of nutrients for the successor crop is directly related to their availability in the soil and their rate of release from residues. Understanding the factors and processes that control the cycling of nutrients allows us to synchronize their availability with the demand of the successor crop. However, different crops have different abilities to accumulate nutrients in biomass, releasing them in the soil through the decomposition of crop residues (OLIVEIRA et al., 2019).

Currently, the most commonly used forage grasses in such systems are those of the genus *Brachiaria* (GUARNIERI et al., 2019; SILVA et al., 2019), and recently, due to the emergence of new Panicum maximum cultivars, this species has also been used (MACHADO et al., 2017; DIAS et al., 2020). Thus, it is necessary to determine the potential of new forage species within integrated crop–livestock systems to produce forage in the off-season.

The biomass produced by perennial tropical forages promotes large stocks of organic matter in the soil, which in turn contributes to nutrient cycling, especially nitrogen and carbon replacement and water maintenance, and improves soil properties (RYSCHAWY et al., 2017). In contrast, the mulch biomass produced by maize grown in succession to soybean is inefficient for nutrient cycling for the subsequent soybean crop. Therefore, the objective of this study was to evaluate the nutriente cycling in the biomass of the Paiaguas palisadegrass and Tamani guinea grass in an integrated crop-livestock and second-crop maize.

MATERIAL AND METHODS

This study was conducted at the Institute of Science and Technology Comigo in Rio Verde, state of Goias-GO, Brazil, from November 2017 to February 2019. The study area presented a six-year history in the crop-livestock integrated under no-tillage system, with annual crops (soybean and maize) and forage for biomass formation (*Brachiaria brizantha*, *Brachiaria ruziziensis* and *Panicum maximum*).

The soil was classified as a typical Dystrophic Red Latosol according to the Brazilian classification system (Santos et al., 2018). The physical and chemical characterization of the soil in the 0-20 cm was carried out before the experiment was implemented, presenting clay, 351 g/kg; sand, 539 g/kg; silt, 110 g/kg; pH in $CaCl_2$: 4.9; Ca: 2.5; Mg: 0.74; Al: 0.1; Al + H: 5.0; K_2O: 0.43; cation exchange capacity (CEC): 8.6 $cmol_c/dm^3$; V: 41% and P (mehlich): 33.7; B: 0.74; Cu: 1.2; Zn: 6.3; Cu: 1.23; Fe: 53.8 mg/m^3; organic matter (O.M.): 27.18 g/kg.

The soybean crop establishment (2017/2018) was carried out on 11/07/2017 and the variety used was M7110PRO, with 0.50 m line spacing. Before the sowing was applied a ton/ha of limestone and gypsum. The seed and monoammonium phosphate (MAP) were mixed together at a dose of 250 kg/ha after which the mixtures were distributed over their respective areas via a Lancer spreader.

For seed treatment it was used 200 mL of Standak Top for each 100 kg of seeds. At 15 days, after sowing (DAS) it was applied 80 kg/ha of K_2O in the source of potassium chloride. The fungicide applications were performed at 40, 60, 75, 85 DAS. Soybean was harvested in February 2018, with an average production of 4339 kg/ha.

The experimental design was a randomized complete block design with four replicates. The treatments consisted of the following cropping systems: integrated crop–livestock with Paiaguas palisadegrass (*Brachiaria brizantha* cv. BRS Paiaguas), integrated crop-livestock with Tamani guinea grass (*Panicum maximum* cv. BRS Tamani), and maize grown in succession/rotation to soybean.

The forages were implanted in succession/rotation to soybean on February 28, 2018, using 5 kg/ha of seeds for Paiaguas palisadegrass and 3.5 kg/ha for Tamani guinea grass, with 60% and 40% of cultural value (determines the germination and purity of the seed) respectively. The seeds were sown in the respective areas with the aid of the seed drill, with 0.45 m of spacing between lines. The area of each forage plot was 0.24 ha.

The monoculture maize was sown on March 1, 2018 using the hybrid AG 7098 PRO2, in an area of 0.24 ha, aiming to reach final population between 250 to 300 thousand plants ha-1 with base fertilization of 300 kg/ha of the fertilizer formulated 08-20-18 (N-P-K) applied in the furrow of planting. In the phenological stage V6, 90 kg/ha of nitrogen was applied to the urea source. The harvest of maize for grain was carried out at 156 days, on August 3, 2018, with an average production of 4200 kg/ha.

After the development of the forages, at 84 days after sowing, were inserted in the area cattle of the Nelore breed, with average age of 13.25 months, with average initial body weight of 239.43 kg. The animals remained in the experimental area from May to August 2018, in rotating pasture, being seven days of occupation and 21 days of rest. The rate of occupancy was variable and adjusted, whenever necessary, throughout the experiment, according to the availability of forage.

The animals were removed from the area on August 23, 2018 and the forages was left to rest for 41 days for sprouting, for later drying to form biomass for sowing soybeans. Desiccation was performed on September 25, 2018 with application of glyphosate herbicide in a dose of 4 L/ha (522 g/L of i. a.), with syrup volume of 150 L/ha.

Mulch decomposition was evaluated for dead forage material collected in 25 x 30 cm litter bags made of a 2-mm mesh (THOMAS and ASAKAWA, 1993). For this, four bags containing biomass samples of each species in amounts proportional to the dry mass produced per hectare were placed in direct contact with the soil.

At 30, 60, 90 and 120 days after the bags were placed on the soil, one litter bag was removed from each plot to evaluate the mulch biomass and nutrient cycling the 120-day period. On the basis of the initial mass (kg/ha) in the systems, the loss percentage was calculated as the ratio of the mass of the litter bags (kg/ha) to the initial production.

At each evaluation time point, the material was subsequently sent to the laboratory. The soil debris was removed by washing the material with running water until all the debris was gone, after which the material was dried in an oven at 55°C until it reached a constant weight, according to the methods of Costa et al. (2017). The biomass samples were ground (2 mm) in a mill to determine the nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S) contents according to the methods of Malavolta et al. (1997). The N, P_2O_5 and K_2O fertilizer equivalents of the mulch biomass of the forage and maize cropping systems were determined considering the atomic mass of the elements according to analytical chemistry conventions and the N, P and K concentrations of the biomass analysed (DIAS et al., 2020).

To describe the nutrient contents, the data were fitted together with the standard error to an exponential mathematical model ($y = a + bx$) via Sigma Plot software. To calculate the half-life (t1/2), i.e., the time required for 50% of the remaining biomass to be decomposed, the equation proposed by Paul and Clark (1989) was used, namely, t1/2 = 0.693/k, where t1/2 is the half-life of the dry biomass and k is a constant of the dry biomass decomposition. The data concerning the fertilizer equivalents, were analysed by analysis of variance by the use of R software version 3.1.1 (FERREIRA et al., 2014). The means were compared according to Tukey's test at a significance level of 5%.

RESULTS AND DISCUSSIONS

There was an exponential reduction in nutrient accumulation for all biomasses of the cropping systems. Nitrogen and phosphorus accumulation (Figure 1a, b) after 30 days were similar between the forages but was lower in the maize group at all decomposition times. Comparing the initial nitrogen and phosphorus accumulations with the values reached after 120 days of management, a release of 80.5, 81.4, and 75.3% nitrogen and 94.1, 96.6, and 97.7% phosphorus was observed for Paiaguas palisadegrass, Tamani guinea grass, and maize, respectively.

The higher nitrogen accumulation in Paiaguas palisadegrass and Tamani guinea grass can be attributed to the higher biomass production of these forages, as well as to the higher production of leaves in these grasses, where greater amounts of nutrients are concentrated, favouring nitrogen cycling. Another factor that may have contributed to the greater nitrogen accumulation is the return of nutrients through the excretion of manure and urine, increasing nutrient recycling (CARVALHO et al., 2010).

Considering that part of the nitrogen accumulated in the studied biomasses will be deposited in the soil, it can be inferred that the biomass of Paiaguas palisadegrass and Tamani guinea grass contributed significantly to the supply of nitrogen to soybean in the initial phase, a period in which biological nitrogen fixation is not effective. Maize biomass had an initial nitrogen accumulation of 34.75 kg/ha, which is insufficient to meet the demand of soybean. Soybean uptakes an average of 190 to 372 kg/ha of nitrogen, 65 to 85% of which comes from the symbiotic fixation of atmospheric N_2, and the rest is provided by the soil (OLIVEIRA JUNIOR et al., 2020).

Paiaguas palisadegrass and Tamani guinea grass at 0, 30, 60, and 90 days showed higher potassium accumulation than maize (Figure 1c). At 120 days, the values were similar between the cropping systems: Paiaguas palisadegrass, Tamani guinea grass, and maize released 94.1, 96.6, and 97.7% potassium, respectively.

Of all the nutrients, potassium had the shortest half-life (Paiaguas palisadegrass: 19 days; Tamani guinea grass: 21; maize: 34), because it is an element that is not part of any structure or organic molecule in the plant, rather being predominantly found as free cations with high mobility in plants, which are easily washed away by rainwater after the rupture of plasma membranes (TAIZ et al., 2017). Thus, potassium is readily available and released with little dependence on microbial processes (ASSMANN et al., 2017). Miguel et al. (2018) observed accelerated release of potassium from the biomass to the soil, especially in the first 30 days.

Nitrogen and potassium are the two nutrients most uptaken by forage plants (COSTA et al., 2017), and in the present study, they were found in greater abundance in the Paiaguas palisadegrass and Tamani guinea grass biomasses. The phosphorus, potassium, and sulfur accumulation were satisfactory in the biomass of the Paiaguas palisadegrass and Tamani guinea grass cropping systems for the uptake required by soybean as a successor crop, showing that these forages can release amounts close to the crop needs.

For calcium, magnesium, and sulfur (Figure 1d, e, f) the highest nutrient accumulations at 30 to 120 days were obtained in Paiaguas palisadegrass, followed by Tamani guinea grass, with maize having the lowest potential to accumulate these nutrients at all soybean cropping times. At 120 days, Paiaguas palisadegrass, Tamani guinea grass, and maize had respective release rates of calcium of 86.5, 84.4, and 83.8%; of magnesium, 81.7, 82.3, and 78.7%; and of sulfur, 85.1, 86.1, and 85.2%.

The accumulation of nutrients and the half-lives of calcium, magnesium, and sulfur show the importance of nutrient cycling by Tamani guinea grass and Paiaguas palisadegrass for the supply of these nutrients to the soybean crop. Sulfur and magnesium are released into the soil faster than calcium because they are part of sulfonated amino acids. Conversely, calcium is a predominant constituent of calcium pectates in plant tissue. Pectates are more insoluble and take longer to be decomposed by microorganisms (BUCHELT et al., 2020).

The highest macronutrient accumulation in soybean occurs between 82 and 92 days, and the highest absorption rate occurs between 39 and 58 days (MALAVOLTA et al., 1997). In the present study, the half-life of nutrients was on average 46 days, except for potassium, and greater release of nutrients was observed up to 85 days, showing the potential of grasses as a reserve and supply of nutrients for successor crops.

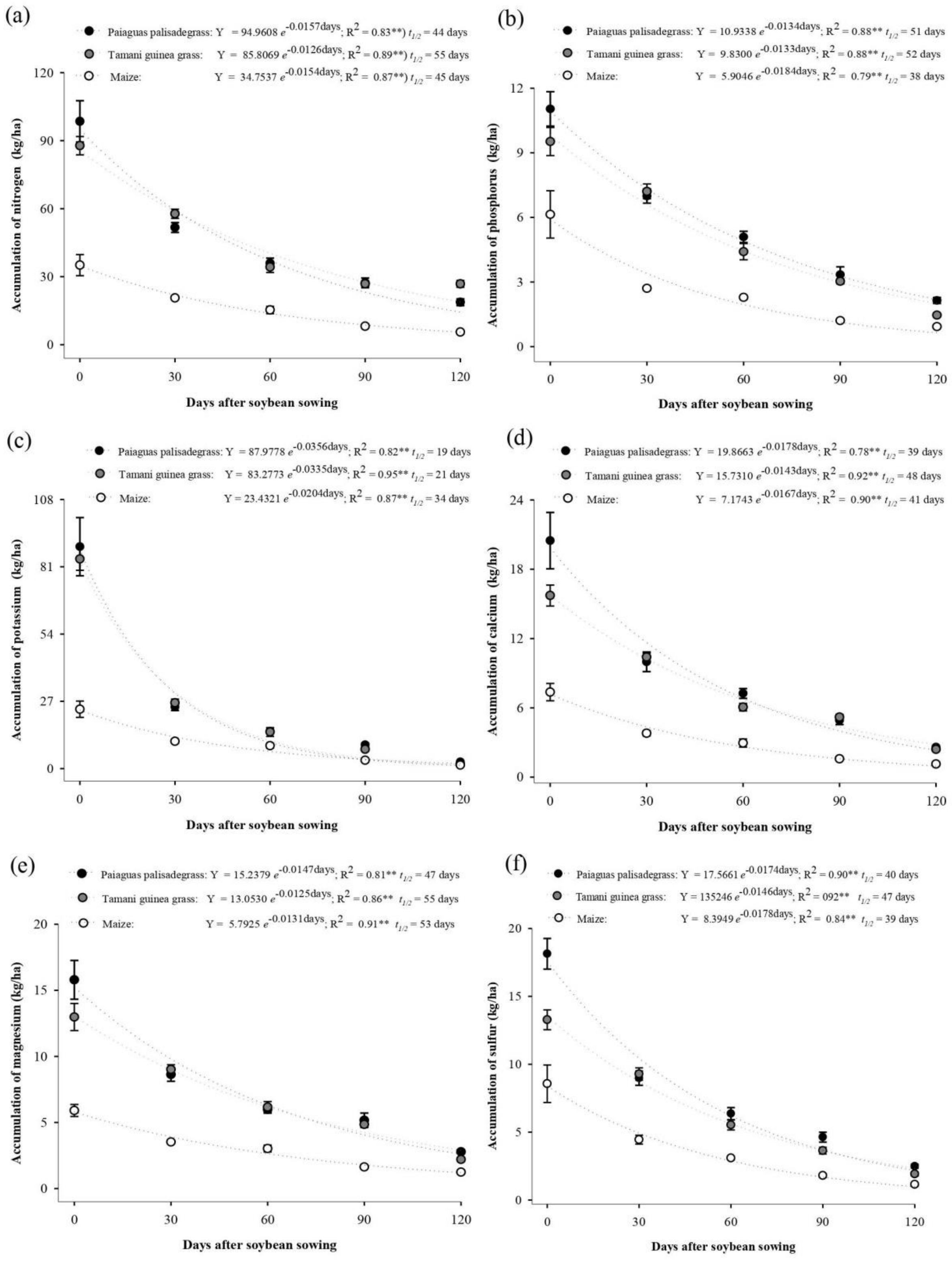

Figure 1. Accumulation of nitrogen (a), phosphorus (b), potassium (C), calcium (d), magnesium (e), and sulfur (f) in the biomass of Paiaguas palisadegrass, Tamani guinea grass, and maize during soybean cropping (0 to 120 days).

The order of nutrient accumulation of the remaining biomass of Paiaguas palisadegrass and Tamani guinea grass was N > K > Ca > S > Mg > P. For maize biomass, it was N> K> S > Ca > P > Mg. The nutrients with the highest accumulated concentrations in the biomass were nitrogen and potassium.

Phosphorus, calcium, magnesium, and sulfur had the lowest accumulated concentrations; however, these values are also indicative of nutrient cycling, since smaller amounts of these nutrients are required by successor crops.

Evaluating the fertilizer equivalent, Table 1 shows that Paiaguas palisadegrass and Tamani guinea grass provided greater amounts of nitrogen, phosphorus, and potassium equivalents than maize. Release of nutrients from the straw of these grasses has the potential to save 207 kg of urea, 128 kg of single superphosphate, and 170 kg of potassium chloride.

The amount and release of nutrients from residues of previously cultivated biomass are highly important in nutrient management from the perspective of cycling in production systems. High biomass production may lessen the need to add nutrients from external sources, reducing production costs and potentially reducing nutrient losses due to denitrification or leaching (SOARES et al., 2019).

Table 1. Equivalent contents of N, P_2O_5, and K_2O in the mulch biomass of different cropping systems.

Cropping systems	**Equivalent (kg/ha)**		
	N	**P_2O_5**	**K_2O**
Paiaguas palisadegrass	98.4 a	25.3 a	107.2 a
Tamani guinea grass	87.7 a	21.8 a	95.8 a
Maize	35.0 b	14.0 b	28.7 b
SEM	6.0	1.4	9.1
P value	<0.001	<0.001	<0.001

Means followed by different letters differ by Tukey’s test at 5% probability.

The data on fertilizer equivalents show the importance of forages to the nutritional balance of plants in integrated production systems. The values of fertilizer equivalents (N, P_2O_5, and K_2O) in the forage plants were higher than those found in maize biomass due to the higher biomass production and nutrient release from plant residues, which is interconnected with the use of animal excreta that constitute a nutrient return pathway in the soil, improving the dynamics of mineralization and releasing nutrients more efficiently to the system (DIAS et al., 2020).

Assmann et al. (2017) emphasize the importance of considering the nutrients from biomass in integrated systems in the calculation of fertilizer recommendations because a large proportion of these nutrients return to the soil. Thus, when considering the high cost of fertilizers, it is possible that the continuous use of cover crops in agricultural an production systems allows the most efficient use of nutrients available in the soil at lower production costs and maintains greater sustainability in production.

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It is worth emphasizing the importance of considering the biomass nutrients in integrated systems in the calculation of fertilizer recommendations because a large proportion of these nutrients return to the soil (ASSMANN et al., 2017). Thus, when considering the high cost of fertilizers, it is possible that the continuous use of cover crops in agricultural production systems allows the most efficient use of nutrients available in the soil at lower production costs and maintains greater sustainability in production.

CONCLUSIONS

The use of the integrated crop-livestock system in the form of forage succession provided greater nutrient cycling as a result of the better utilization of the animals excreta, than the cropping of maize in succession, thus contributing to agricultural sustainability.

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SEASONAL CHANGES IN LEVELS OF CHLOROPHYLL, NITRATE AND TOTAL SOLUBLE CARBOHYDRATES OF BRACHIARIA DECUMBENS IN A LONG-TERM SILVOPASTORAL SYSTEM

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ABSTRACT

Our objective was to quantify the levels of chlorophyll (Chl), nitrate and total soluble carbohydrates in leaf blades of *Brachiaria decumbens* grown in the understory of a silvopastoral system (SPS) under intense shade and compare them to those grown in an open pasture (OP), with *B. decumbens* under full sunlight. Two treatments, corresponding to the specific production system (SPS and OP) were evaluated over four seasons: spring 2016, summer 2017, autumn 2017, and winter 2017. In the SPS, we observed an increase in the levels of chlorophyll and nitrate, and a reduction in total soluble carbohydrates relative to those in OP. This pattern of response was also influenced by the seasons, with higher levels of chlorophyll and nitrate during seasons with greater availability of resources. In contrast, total soluble carbohydrates were lower in spring and summer and higher in autumn and winter. Our results demonstrated that intense light restriction (70% shading) in an SPS reduces the levels of total soluble carbohydrates and increases the levels of chlorophyll and nitrate, which are directly related to the productivity, longevity, and nutritional value of the forage.

Key words: nitrate; shading; silvopastoral system

INTRODUCTION

The silvopastoral system (SPS) has been considered a promising alternative for sustainable management of land use (PACIULLO et al., 2017). Despite recent advances in our understanding of the morphophysiological responses of shaded forages, little is currently known concerning the responses of metabolites related to carbon and nitrogen in forages grown in SPS. Accordingly, it remains unclear how photosynthetically active radiation (PAR) reductions modifies the levels of these metabolites in the forage and how these metabolites may vary over the seasons due to changes in climatic conditions. This information would likely provide a better understanding of how these changes are related to forage productivity and the performance of animals that consume that forage. Based on that, we hypothesized that intense shade provided by trees in the SPS alters the levels of chlorophyll, nitrate, and total soluble carbohydrates in *B. decumbens*. We therefore quantified levels of levels of chlorophyll, nitrate, and total soluble carbohydrates in leaf blades of *B. decumbens* growing under the understory of an SPS under intense shading and compare it to those found in leaf blades grown in an OP (*B. decumbens* under full sunlight) over four seasons (spring 2016, summer 2017, autumn 2017, and winter 2017) in southeastern Brazil.

MATERIAL AND METHODS

The experiment was conducted at Embrapa Dairy Cattle research farm, in Coronel Pacheco, Minas Gerais, Brazil (21°33'S and 43°06'W; 410 m a.s.l.). The experiment began on September 22, 2016, and ended 22 September, 2017, and was composed of an SPS and OP, established in November 1997 in a mountainous area. Evaluations were performed in the grove (intra-rows) of SPS and the OP. The forage was composed of *B. decumbens*. The grove in the SPS was composed of trees of the species *Eucalyptus grandis* and tree legumes *Acacia mangium*, which were planted perpendicular to the incline of the slope in a north-south direction to prevent surface erosion of soils. Trees were arranged in groves comprising four parallel rows with an intra-row spacing of 3.0 m and an inter-row spacing of 3.0 m, totaling 81 trees/ha. The trees were planted alternately (mixed) in each of the four rows. The percentage of shading in the experimental area in the SPS was measured using the AccuPAR LP-80 ceptometer (Decagon Devices, Pullman, WA, USA), where, ten through non-destructive measures, the understory PAR was evaluated. Measurements were made during clear skies at 9:00 am, 12:00 pm, and 3:00 pm, one meter above ground. From these data, we calculated a reduction of the incidence of PAR by approximately 70% relative to OP, thus characterizing an intensely shaded environment. The experimental area of 500 m^2 was subdivided into 16 plots (8 plots for each system) of 2 m^2 distributed into two blocks. Before the experiment began, animals were excluded from the experimental area for one year, so that there was no residual effect of excreta previously deposited on the soil. Throughout the experimental period, the plots were periodically harvested to maintain an herbage height of 35 cm ± 10 cm, and the plant cuttings were removed from the plots, simulating continuous grazing. Two treatments, corresponding to a specific production system (SPS and OP), were evaluated over four seasons (spring 2016, summer 2017, autumn 2017, and winter 2017). We used a randomized block design (two blocks) with four replicates (plots) within a block ($n = 8$), and the season was considered a repeated measure. In each plot, three tillers were collected in a usable area of 1 m^2, in plants located in the central part of the plots, leaving a 0.5 m border at the ends. From each tiller the last completely expanded leaf blade (recognized by +1 leaf blade) was collected, every 28 days, between 08:00–10:00 h. The central vein was removed from each leaf blade, and the three leaf blades collected from each plot were combined to form a single replicate. After harvesting, the leaf samples were snap frozen in liquid nitrogen and stored at −80°C until further analyses. The snap frozen samples were lyophilized (L 120, Liotop brand) for 76 h at −50°C. The levels of metabolites were quantified according to procedures in the following references: total chlorophyll contents ($a + b$) (PORRA et al., 1989); nitrate (FRITZ et al., 2006). The quantification of total soluble carbohydrates was performed by the phenol-sulfuric method (DUBOIS et al., 1956; MASUKO et al., 2005). All metabolites were determined in an OptiMax Tunable Microplate Reader (ELISA) microplate reader. Repeated measures analyses were conducted with the PROC MIXED procedure in SAS® (SAS Institute Inc., Cary, NC, USA). The means of the two systems were compared using the F-test, and the season means were compared using the Tukey–Kramer test of the LSMEANS command. For all analyses, $\alpha = 0.05$ was defined as the critical level of probability for type I error.

RESULTS AND DISCUSSIONS

The levels of total chlorophyll and nitrate in leaf blades of *B. decumbens* were significantly different between the production systems and seasons (Figure 1). There was an interaction between production systems and seasons for the variables total Chl ($p = 0.0002$) and nitrate ($p < 0.0001$). When comparing the systems, higher levels of total Chl were found in the SPS in all seasons (Figure 1a). In both systems, higher levels of total Chl were observed in the autumn. Chlorophylls are the most abundant photosynthetic pigments in plants and are responsible for absorbing light energy and converting it to chemical energy. Several studies of tropical forages have observed that, under shading environments, the amount of Chl increases in a direct relationship with to monoculture cultivation (DIAS-FILHO, 2002; OLIVEIRA et al., 2013). These higher levels, also observed in our study, are associated with the increases in the photosynthetic efficiency in response to light restriction (DO NASCIMENTO et al., 2019). As plants become more efficient at absorbing light energy, their growth increases. The higher levels of Chls observed in the SPS relative to OP can also be correlated with the greater availability of nitrogen in the SPS. Higher levels of Chls were observed during autumn in both systems and can be explained, at least partially, by the greater yet atypical precipitation during this season, even with reduced light intensity. Therefore, the increased amount of chlorophyll enhanced light capture efficiency even with a reduction in light intensity and temperature in autumn. The lower chlorophyll levels observed during winter may be, however, associated with a reduction in light intensity, temperatures, and water in the soil, resulting in a decrease in photosynthetic rates and growth. Higher levels of nitrate were observed in SPS than OP in spring, summer, and winter, with no difference between systems in autumn (Figure 1b). Moreover, the SPS was characterized by the highest levels in spring, followed by summer and the lowest levels in autumn and winter. Nitrate levels in the winter were reduced by 92% (0.26 g/kg) relative to spring (3.18 g/kg), a period in which less nitrogen absorption may occur as it is less mobilized in the soil due to the reduction of water content. Open pasture, on the other hand, maintained similar nitrate levels throughout the experimental period. The higher levels of nitrate observed in SPS relative to OP can be explained by the lower amount of PAR that reaches the understory, affecting the internal assimilation rates of nitrogen due to the lower availability of carbon skeletons via photosynthesis. The low light availability is also a stress. Neel and Belesky (2017) also observed higher levels of nitrate in C_3 forage in SPS relative to OP. Nitrate can accumulate in vacuoles without causing any harmful effects to the plant, unlike nitrite and ammonium ions, which must be reduced and assimilated immediately. It is important to mention, however, that it high levels of nitrate can affect the ingestive behavior of animals that consume this forage and consequently influence animal production. Accordingly, it has been observed that animals prefer to graze in sunnier areas over shaded areas (NEEL et al., 2008). Notably, the nitrate concentrations found in the present study were below the limits considered toxic to animals. Nitrate values between 6.6 to 13.3 g/kg of DM can reduce the daily intake of DM by 50%, and values between 13.3 to 19.9 g/kg of DM can reduce the DM consumption by up to 75% (ESSIG et al., 1988). The levels of total soluble carbohydrates were influenced ($p = 0.0001$) by the interaction between the production system and season (Figure 2). During the spring and summer, there was no difference between the systems. In autumn and winter, SPS showed lower levels of total soluble carbohydrates relative to those of OP. Higher levels of total soluble carbohydrates in the SPS were observed in winter, followed by autumn, which did not differ from spring, and a lower level was observed in summer, which was similar to spring. In OP, higher levels of total soluble carbohydrates were observed in winter, followed by autumn, spring, and lower levels were observed in summer. The similarity in the levels of total soluble carbohydrates between systems during spring and summer can be explained, at least partially, by the higher synthesis and use of carbohydrates for biomass production during seasons with more favorable climatic conditions. During autumn and winter, when usually plant growth is reduced the trend is that these compounds are stored and also transported to drain organs (stem and roots). However, in these seasons, the levels of total soluble carbohydrates were lower in SPS than in OP. In general, under shade, forage was characterized by lower levels of carbohydrates. This reduction may be associated with a thinner leaf mesophyll under shaded environments to increase photosynthetic efficiency (GEREMIA, 2016). According to Ciavarella et al. (2000), under shaded environments, grasses prioritize the allocation of photoassimilates to maintain and increase leaf area and stems that ultimately also increase light uptake. Plant growth and development are dependent on the interaction between the metabolism of carbon and nitrogen (NUNES-NESI et al., 2010). Our, results indicate that changes in forage growth are also associated with metabolic changes. Our results indicate that metabolites related to carbon and nitrogen are altered with shading and that magnitude of these effects may vary with the season.

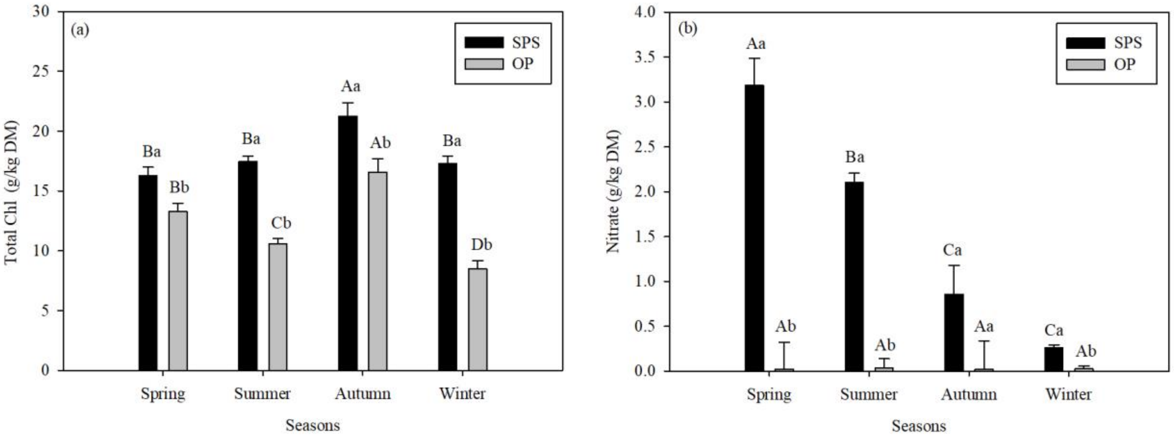

Figure 1. Total chlorophyll (Chl) and Nitrate (d) yield (g/kg; 100 % dry-matter basis) in leaf blades of Brachiaria decumbens in a silvopastoral system (SPS) and open pasture (OP) by season (spring, summer, autumn, and winter). Means followed by different letters, lowercase letters comparing the systems in each season, and uppercase letters comparing each system in the seasons available, are significantly different ($p < 0.05$). Vertical bars indicate the standard errors of the means.

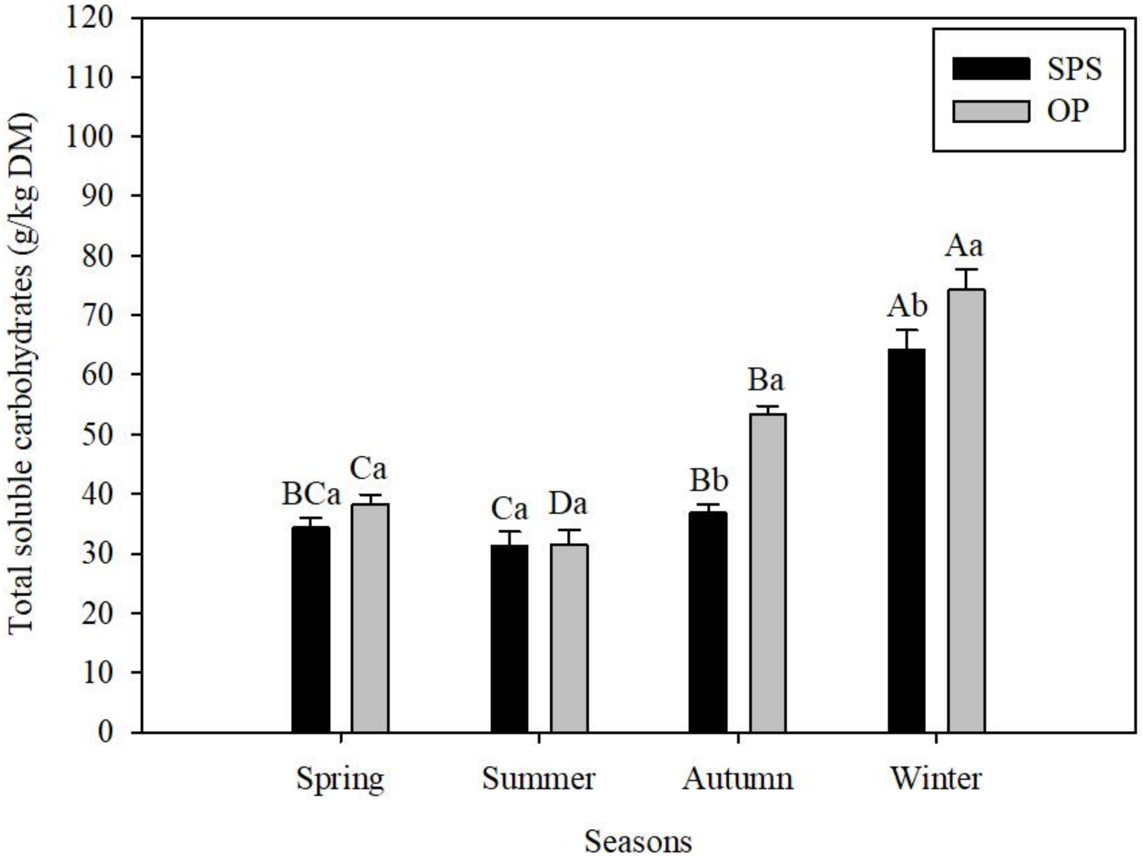

Figure 2. Total soluble carbohydrates (g/kg; 100% dry-matter basis) in leaf blades of Brachiaria decumbens in a silvopastoral system (SPS) and open pasture (OP) by season (spring, summer, autumn, and winter). Means followed by different letters, lowercase letters comparing the systems in each season, and uppercase letters comparing each system in the seasons available, are significantly different ($p < 0.05$). Vertical bars indicate the standard errors of the means.

CONCLUSIONS

Our results demonstrated that intense light restriction (70% shading) in a SPS reduces the levels of total soluble carbohydrates, while it increases the levels of chlorophyll and nitrate; higher fluctuations in these metabolites are observed in the seasons of higher growth (spring and summer). Notably, these metabolites are directly related to the productivity, persistence, and nutritional value of the forage. That being said, for a comprehensive understanding of carbon/nitrogen interactions in forage in response to shade, much higher resolution at the whole-plant, cellular, and sub-cellular level is likely required. In summary, our results revealed that intense shading should be avoided and therefore silvicultural interventions, such as thinning or pruning of trees in the SPS, are highly recommended, thereby focusing on animal production that stabilizes the production and quality of the forage in the long-term.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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SOIL MOISTURE UNDER INTEGRATED SOYBEAN PRODUCTION SYSTEM

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ABSTRACT

The soil moisture is an important factor to be considered, for this reason, the aim of this study is to evaluate the soil moisture in the two integration systems, and verify which adapts better to the soybean crop. Soil moisture was evaluated at 2 days pre-planting (November 08, 2017) and 32 Days Post-Planting (DAP), in which the soil was collected at 10 cm depth in the stratified sampling sites (A; B; C; D; and E) in the $ICLF_{28}$, $ICLF_{22}$, and ICL systems in two repetitions and also in a Cerrado area for comparison purposes. The ICLF (agroforestry-pasture system) systems presented lower soil moisture content at 2 days pre-planting and 32 days post-planting of soybeans.

Key words: Rainfall; Eucalyptus; agroforestry

INTRODUCTION

The farmer seeks to maximize land-use with crop diversification, increasing yield, reducing production costs, conserving the environment and increasing income. Crop-livestock-forest integration is a way to lead to a path of change where the concept of traditional property is left and inserted in a level of integrated and sustainable property (SILVA et al., 2016).

An important aspect, but one that has received little attention is how ICLF affects soil water dynamics. Even if water is not considered as a limiting resource in ICLF systems, compared to the other factors such as nutrients, light, temperature, biological competition among the species used, it still needs attention as climate change has increasingly challenged production systems (GIEZE et al., 2019).

Soil moisture is an important factor to be considered as it is essential for plant growth, aids in the nutrients mobilization and uptake and for its influence on the activity of soil fauna (MORRIS et al., 2006). For this reason, the aim was to evaluate soil moisture in integrated systems, in order to verify which one best suits the soybean crop.

MATERIAL AND METHODS

The experimental area used was 48 ha, located in Campo Grande – MS, Brazil (20º 27' S; 54º 37' W; 530 m altitude) at the Brazilian Agricultural Research Corporation (Embrapa), Beef Cattle Unit. The soil of the experimental area was classified as Red Dystrophic Latosol of clayey texture. The maximum precipitation during the eight months of study in the experimental time corresponding to the 2017/18 harvest, was 1,311.17 mm. The average temperature is 25 °C, and the maximum and minimum: 31.3 °C and 20.8 °C, respectively.

A recovery plan of the degraded area was carried out by means of the Integrated Agricultural Production Systems with a management time of 16 years, according to Table 1.

The treatments were arranged in subdivided plots: agroforestry-pasture system with an inter-row distance of 28 m (ICLF$_{28}$); agroforestry-pasture system with inter-row distances of 22 m (ICLF$_{22}$); and agro-pasture system (ICL).

The subplots were composed of the sampling sites, five sites equidistant between rows of eucalyptus trees (ICLF), with full sun cultivation as a witness (ICL). These sites were demarcated on a transect perpendicular to the tree rows (east-west direction). The sampling sites (north-south direction) were identified by letters (A; B; C; D; E), with the following distances from the tree rows: for ICLP$_{28}$: 7 m; 10 m; 11 m; 9 m; 4 m. As the center row was harvested from the old 14 m row spacing, this became a 28 m row spacing for ICLF$_{22}$: 3 m; 7 m; 10 m; 7 m; 3 m. In both systems, 1 m distance between the rows of eucalyptus and the crop was respected.

Soil moisture was evaluated at 2 days pre-planting (November 08, 2017) and 32 Days Post-Planting (DAP), in which soil was collected at 10 cm depth in the stratified sampling sites (A; B; C; D; and E) in the ICLF$_{28}$, ICLF$_{22}$ and ICL systems in two repetitions.

The gravimetric method was used in the evaluation, with the soil collected in aluminum pots, taken to an oven at 105 °C for 24 hours to obtain dry mass. Soil moisture was determined according to Klar et al. (1966):

%M = [(wet mass - dry mass) / dry mass]*100

For the statistical analyses the qualitative factors were submitted to variance analysis and when the F test was significant, the Tukey test was applied, adopting a probability level of 5%.

RESULTS AND DISCUSSIONS

Soil moisture was higher in the ICL, both from 2 days pre-planting and at 32 days post-planting (Table 1). In the ICLF$_{28}$ and ICLF$_{22}$ systems, the presence of the forest component limits the light amount falling on the grass, consequently limiting its growth and mass production. With smaller amounts of dry mass left as residue, the moisture retained by the soil is lower throughout the soybean crop cycle.

Trees are considered natural antagonists because they benefit from water storage, and in the upper part of the soil the grasses also benefit from the water in the upper soil layers, contrasting with trees that their roots take advantage of the underground water resources (SARMIENTO et al., 1984).

Table 1. Soil moisture (%) before and post soybean planting.

	Soil moisture (%)	
System	**2 Days Pre-planting**	**32 Days postplanting**
[1]ICL	21.6 a	17.3 a
[2]ICLF$_{28}$	16.5 b	13.7 b
[3]ICLF$_{22}$	17.7 b	16.2 ab
[4]CV %	8.33	

[1]agro-pasture system (ICL); [2]agroforestry-pasture system with an inter-row distance of 28 m (ICLF$_{28}$); [3]agroforestry-pasture system with inter-row distances of 22 m (ICLF$_{22}$); [4] CV: Coefficient of variation. Means followed by the same lowercase letter in the column do not differ by the Tukey test (P>0.05).

One of the factors for maintaining higher soil moisture is the straw that was left by the Piatã grass prior to soybean sowing, an important factor for maintaining soil moisture in the area. In the system where there is no light restriction (ICL), the grass produces more dry mass, which contributes to the soil moisture retention.

This trend of higher soil moisture in the ICL system extends throughout the soybean cycle (Figure 1), with a significant difference only between the systems with a forest component ($ICLF_{28}$ and $ICLF_{22}$) and the full sun system (ICL). Soil moisture in ICL was higher by 26.31% and 15.72% compared to ICLF, at 2 days pre-planting and 32 days post-planting respectively.

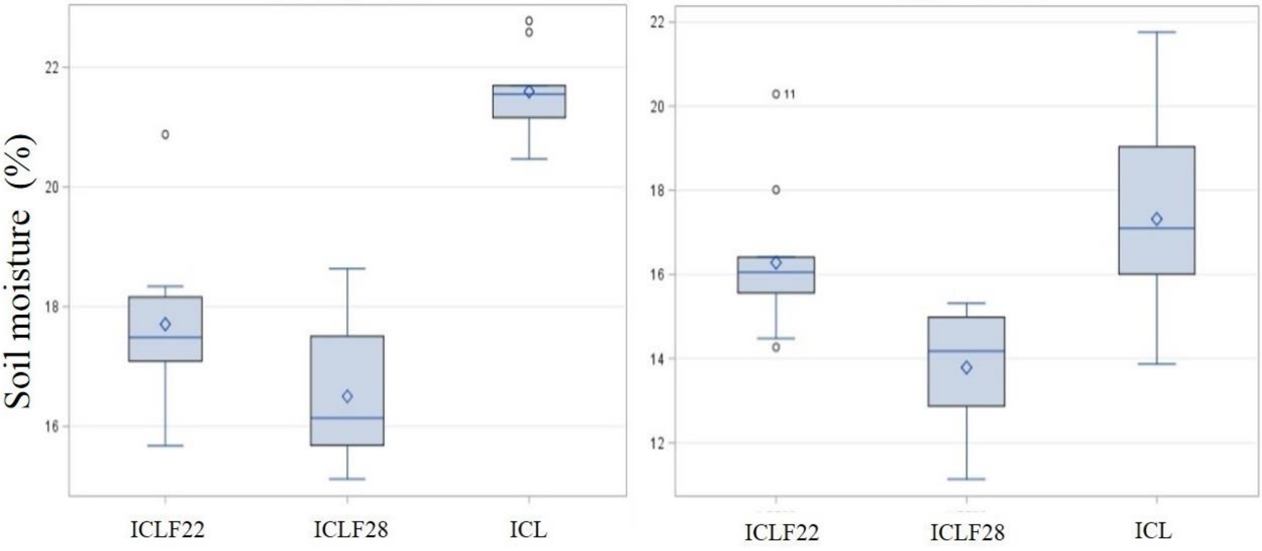

Figure 1. Soil moisture (%) 2 days pré- planting and 32 days post-plantin

The decrease in moisture content in the ICLF system, can be explained by the collection points such as A and D that were close to the row of eucalyptus and that may have reflected in the final mean. In evaluations in the previous two years 2015/16, it was reported that rainfall interception by the tree canopy did not influence the amounts of rainfall received along the points between the tree gradients by the pluviometer. At the points near the tree rows, the plants were approaching the wilting point during the dry season, a strong water stress indicator (GIEZE et al., 2019).

CONCLUSIONS

The ICLF (agroforestry-pasture system) systems presented lower soil moisture content at 2 days pre-planting and 32 days post-planting of soybeans.

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WATER USE EFFICIENCY AND SOIL PHYSICAL ATRIBUTES UNDER FERTILIZER APPLICATION SRATEGIES IN AN INTEGRATED CROP-LIVESTOCK SYSTEM

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ABSTRACT

The agricultural production systems need to achieve more sustainable production and efficiency of water and nutrient use. Integrated Crop-Livestock System (ICLS) conciliate animal and crop production increasing soil physical and chemical quality. This work highlights to analyze the effect of two fertilization approaches in ICLS on the water use efficiency (WUE) and soil physical characteristics. The statistical design was a randomized block arranged in a factorial 2x2 with four replicates, consisting of two fertilization strategies (systems fertilization or conventional crop-oriented) and systems with grazing animals (ICLS) or not (specialized system). The WUE was 84% higher at ICLS (10.06 Kg DM-^{1} mm-^{1}) compared to the specialized system (5.45 Kg DM-^{1} mm). The soybean WUE was not affected by the cropping system. The soil density was 14 % lower at ICLS (0.93 g cm-^{3}) than on non-ICLS (1.09 g cm-^{3}). The total porosity was 16% higher at ICLS (0.65 m^{3} m-^{3}) compared with the specialized system (0.59 m^{3} m-^{3}). The fertilization approaches had no effect on any indicators. This work elucidates that moderate grazing intensities can increase the pasture water use efficiency and production and improve the soil physical characteristics.

Key words: Sustainable; grazing intensity; pasture production

INTRODUCTION

Water is essential for every form of life, for all aspects of socio-economic development, and for the maintenance of healthy ecosystems (FAO, 2020). To develop production systems for better relationship with environment and society, sustainable practices that aim at the concern with the water use on agriculture are essential.

Initiatives that concern about the rational use of water, nutrients and agrochemicals such as no-tillage systems and the integration of crops and livestock are expanding gradually around the world. The Integrated Crop-Livestock System (ICLS) seek to enhance synergisms and emergent properties in areas with agricultural and livestock activities (CARVALHO, 2018). Historically, ICLS are mentioned with increasing yields, smaller nutrients losses to lixiviation and denitrification because of the absorption of forage species (MAZOYER; ROUDART, 2010).

The grazing process stimulates the roots growth that have direct influence on soil structure, improving its physical-hydric quality through the reduction of soil compactation, in addition to the reduction of soil density and increasing total porosity (FRANZLUEBBERS, 2011; AMBUS et al., 2018). These effects allow a better water use by plants due to higher rainfall water infiltration that reduces the erosion risks, and promote retention and redistribution of water in the soil. Those are factors that foster the water absorption by plants during a drought season. Finally, the soil can achieve more organic carbon accumulation and total nitrogen stocks under moderate grazing (DAMASCENA et al., 2009) besides pasture growth and animal intake can have substantial increases (SCHONS, 2021; CARVALHO, 2013).

Traditionally, the amount of chemical fertilizers applied in crops is higher compared to pastures, that has its demands neglected. Besides that, the crops responses to P and K fertilization in soil with high nutrients levels have been irregular (BORING et al., 2018). This demonstrates that we need a better comprehension of the nutrient dynamics in the soil. ICLS introduce a new trophic level compared to crop specialized systems, that creates more complex relationships between the organisms and further complicates the understanding of the fertilization and other practices. Herbivores decouple nutrients in the rumen and return a large portion via urine and dung (HAYNES; WILLIAMS, 1993). Seeking to explore the nutrient cycling, Assmann et al. (2017) exemplified the systems fertilization approaches, which is based on the conceptual framework that the nutrient input must be applied in the system phase that present low nutrient extraction and higher cycling capacity, to goal the higher total systems production. This approach offers lower risk to the environment, more economic and efficient fertilization use, by lower nutrient losses and nutrients inputs requirements.

The relationship between ICLS and system fertilization approaches affect the soil physical and chemicals attributes (BONETTI et al., 2019; DAMASCENA et al., 2009; ASSMANN et al., 2017). In this context, this work highlights the analyze of the effect of two fertilization approaches on an Integrated Crop-Livestock Production System on the water use efficiency and soil physical characteristics.

MATERIAL AND METHODS

The experiment is located at the Agronomic Experimental Station of the Federal University of Rio Grande do Sul, in the municipality of Eldorado do Sul (latitude 30º05'22 " S and longitude 51º39'08" W and altitude 46m). The climate is a humid subtropical "Cfa" according to the Köppen classification and the soil is classified as an Acrisol.

The experimental design was a randomized block, arranged in a factorial 2x2 with four replicates, consisting of two fertilization strategies (system fertilization of P and K at pasture phase and conventional fertilization of these nutrients at crop phase) and systems with grazing (ICLS) and without grazing at pasture phase (specialized system). The layout was 16 paddocks with average area of 2750 m².

At the ICLS, the pasture management was conducted under continuous stocking according to the "Rotatinuous" concept (CARVALHO, 2013). To maintain the goal sward height of *Lolium multiflorum* Lam. (15 cm) we used the "put and take method" (MOTT; LUCAS, 1952) with 3 testers animals, which were sheep (Corriedale). Nitrogen fertilization (150 kg N ha^{-1}) was carried at the establishment of the pasture phase. The forage accumulation rate in each grazing cycle (28 days) was assessed by four exclusion cages per experimental unit. The total forage production was defined by the initial forage mass, plus forage accumulation multiplied by the number of days of the experimental period. At the end of the grazing period, sheep were removed, and the area was desiccated with glyphosate (3 L ha^{-1}) and suflufenacil (50 g ha^{-1}). The soybean was sown with of row space of 0,45 m and population of 280.000 plants ha^{-1}. The soil samples were collected at the mid of pasture phase.

The water use efficiency (WUE; kg ha^{-1} mm^{-1}) of Italian ryegrass and soybean was calculated dividing the total aerial biomass produced (kg ha^{-1}) per unit rainfall, that was: 872.8 mm on the pasture phase (april-october, 2020) and 98.5 mm on the beginning of the crop phase (october-december, 2020). Undisturbed soil samples were collected for the determination of the soil density (TEIXEIRA et al., 2017) and the initial (θ_0) and final (θ_s) soil moisture, considering θ_s equal to the total soil porosity (?). The soybean samples were collected 21 days after sowing (V3-V4 stadium), cutting the plants just over the soil surface. Then the samples were weighted to determine the dry matter content. The data were submitted at analysis of variance at 5% of significance.

RESULTS AND DISCUSSIONS

Moderate grazing in ICLS promoted higher water use efficiency of ryegrass, decreased the soil density and increased the soil total porosity (Table 1 and Figure 1). The fertilization approaches and ICLS or non-ICLS factors did not presented interaction ($p > 0.05$).

The water use efficiency of ryegrass was affected by the grazing animal. At ICLS the WUE was 84% higher (10.06 kg DM^{-1} mm^{-1}) than the specialized system (5.45 kg DM^{-1} mm^{-1}). On the contrary, the soybean WUE was not affected by the grazing animal.

Table 1. Water use efficiency (kg DM-^{1} mm-^{1}) of Italian ryegrass and soybean, soil density (g cm-^{3}) and total porosity (m^{3} m-^{3}) at pasture phase in an integrated crop-livestock system (ICLS) or specialized (SS) with system (SF) or crop fertilization (CF).

Identification		Units	ICLS	SS	P-value	SF	CF	P-value
Water	Ryegrass	Kg DM^{-1}mm^{-1}	10.1 a	5.5 b	0.01	8.1 a	7.4 a	0.63
Use Efficiency	Soybean	Kg DM^{-1}mm^{-1}	1.8 a	2.2 a	0.1	1.8 a	2.2 a	0.14
Soil atributes	Soil density	g cm^{-3}	094 a	1.09 b	<0.01	0.99 a	1.03 a	0.13
(Pasture phase)	Total Porosity	m^{3} m^{-3}	0.65 a	0.59 b	<0.01	0.62 a	0.61 a	0.13

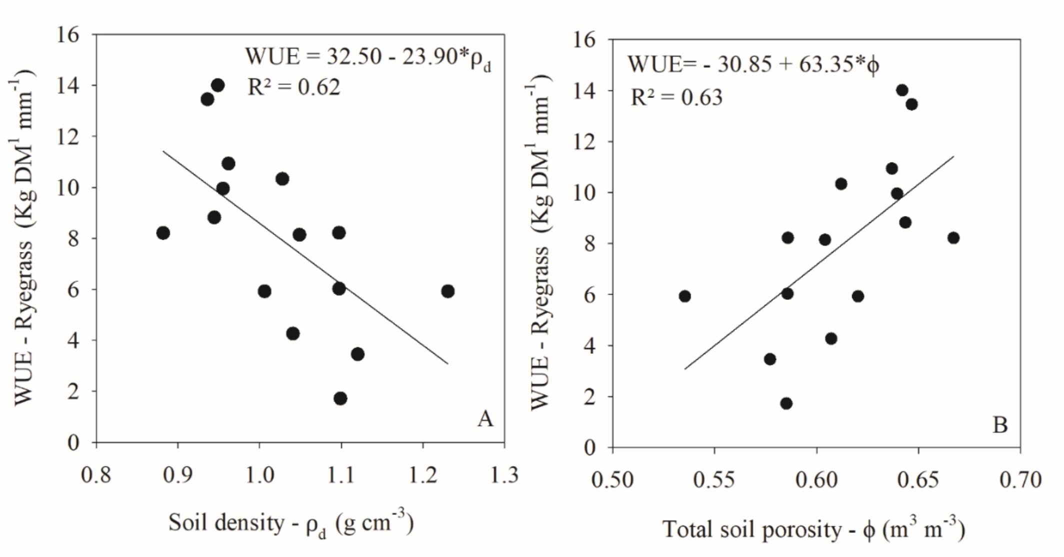

Figure 1. Effect of density (A) and total soil porosity (B) in water use efficiency ryegrass.

CONCLUSIONS

It is important to stand out that these results are of an ICLS conducted under moderate grazing (15 cm for ryegrass), but this response cannot be expected at high grazing intensities due to the negative effect of intense defoliation on root growth. Overgrazing remove a great portion of the plants leaves, that reduce the photosynthesis and the plant energy sources. Besides, the soil compaction also affects negatively the root growth, associated with the increase on soil density and decrease of porosity.

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5. Technology transfer to integrated systems

II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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CAN CANOPY HEIGHT OF MIXED PASTURES IN INTEGRATED CROP-LIVESTOCK SYSTEMS BE ESTIMATED USING PLANETSCOPE IMAGERY?

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ABSTRACT

Canopy height (CH) is one of the key parameters used to evaluate forage biomass production and support grazing management decisions in intensively managed fields. In this study, we demonstrate the potential of using textural information derived from PlanetScope (PS) imagery to estimate CH of intensively managed mixed pastures in an Integrated Crop–Livestock Systems (ICLS) in the western region of São Paulo State, Brazil. PS images and field data of CH were acquired during the forage growing season of 2019 (from May to November) to calibrate and validate the CH prediction models using the Random Forest (RF) regression algorithm. We used as predictor variables eight second-order texture measures derived from the green, red, near-infrared spectral bands of PS images using the grey level co-occurrence matrix (GLCM) statistical texture approach. Pasture CH varied from 0.12 to 1.20 m with a coefficient of variation equal to 63.34%. Our best RF model was able to predict the spatiotemporal changes in pasture CH with high accuracy ($R^2 = 0.88$) even with the high variability of the pasture CH through the forage growing season, mainly due to forage composition (different proportions of millet and ruzi grass) and grazing activities.

Key words: integrated systems; nano-satellites; texture measures

INTRODUCTION

Canopy height (CH) is one of the key parameters adopted to manage pasture fields since it is directly related to forage biomass production. Field measurements of pasture CH can be easily carried out using nondestructive sampling techniques (e.g., sward sticks and Robel poles) (BAXTER et al., 2017). However, these techniques are unlikely to give representative information of large pasture areas for being dependent on sampling design distribution and intensity.

Remotely sensed data derived from various sensors have been successfully used to predict pasture CH over the years (BATISTOTI et al., 2019; TISCORNIA et al., 2019) for providing wall-to-wall mapping of continuous measures of pastureland characteristics. The pasture canopy structure can be quantified using the spectral properties of remotely sensed imagery. Specifically, the spatial distribution and variation of spectral values across the pixels of a remotely sensed image result in this image's textural information (HARALICK; SHANMUGAM; DINSTEIN, 1973). Texture measures derived from high spatial resolution optical imagery hold particular potential for quantifying the variability in structurally complex canopies, such as in mixed pasture fields.

The high spatial and temporal resolutions offered by the recent constellations of nano-satellites such as Planet CubeSats are very promising for monitoring intensively managed pasture fields at a finer scale. To this date, only a few studies have explored the potential of using texture measures derived from PlanetScope (PS) images for monitoring mixed pasture fields. In this study, we assessed the performance of textural information derived from PS imagery to estimate canopy height (CH) of intensively managed mixed pastures in an Integrated Crop–Livestock Systems (ICLS) in the western region of São Paulo State, Brazil.

MATERIAL AND METHODS

The study area corresponds to four commercial fields of mixed pastures with approximately 50 ha each, located in the western region of São Paulo State, Brazil, between the geographic coordinates 21º37’30” S - 51°56’00” W and 21º38’30” S - 51°54’00” W. According to Köppen’s climatic classification system, the study area has tropical climatic conditions (type Aw), with drier months during the winter (*i.e.,* June–August) (ALVARES et al., 2013). The mean annual rainfall varies between 1,200 mm to 1,400 mm, concentrated in December and January.

The four fields have trees for shade and are split into 13 paddocks on which grazing livestock (cattle) rotates between them throughout the forage growing season. The area has been intensively managed as an ICLS based on cultivated mixed pasture rotation during the dry season (usually between April and October) and soybean cultivation in the wet season (usually between November and March). The pasture under study comprises a mixture of ruzi grass (*Urochloa ruziziensis*) and millet (*Pennisetum glaucum*), sown at a proportion of 15 kg ha^{-1} of millet and 5 kg ha^{-1} of ruzi grass in a spacing of 17 cm between rows. Pasture sowing began after the soybean harvest on March 28th and lasted until April 6th, 2019.

Field data collection of pasture canopy height (CH) was carried out during the forage growing season of 2019 using a sampling grid with one hundred georeferenced points distributed within the study area with a sampling intensity of 25 points per field using a stratified systematic unaligned sampling design. Field data collection campaigns were conducted on six dates: May 17th, May 25th, June 18th, July 14th, August 12th, and November 02nd, 2019. The field campaign dates were defined to capture different phases of the forage growth cycle (millet and ruzi grass) and in the function of animals’ entry and exit in the paddocks (defined by the farm manager). The numbers of sampling points measured in each field campaign varied according to paddock rotation, totalizing 346 field-sampled points.

The CH measurements were performed using a sward stick in 11 representative locations within a buffer of 5 m around the centroid of each sampling point. To obtain the mean CH, we calculated a weighted mean height based on the proportion of millet:ruzi grass in each sampling point. To determine that proportion at each sampling point, all millet and ruzi grass plants were collected in a 1 m^2 frame close to the ground. The fresh biomass of all plants was weighted in the field using a hanging scale, and then the ruzi grass and millet were separated and weighted again. Next, the samples of millet and ruzi grass plants were sent to the laboratory for drying, placed in an oven at 65 °C for 72 hours, and weighed to obtain the dry weight (dry mass in g m^{-2}). The proportion of millet at a specific sampling point was determined by dividing the weight of millet dry mass by the total plant weight in that sampling point. The same procedure was adopted to determine the proportion of ruzi grass in each sampling point.

Cloud-free PlanetScope (PS) CubeSat multispectral images covering the study area were acquired for this study on dates that most closely coincided with the field campaign dates (*i.e.*, May 20th, May 27th, June 17th, July 11th, August 10th, and November 02nd, 2019, respectively), and downloaded from the SCCON (Santiago & Cintra Consulting) platform. PlanetScope is a constellation of nano-satellites with more than 130 CubeSats 3U form factor (0.1 m by 0.1 m by 0.3 m) with the capability to image all of the Earth's land surface daily. The PS sensor has four spectral bands: blue (B: 455–515 nm), green (G: 500–590 nm), red (R: 590–670 nm), and near-infrared (NIR: 780–860 nm) with a spatial resolution of ∼3 m. The Planet Surface Reflectance (SR) Product was used in this study (PLANET LABS, 2020).

To explore the potential of using textural information from PS imagery to estimate CH in our study area, we used the grey level co-occurrence matrix (GLCM) statistical texture approach to derive texture images (HARALICK; SHANMUGAM; DINSTEIN, 1973). Texture measures quantify the heterogeneity in the greyscale values of pixels within a defined area of an image. Eight second-order GLCM texture measures, including mean (MEA), variance (VAR), homogeneity (HOM), contrast (CON), dissimilarity (DIS), entropy (ENT), second moment (2M), and correlation (COR), were calculated using the texture co-occurrence measures procedure available at ENVI/IDL software (Harris Geospatial Solutions, Inc., Broomfield, CO, USA). The eight texture measures were calculated for the G, R, and NIR bands of PlanetScope images using a window size of 5 × 5 pixels and the offset (θ) of 135°. All GLCMs were constructed using a 64 grey level quantization, and the B band was not used to derive GLCM textures for being strongly influenced by atmospheric scattering.

The Random Forest (RF) machine learning algorithm (BREIMAN, 2001) was used to estimate pasture CH, using as predictor variables the GLCM texture measures. From the coordinates of the sampling points, we extracted the textural information of the PS images and then associated it with the field-based measures of pasture CH for the model development. The 346 field-sampled points were randomly divided into 70% and 30% for training and validation of the RF models. The development of RF models involves a hyperparameter tuning process that maximizes the predictive accuracy of the models. Optimal values of the hyperparameters *ntree* (number of decision trees) and *mtry* (number of predictor variables randomly sampled at each split) were selected according to the accuracy estimation in the training dataset using the 5-fold cross-validation method. Next, we carried out the feature selection based on the built-in feature importance measures of the RF algorithm, enabling the most important variables in each model run to be identified. The importance of the predictor variables in the RF models was evaluated by calculating the mean square error increase (IncMSE) when a variable is randomly permuted (BREIMAN, 2001), reflecting the importance of each predictor in the prediction accuracy of pasture CH. The RF models' performance was assessed using the root mean square error (RMSE) in absolute and percentage terms and the coefficient of determination (R^2), calculated based on field-based pasture CH measurements in the testing dataset. All CH modeling analyses and evaluations were performed using the *mlr* package in R software (BISCHL et al., 2016).

RESULTS AND DISCUSSIONS

Pasture CH varied from 0.12 to 1.20 m with a coefficient of variation equal to 63.34%, highlighting the complexity and variability of mixed pastures throughout the forage growing season. The maximum values of CH (> 0.9 m) were measured in the fields in May, mainly due to the high proportion of millet (79%) in the pasture canopy structure. After the first grazing cycles, the proportion of millet in the pasture canopy structure was reduced (45% in June and 15% in July), and the growth of ruzi grass was favored. As a result, the measured values of CH were lower in June and July (< 0.68 m). In August, the proportion of millet in the pasture canopy structure was 3%. The entire ruzi grass establishment was observed in November, the month in which the lowest values of CH (< 0.38 m) were observed in the fields. Consequently, the high variability of pasture CH during the forage growing season was mainly due to the different proportions of millet and ruzi grass, grazing activities, and pasture coverage. Millet and ruzi grass are two plants with different structural properties and growth rates. Millet shows a rapid initial growth rate and is a tall, robust, and erect annual bunchgrass with long narrow leaves. On the other hand, ruzi grass is a creeping perennial with short rhizomes, which form a dense leafy cover over the ground.

The texture measures derived from the PS images were able to capture the variation in pasture CH throughout the forage growing season with high accuracy ($R^2 = 0.88$) and low prediction errors (RMSE = 0.10 m or 22.18%), based on the best RF model and the validation dataset (Figure 1 (a)). The predicted and measured values of CH showed a good agreement; however, we observed a slight trend of underestimation of CH higher than 1.0 m. The feature importance metric of the best RF model (Figure 1 (b)) shows that the MEA textures obtained from the G, R, and NIR spectral bands were the most important predictor variables in the estimation of CH. The ENT, CON, HOM, DIS, and 2M textures derived from the three PS spectral bands were the subsequent most important variables for CH predictions. On the other hand, the textures VAR and COR were not selected by the best RF model. The superior performance of the MEA texture in predicting vegetation structural parameters has been previously reported in the literature (WOOD et al., 2012; LI et al., 2019; ZHENG et al., 2019) and is mainly due to the MEA texture's ability in minimizing the interference of the background and smoothing the image. Texture measures are key spatial features derived from high spatial resolution remotely sensed imagery such as PS images and capture the canopy structure information needed for CH estimation in mixed pasture fields.

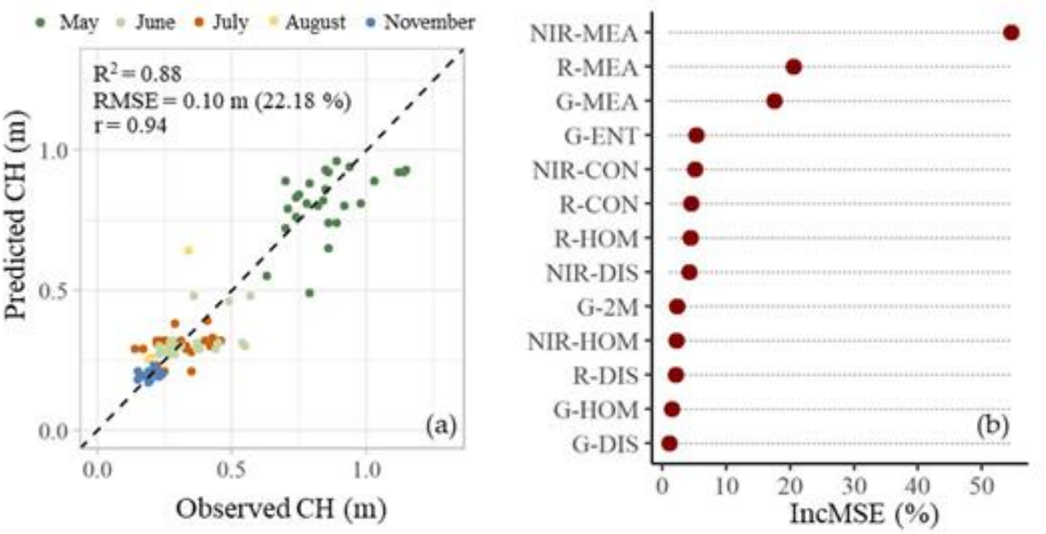
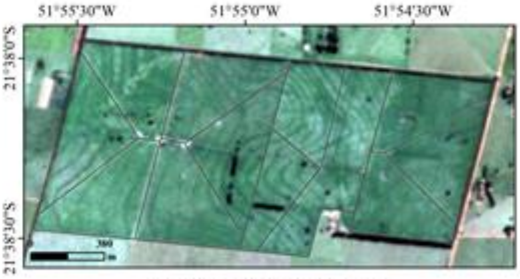


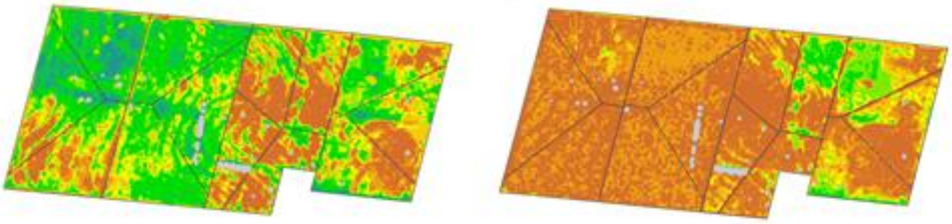
Figure 1. (a) Scatterplot of the predicted versus measured values of pasture canopy height (CH, m) obtained using the Random Forest (RF) model based on the testing dataset. A 1:1 line (black, dashed) is provided for reference. (b) Importance of the predictor variables as measured by the feature importance metric in the RF model.

The predicted values of pasture CH for the entire study area for different months of the forage growing season are shown in Figure 2. The spatiotemporal variations in pasture CH throughout the forage growing season agree with the field measurements of CH and the expected changes in pasture vegetation, mainly due to forage development (different proportions of millet and ruzi grass in the pasture vegetation) and grazing activities.

The unique combination of high temporal (daily) and high spatial (3 m) resolution imagery offered by the Planet's constellation of CubeSats is essential for pasture monitoring at a finer scale in intensively managed fields. The texture measures derived from PS imagery allow the incorporation of both spectral and spatial information in the CH prediction of pasture fields, resulting in enhanced estimation accuracy of CH models (DOS REIS et al., 2020). However, PS images obtained from different nano-satellites may present cross-sensor variations (HOUBORG; MCCABE, 2018), which affect the generalization of models produced based on the relationship between field-based CH measurements and variables derived from PS imagery. Despite possible limitations related to image calibration and data accessibility, PS imagery shows outstanding potential for estimating CH of pasture fields.

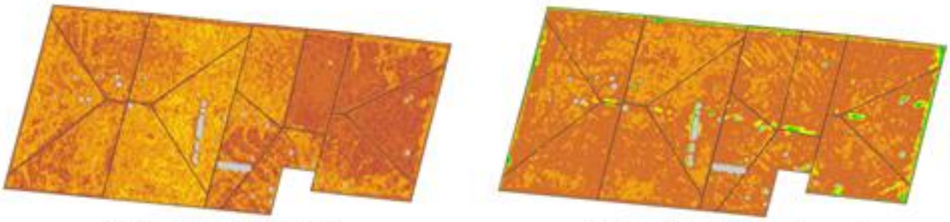


(a) PlanetScope image



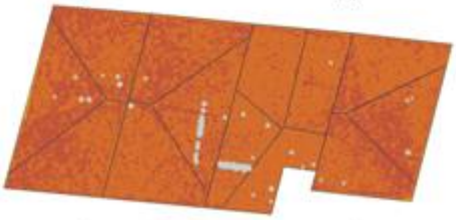
(b) Predicted CH - May

(c) Predicted CH - June



(d) Predicted CH - July

(e) Predicted CH - August



(f) Predicted CH - November

Figure 2. PlanetScope image (true color composite red-green-blue (RGB):321) of the study area on May 20th, 2019 (a), and the pasture canopy height (CH) spatial maps predicted by the RF model for the entire study area in May (a), June (b), July (c), August (d), and November (e).

CONCLUSIONS

We demonstrate in this study the potential of using textural information derived from PlanetScope (PS) imagery to estimate canopy height (CH) of intensively managed mixed pastures in an Integrated Crop–Livestock System (ICLS). Our best Random Forest (RF) model was able to predict the spatiotemporal changes in pasture CH with high accuracy ($R^2 = 0.88$) even with the high variability of the pasture CH through the forage growing season, mainly due to forage composition (different proportions of millet and ruzi grass) and grazing activities.

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UROCHLOA RUZIZIENSIS SEEDS GERMINATION SUBMITTED TO DIFFERENT FUNGICIDES AND DOSES

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ABSTRACT

Aimed to test the *Urochloa ruziziensis* seeds germination submitted to different fungicides and doses. The seeds used for the test had 72% of cultural value. The experiment was evaluated in a completely randomized design with treatments arranged in a double factorial scheme (3x4), with three fungicides (Carbendazim Nortox: a.i *Carbendazim*; Derosal Plus: a.i *Carbendazim* + *Tiram*; Vitavax Thiram: a.i *Carboxina* + *Tiram*), four doses (0%, 50%, 100% and 150% to the recommendation of the manufacturer of each product), with four repetitions. Each plot was considered a gerbox, totaling 12 treatments and 48 plots in each trial. The germination and tetrazolium tests were carried out and the seedling dry mass variables, shoot and root length, and abnormal seedlings were quantified. The variables first count and shoot length were not influenced by the dose, fungicide, in mean 29.75% and 25.73 cm, respectively. Analyzing the doses effect on the germination seeds, a reduction in germination was observed as the doses were increased, with greater means for seeds that were not submitted to chemical treatment. The fungicide *Carbendazim* provided a better response to the variables abnormal seedlings and root length, as well as, it provided a positive effect on the dry mass of seedlings as the dose increased.

Key words: abnormal seedlings; root length; seedling dry mass

INTRODUCTION

Urochloa grasses are widely used in Brazilian livestock and the beef produced in Brazil is predominantly based on pasture (D'OTTAVIO et al., 2018). Currently, pastures are strongly associated with intercropping with grains (MATEUS et al., 2007). Among the prominent species, *U. ruziziensis* is the most-used grass in the No-Tillage System and Integrated Production Systems (JAKELAITIS et al., 2004).

To guarantee a prominent position, quality standards of forage seeds, recommended by different laws and standards, must be met for commercialization, namely: purity, viability, and germination percentages (MAPA, 2008). However, sustainability in the production of these seeds is threatened by the high fungi incidence (VECHIATO et al., 2010).

The contamination of these seeds occurs mainly in the soil, where contaminating microorganisms are found, such as *Pythium* sp., *Rhizoctonia* and *Fusarium* sp. Other microorganisms frequently found in forage seeds are the fungi *Bipolaris* sp., *Phoma* sp. and *Curvularia* sp. Such pathogens are of fast mycelial growth and sporulation, facilitating the contamination of healthy seeds in transport, processing and storage (FAVORETO et al., 2011).

Thus, seed sanity represents an important factor for the establishment and maintenance of good quality tropical pastures (MARCHI et al., 2006). When contaminated, they are mechanisms for introducing and dispersing the pathogen into the soil and intercropping crops (TSUHAKO, 2009). Furthermore, pathogens affect the seeds physiological quality, negatively influencing germination, seedling development and longevity of forages in the field (FERNANDES et al., 2005; VECHIATO and APARECIDO, 2008).

In this sense, the use of fungicides in seed treatment provides the plant with defense conditions, allowing greater potential for the crop initial development (CASTRO et al., 2008). Therefore, the use of fungicides in the seeds provides satisfactory conditions for the expression of the maximum productive potential. Fungicides are used mainly to enable the expression of the germinative capacity of infected seeds, controlling pathogens transmitted by the seed and protecting them from soil fungi (MERTZ et al., 2009; RAMIRO et al., 2019).

However, for the pathogens control in forage grass seeds, one of the major obstacles refers to the lack of information in the literature on chemical control and its effect on the physiological quality of the seed. Therefore, studies should be carried out to guide the pathogen management program in forage grass seeds.

Thus, the aim was to test the *U. ruziziensis* seeds germination submitted todifferent fungicides and doses, under the physiological quality caused by the treatment of these seeds.

MATERIAL AND METHODS

The research was carried out at the Phytopathology Laboratory of the Faculty of Agronomy and Animal Science, Federal University of Mato Grosso, *Campus* Cuiabá. *U. ruziziensis* seeds with 72% cultural value were evaluated. A batch from the 2018/2019 harvest was used. The seeds were 88.2% pure and 81% germinated.

The experiment was evaluated in a completely randomized design with treatments arranged in a double factorial scheme (3x4), with three fungicides (Carbendazim Nortox: a.i *Carbendazim*; Derosal Plus: a.i *Carbendazim* + *Tiram*; Vitavax Thiram: a.i *Carboxina* + *Tiram*), four doses (0%, 50%, 100% and 150% to the recommendation of the manufacturer of each product), with four repetitions. Each plot was considered a gerbox, totaling 12 treatments and 48 plots in each trial.

Before starting the evaluations, the batch was completely homogenized to then determine the parameters of mass of one thousand seeds (g) and moisture content (%) at the time of their commercialization. Subsequently, the seeds were treated in a transparent plastic bag, to allow better homogenization, containing the amount equivalent to 50 g of pure seeds for each fungicide evaluated.

After the products application and respective doses, the seeds were submitted to germination (Brasil, 2009), first count, seedling dry mass, shoot and root length, abnormal seedlings (NAKAGAWA, 1999), and tetrazolium tests (VERA et al., 2018).

For the analysis of variance, the data were transformed by arcsine ($\sqrt{x}$ / 100). The data collected were subjected to analysis of variance and regression at 5% probability. All analyzes were performed using the RStudio statistical software, version 1.1.463.

RESULTS AND DISCUSSIONS

The variables first count and shoot length were not influenced by the dose, fungicide or by the interaction between dose x fungicide ($P>0.05$), in mean 29.75% and 25.73 cm, respectively.

The germination was influenced by the dose (Figure 1) and the abnormal seedlings and root length variables were affected by the fungicide (P <0.05). Analyzing the doses effect on the *U. ruziziensis* seeds germination, a reduction in germination was observed as the doses were increased, with greater means for seeds that were not submitted to chemical treatment (Figure 1).

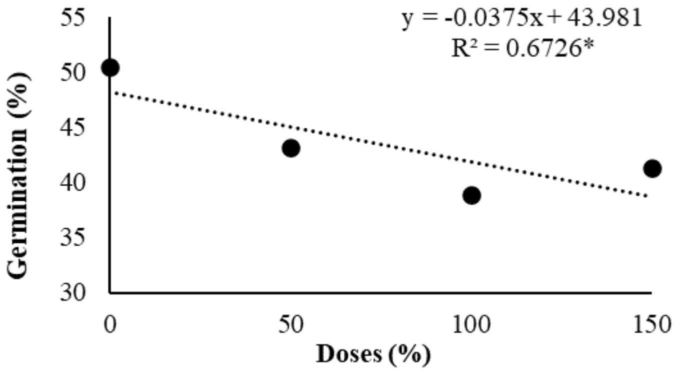

Figure 1. Doses effect on the *U. ruziziensis* seeds germination.

The fungicide *Carboxina* + *Tiram* provided the greatest value of abnormal seedlings (14.66%), and *Carbendazim* the least (7.66%). The fungicide *Carbendazim* + *Tiram* promoted intermediate values for abnormal seedlings (11.83%).

For the root length variable, the fungicide *Carbendazim* provided the greatest value (29.38 cm). The fungicides *Carbendazim* + *Tiram* and *Carboxina* + *Tiram* promoted the lowest root length value, in mean 23.35 cm.

The seedling dry mass was influenced by the interaction effect between dose x fungicide (Figure 2; P<0.05). The 0% dose provided 99.5 mg dry seedling mass. There was no difference in the variable seedling dry mass between the fungicides at the 150% dose (mean of 117.3 mg) and at the 100% dose (mean of 111.00 mg), whereas, at the dose of 50%, the greatest mass was obtained by using *Carbendazim* + *Tiram* (127.75 mg) and, the lowest, by *Carboxine* + *Tiram* (80.50 mg). At the 50% dose, the intermediate value for dry seedling mass was obtained by the fungicide *Carbendazim* (103.50 mg). Regarding the dose effect on the seedling dry mass, there was a positive linear effect as a function of the increase in the dose of *Carbendazim* (Figure 2). The increase in the doses of *Carbendazim* + *Tiram* and *Carboxina* + *Tiram* promoted a negative and positive quadratic effect, respectively.

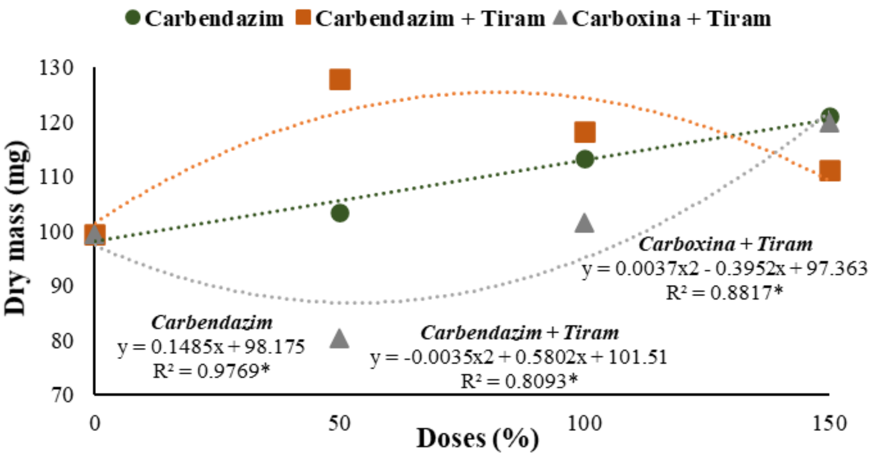

Figure 2. Unfolding of the significant interaction between doses and fungicides on the dry mass of seedlings of *U. ruziziensis* seeds.

CONCLUSIONS

The fungicide *Carbendazim* provided a better response to the variables abnormal seedlings and root length, as well as it provided a positive effect on the dry mass of seedlings as the dose increased.

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SANITARY QUALITY OF UROCHLOA RUZIZIENSIS SEEDS SUBMITTED TO CHEMICAL TREATMENT FOR USE IN INTEGRATED SYSTEMS

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ABSTRACT

The aim was to test fungicides and doses in the *Urochloa ruziziensis* seeds treatment of low cultural value caused by the sanity effect. The experiment was developed at the Phytopathology Laboratory of the Federal University of Mato Grosso, Cuiabá – Brazil. The design used was completely randomized, with the treatments arranged in a double factorial scheme (3x4), with three active ingredients (*Carbendazim*; *Carbendazim* + *Tiram*; *Carboxina* + *Tiram*) and four doses (0%; 50%; 100%; 150% in relation to the manufacturer recommendation of each product) with four repetitions. The data collected were subjected to analysis of variance and regression at 5% probability. Different fungal genera were found in the seeds of *U. ruziziensis*: *Rhizoctonia* sp., *Fusarium* sp., *Bipolaris* sp., *Mucor* sp., *Rhizopus* sp., *Aspergillus* sp., *Phoma* sp., *Curvularia* sp. and *Cladosporium* sp.. There was an interaction effect ($P<0.05$) between the fungicidal and dose factors on the *Rhizoctonia* sp., *Bipolaris* sp., *Rhizopus* sp., *Aspergillus* sp. and *Curvularia* sp. incidence. Isolated effect ($P<0.05$) of the dose factor was observed on the incidence of fungi *Fusarium* sp., *Cladosporium* sp. and *Phoma* sp.. The treatment with the fungicides *Carboxina* + *Tiram* or *Carbendazim* + *Tiram* proved to be efficient in the control of pathogens associated with seeds.

Key words: *Carbendazim* + *Tiram*; dose; incidence

INTRODUCTION

Urochloa grasses are prominent in the production process. The various species of this genus are internationally recognized for their contribution to the advancement of Brazilian livestock. Pasture, in addition to being the main source of bovine food, is also used in intercropping with grains (MATEUS et al., 2007). Among the prominent species, *Urochloa ruziziensis* is the most used grass in the No-Tillage System and in Integrated Production Systems (JAKELAITIS et al., 2004).

To guarantee a prominent position, quality standards for forage seeds, recommended by different laws and standards, must be met for commercialization (MAPA, 2008). However, sustainability in the production of these seeds is threatened by the high fungi incidence (VECHIATO et al., 2010).

The contamination of these seeds occurs mainly in the soil, where contaminating microorganisms are found, such as *Rhizoctonia* sp. and *Fusarium* sp. Other microorganisms frequently found in forage seeds are the fungi *Bipolaris* sp., *Phoma* sp. and *Curvularia* sp. Such pathogens are of rapid mycelial growth and sporulation, facilitating the contamination of healthy seeds in transport, processing and storage (FAVORETO et al., 2011).

Seed sanity represents an important factor for the establishment and maintenance of good quality tropical pastures (MARCHI et al., 2006). When contaminated, they are mechanisms for introducing and dispersing the pathogen into soil and intercropping crops (TSUHAKO, 2009), causing disease in soybean and maize crops.

In this sense, the use of pesticides in seed treatment provides the plant with defense conditions, enabling greater potential for the initial development of the crop (CASTRO et al., 2008). In addition, the seeds treatment with fungicides provides satisfactory conditions for them to reach their maximum productive potential, being used, mainly, with the purpose of allowing the expression of the germinative capacity of infected seeds, controlling pathogens transmitted by the seed and protecting them from the soil fungi (RAMIRO et al., 2019).

Thus, the aim was to test different fungicides and doses on *U. ruziziensis* seeds of low cultural value on the sanity effect caused by the treatment on these seeds.

MATERIAL AND METHODS

The work was developed at the Phytopathology Laboratory of the Faculty of Agronomy and Animal Science, Federal University of Mato Grosso, Cuiabá, Brazil. A batch of *U. ruziziensis* seed with 48% cultural value was purchased from a commercial forage seed company. The batch used came from seed production fields of the 2018 and 2019 crop, with 60.5% purity and 84% germination.

The design used was completely randomized in a double factorial scheme (3x4). The experiment consisted of 12 treatments, three fungicides (Carbendazim Nortox: a.i. *Carbendazim*; Derosal: a.i. *Carbendazim* + *Tiram*; Vitavax Thiram: a.i. *Carboxina* + *Tiram*), and four doses (0%; 50%; 100%; 150% of the manufacturer recommendation of each product) with four repetitions.

The seeds were separated into sub-samples of 50 grams of pure seeds, submitted to treatments in a transparent plastic bag and homogenized. After the products application and doses, sanitary quality analyzes of detection and identification of fungi associated with the seeds were carried out.

The modified Blotter test method with water restriction was used. 200 seeds were analyzed in duplicate, divided into four petri dishes (120x20mm). The seeds were placed on two sheets of sterile germitest paper and moistened with a water-based sodium chloride (NaCl) solution at -0.80 MPa, in order to inhibit their germination, making it easier when evaluating the test. Then, they were incubated for seven days in biological oxygen demand (B.O.D.) the temperature of 22 ºC and alternation of 12 light hours (BRASIL, 2009).

After the time, fungi were identified at the gender level with the help of the literature proposed by Barnett and Hunter (1972) and, when necessary, slides were made to identify the morphology and structure.

The data were discovered by analyzing the variation and regression at 5% probability. The analyzes were performed using the RStudio statistical software, version 1.1.463.

RESULTS AND DISCUSSIONS

Different genera and fungi incidences were found in the seeds of *U. ruziziensis*: *Rhizoctonia* sp. (27.57%), *Fusarium* sp. (19.38%), *Bipolaris* sp. (15.06%), *Mucor* sp. (14.43%), *Rhizopus* sp. (9.88%), *Aspergillus* sp. (8.26%), *Phoma* sp. (3.42%), *Curvularia* sp. (1.0%) and *Cladosporium* sp. (1.0%).

The genera *Rhizoctonia*, *Fusarium*, *Bipolaris*, *Phoma* and *Curvularia* have been identified as the main pathogens associated with commercial brachiaria seeds (GUIMARÃES et al., 2006). Once contaminated, the viability of the seed is drastically reduced, which can lead to the death of the seed before germination. The same fungi have also been observed in seeds of *Panicum maximum* (GOMES et al., 2008; MARCHI et al., 2010).

There was an interaction effect ($P<0.05$) between the fungicidal and dose factors on the *Rhizoctonia* sp., *Bipolaris* sp., *Rhizopus* sp., *Aspergillus* sp. and *Curvularia* sp. incidence (Table 1). Regardless of the dose applied, the treatment with a.i. *Carbendazim* promoted a lower control over the fungi *Rhizoctonia* sp., *Rhizopus* sp. and *Aspergillus* sp.

Table 1. Fungicides and doses effect on the incidence of pathogenic fungi present in *U. ruziziensis* seeds of low cultural value.

Fungicide	**Dose (%)**			
	0	**50**	**100**	**150**
	Rhizoctonia sp. (%)			
(a.i. *Carbendazim*)	55.97	51.72 a	58.81 a	38.26 a
(a.i. *Carbendazim+Tiram*)		16.64 b	26.50 b	14.20 b
(a.i. *Carboxina+Tiram*)		26.85 b	33.37 b	2.88 c
	Bipolaris sp. (%)			
(a.i. *Carbendazim*)	30.58	45.29 a	25.05 b	47.89 a
(a.i. *Carbendazim+Tiram*)		21.39 b	37.98 a	19.38 c
(a.i. *Carboxina+Tiram*)		0.00 c	7.95 c	30.23 b
	Rhizopus sp. (%)			
(a.i. *Carbendazim*)	20.05	30.05 a	29.82 a	39.07 a
(a.i. *Carbendazim+Tiram*)		17.55 b	6.43 b	11.55 b
(a.i. *Carboxina+Tiram*)		8.15 b	11.34 b	4.05 b
	Aspergillus sp. (%)			
(a.i. *Carbendazim*)	16.76	7.61 a	20.94 a	15.67 a
(a.i. *Carbendazim+Tiram*)		8.46 a	5.57 b	0.00 b
(a.i. *Carboxina+Tiram*)		12.00 a	13.23 ab	0.00 b
	Curvularia sp. (%)			
(a.i. *Carbendazim*)	2.03	4.06 b	3.54 a	22.96 a
(a.i. *Carbendazim+Tiram*)		18.21 a	4.91 a	2.88 b
(a.i. *Carboxina+Tiram*)		0.00 b	0.00 a	4.06 b

Means followed by the same letter in the column do not differ significantly by Tukey test at 5% probability. a.i.: active ingredient of the product.

The treatment with *Carboxina* + *Tiram*, within the dose of 150%, was the most efficient in the *Rhizoctonia* sp. control, expressing a strong reduction in the fungus incidence (2.88%). On the other hand, the *Rhizopus* sp. control was more efficient by the use of *Carbendazim* + *Tiram* and *Carboxina* + *Tiram* in the seeds treatment, regardless of the dose used.

When *Carboxina* + *Tiram* was used at a dose of 50% of the recommendation, eradication of *Bipolaris* sp. was verified. The same treatment, carried out at the manufacturer's recommended dose (100%), also promoted an efficient control compared to the other fungicides. This result corroborates the observations made by Giebelmeier et al. (2012), who showed better phytopathogens control in seeds treated with *Carboxina* + *Tiram*.

Although the seeds treated with *Carbendazim* + *Tiram* showed low control in the use of the 50% and 100% dose of the manufacturer, when the 150% dose was used, there was a control over the *Bipolaris* sp. incidence, indicating better efficiency of this a.i. in overdose.

The *Aspergillus* sp. incidence was not modified by the use of different fungicides within the 50% dose. However, applying the dose of 100%, the use of *Carbendazim* + *Tiram* is recommended and, when used high dose (150%), it is recommended both the treatment with *Carbendazim* + *Tiram*, and with *Carboxina* + *Tiram*, since both promoted the eradication of this fungus in the seeds.

The *Curvularia* sp. incidence was efficiently controlled when the treatment with *Carbendazim* + *Tiram* was used in the lowest dose (50%). Using the highest dose (150%), only the fungicide *Carbendazim* promoted low control in relation to the other fungicides. There was no difference between the fungicides for the standard dose.

There was an effect ($P<0.05$) of the doses within the different chemical treatments (Figure 1). On the *Rhizoctonia* sp. incidence (a), comparing with the seeds that were not treated (55.97%), the use of both fungicides, reduces the contamination of the seeds due to the increase of the doses.

Whereas the fungus *Rhizoctonia* sp. has the ability to become pathogenic in seedlings, treatments that eliminate this pathogen from seeds that are not essential for the production of healthy seeds (LAZAROTTO et al., 2013).

Chemical treatment with increasing doses of *Carboxin*a + *Tiram* promoted a cubic effect on the *Bipolaris* sp. (b) incidence, with greater control in the use of the 73.5% dose, found by the minimum point of the function. The increase in *Carbendazim* doses, on the other hand, promotes an increasing linear effect on the pathogen incidence.

The dose increase, when using the fungicides *Carbendazim* + *Tiram* and *Carboxina* + *Tiram*, promoted a negative linear effect on the *Rhizopus* sp. (c) and *Aspergillus* sp. (d) incidence. The 150% dose conditioned the eradication of *Aspergillus* sp. in the seed treated with *Carbendazim* + *Tiram*.

Regarding the *Curvularia* sp. control, the treatment with *Carbendazim* at an approximate dose of 50% (minimum point of 40.08%) showed greater efficiency, with a tendency to increase the incidence according to the use of larger doses. In contrast, the highest dose of *Carbendazim* + *Tiram* was responsible for the reduction in the pathogen incidence.

It was observed an effect ($P<0.05$) isolated from the dose factor on the *Fusarium* sp., *Phoma* sp. and *Cladosporium* sp. incidence. As a higher dose of fungicide is used, there is a negative linear effect of reduction on the *Phoma* sp. ($y= -0.0417x + 4.865^{*}$ $R^2=0.60$) and *Cladosporium* sp. ($y= -0.0122x + 1.421^{*}$ $R^2=0.60$) incidence, and negative quadratic effect for *Fusarium* sp. ($y = 0.0017x^2 - 0.4484x + 37.865^{*}$ $R^2=0.92$) incidence. The 150% dose promoted 100% control over the *Phoma* sp. and *Cladosporium* sp. incidence.

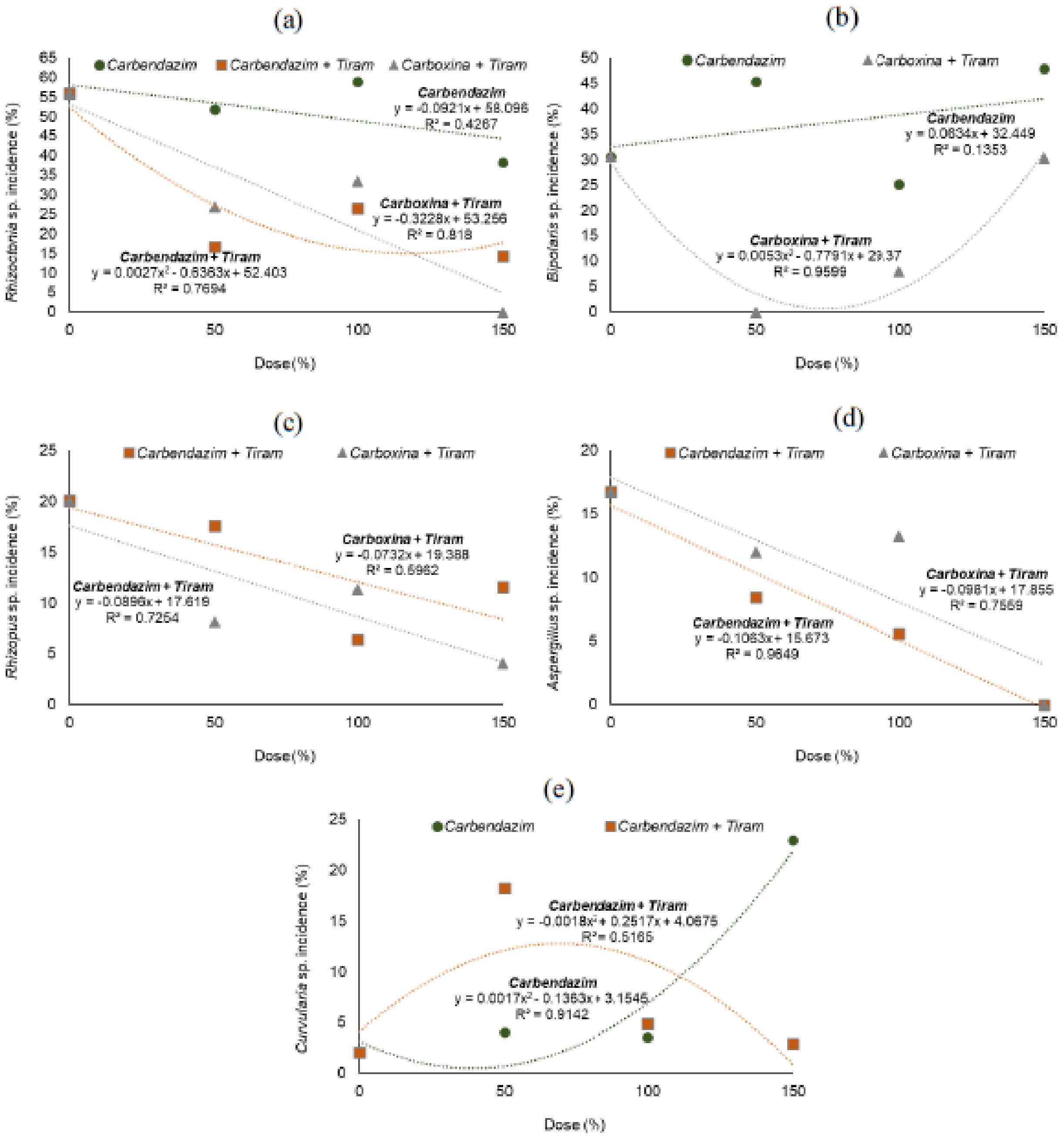

Figure 1. Split of the significant interaction between doses and fungicides on the *Rhizoctonia* sp. (a), *Bipolaris* sp. (b), *Rhizopus* sp. (c), *Aspergillus* sp. (d) and *Curvularia* sp. (e) incidence present in seeds of *U. ruziziensis.*

CONCLUSIONS

Commercial seeds of *U. ruziziensis* of low cultural value have different pathogenic fungi associated with the tegument.

Treatments with *Carboxin* + *Tiram* or *Carbendazim* + *Tiram* are efficient in controlling pathogens associated with seeds.

The overdose of fungicides promotes greater control over the *Fusarium* sp., *Cladosporium* sp. and *Phoma* sp. incidence.

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PHYSIOLOGICAL QUALITY OF UROCHLOA RUZIZIENSIS SEEDS SUBMITTED TO ACCELERATED AGING, TREATED WITH DIFFERENT FUNGICIDES AND DOSES

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ABSTRACT

Aimed to evaluate the physiological quality of *Urochloa ruziziensis* seeds submitted to different fungicides and doses, in terms of accelerated aging test. The seeds used for the test had 72% of cultural value. The experiment was evaluated in a completely randomized design with treatments arranged in a double factorial scheme (3x4), with three fungicides (Carbendazim Nortox: a.i *Carbendazim*; Derosal Plus: a.i *Carbendazim* + *Tiram*; Vitavax Thiram: a.i *Carboxina* + *Tiram*), four doses (0%, 50%, 100% and 150% to the recommendation of the manufacturer of each product), with four repetitions. Each plot was considered a gerbox, totaling 12 treatments and 48 plots in each trial. After the products application and respective doses, the seeds were submitted to the accelerated aging test and then to the germination, seedling dry mass, shoot and root length, and tetrazolium tests. The treatment with the fungicide *Carboxina* + *Tiram* promoted a greater percentage of abnormal seedlings (17.5%). The least rate was presented by the seeds treated with *Carbendazim* (8.66%) and the intermediate rate was presented by the fungicide *Carbendazim* + *Tiram* (13.66%). The use of the fungicide *Carbendazim* at a dose of 50% promoted the best physiological responses for the seeds of *U. ruziziensis* to other fungicides and doses.

Key words: abnormal seedling; grass; root length

INTRODUCTION

The *Urochloa* genus is part of the grasses that are extensively used in Brazilian livestock. Pasture, in addition to being the main source of bovine food, is also used in intercropping with grains (MATEUS et al., 2007). Among the prominent species, *U. ruziziensis* is the most-used grass in the No-Tillage System and Integrated Production Systems (JAKELAITIS et al., 2004).

Livestock systems strongly supported by pastures, need to pay attention to the seed quality recommendations, which are governed by laws and standards that quantify the percentages of purity, viability, and germination (MAPA, 2008). Thus, sustainability in the production of these seeds is threatened by the high fungi incidence (VECHIATO et al., 2010).

The contamination of these seeds occurs mainly in the soil, where contaminating microorganisms are found, such as *Pythium* sp., *Rhizoctonia* and *Fusarium* sp. Other microorganisms frequently found in forage seeds are the fungi *Bipolaris* sp., *Phoma* sp. and *Curvularia* sp. Such pathogens are of rapid mycelial growth and sporulation, facilitating the contamination of healthy seeds in transport, processing and storage (FAVORETO et al., 2011).

Thus, seed health represents an important factor for the establishment and maintenance of good quality tropical pastures (MARCHI et al., 2006). When contaminated, they are mechanisms for introducing and dispersing the pathogen into the soil and intercropping crops (TSUHAKO, 2009). Besides that, pathogens affect the physiological quality of the seeds, negatively influencing germination, seedling development, and longevity of forages in the field (FERNANDES et al., 2005; VECHIATO; APARECIDO, 2008).

In this sense, the use of fungicides in seed treatment provides the plant with defense conditions, allowing greater potential for the initial development of the crop (CASTRO et al., 2008). Therefore, the use of fungicides in the seeds provides satisfactory conditions for the expression of the maximum productive potential. Fungicides are used mainly to enable the expression of the germinative capacity of infected seeds, controlling pathogens transmitted by the seed, and protecting them from soil fungi (MERTZ et al., 2009; RAMIRO et al., 2019).

However, for the pathogens control in forage grass seeds, one of the major obstacles refers to the lack of information in the literature on chemical control and its effect on the physiological quality of the seed. Therefore, studies should be carried out to guide the pathogen management program in forage grass seeds.

Thus, the aim was to evaluate the physiological quality of *U. ruziziensis* seeds submitted to different fungicides and doses, in terms of accelerated aging test.

MATERIAL AND METHODS

The research was carried out at the Phytopathology Laboratory of the Faculty of Agronomy and Animal Science, Federal University of Mato Grosso, *Campus* Cuiabá. *U. ruziziensis* seeds with 72% cultural value were evaluated. A batch from the 2018/2019 harvest was used. The seeds were 88.2% pure and 81% germinated.

The experiment was evaluated in a completely randomized design with treatments arranged in a double factorial scheme (3x4), with three fungicides (Carbendazim Nortox: a.i *Carbendazim*; Derosal Plus: a.i *Carbendazim* + *Tiram*; Vitavax Thiram: a.i *Carboxina* + *Tiram*), four doses (0%, 50%, 100% and 150% to the recommendation of the manufacturer of each product), with four repetitions. Each plot was considered a gerbox, totaling 12 treatments and 48 experimental units in each trial.

Before starting the evaluations, the batch was completely homogenized to then determine the parameters of mass of one thousand seeds (g) and moisture content (%) at the time of their commercialization. Subsequently, the seeds were treated in a transparent plastic bag, to allow better homogenization, containing the amount equivalent to 50 g of pure seeds for each fungicide evaluated.

After the products application and respective doses, the seeds were submitted to the accelerated aging test (BRASIL, 2009) and then to the germination (BRASIL, 2009), seedling dry mass, shoot and root length (NAKAGAWA, 1999), and tetrazolium tests (VERA et al., 2018).

For the analysis of variance, the data were transformed by arcsine ($\sqrt{x} / 100$). The data collected were subjected to analysis of variance and regression at 5% probability. All analyzes were performed using the RStudio statistical software, version 1.1.463.

RESULTS AND DISCUSSIONS

The variables first count, shoot length and root length ($P<0.05$) were influenced by the interaction between dose x fungicide (Table 1 and Figure 1).

There was no effect among fungicides within the 100% dose for the variables first count and shoot length (Table 1). At the 50% dose, the best performance in both variables occurred with the use of the ingredient *Carbendazim*, while at the dose of 150% this effect was verified with the use of *Carbendazim* and *Carbendazim + Tiram*.

In the root length, the fungicides showed the same effect in the use of the lowestdose (50%) and, in larger doses, there was an increase in the root increment through the use of the fungicide *Carbendazim + Tiram.*

Observing the doses within each fungicide, it was found that the seeds vigor is negatively influenced as the doses of the fungicides *Carbendazim* and *Carboxina + Tiram* are increased (Figure 1).

The dose, using the *Carbendazim + Tiram* treatment, had a quadratic effect on the first count, with a reduction in the percentage values between 50% and 100%.

There was no significant effect (P>0.05) for doses on the shoot length of seedlings treated with *Carbendazim* and *Carbendazim + Tiram*. However, a reduction in the length of shoot length was observed with the increase of doses in the use of *Carboxine + Tiram*.

In the root length of the seedlings, there was a dose effect only for the fungicides *Carbendazim* and *Carboxina + Tiram,* with a reduction in root length due to the increase in doses.

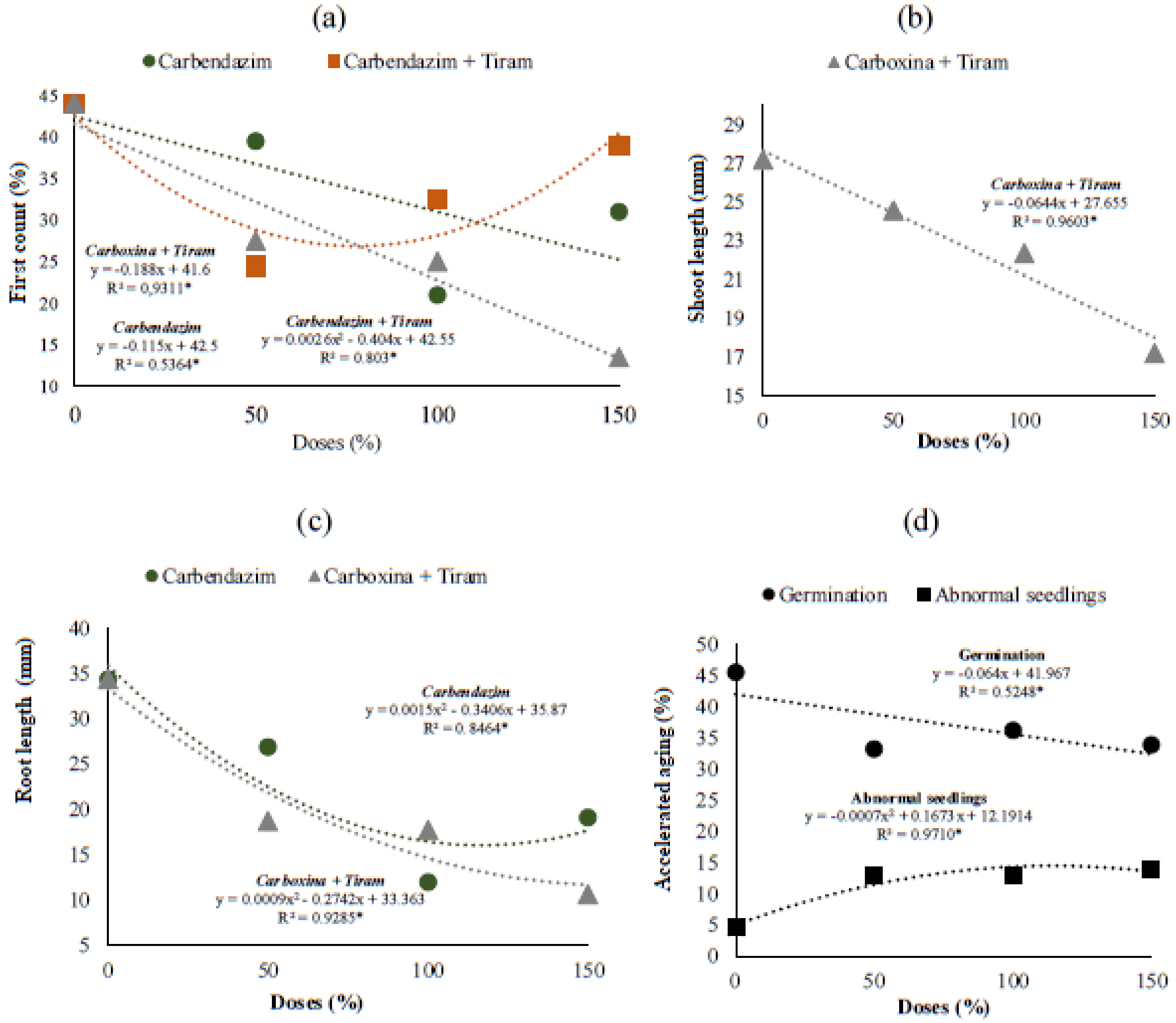

Figure 1. Doses and fungicides effect on the first count (a), shoot (b), root length (c) and doses effect on the germination and abnormal seedlings (d) of *U. ruziziensis* seeds.

The germination variable was influenced (Figure 1) by the dose and the abnormal seedling variable was affected by the fungicide and the dose ($P<0.05$).

Chemical treatment and increased doses, after accelerated aging, impaired the seeds physiological quality, reducing the germination percentage. Furthermore, the abnormal germination percentage was greater in seeds submitted to chemical treatment (Figure 1).

The treatment with the fungicide *Carboxina* + *Tiram* promoted a greater abnormal seedlings percentage (17.5%). The lowest rate was presented by the seeds treated with *Carbendazim* (8.66%) and the intermediate rate was presented by the fungicide *Carbendazim* + *Tiram* (13.66%).

Table 1. First count, shoot, and root length of *U. ruziziensis* seeds submitted to seed treatment with different fungicides and doses after the accelerated aging test.

Fungicide	**Dose (%)**			
	0	**50**	**100**	**150**
	First count (%)			
Carbendazim	44.00	39.50 a	21.00 a	31.00 a
Carbendazim+Tiram		24.50 b	32.50 a	39.00 a
Carboxina+Tiram		27.50 ab	25.00 a	13.50 b
	Shoot length (mm)			
Carbendazim	27.20	33.65 a	25.55 a	30.55 a
Carbendazim+Tiram		22.80 b	26.25 a	26.80 a
Carboxina+Tiram		24.55 b	22.35 a	17.20 b
	Root length (mm)			
Carbendazim	34.40	26.90 a	12.00 b	19.10 ab
Carbendazim+Tiram		21.65 a	29.75 a	28.60 a
Carboxina+Tiram		18.70 a	17.70 b	10.65 b

Means followed by the same letter in the column do not differ significantly by Tukey test at 5% probability. a.i: active ingredient.

CONCLUSIONS

The use of the fungicide *Carbendazim* at a dose of 50% promoted the best physiological responses for the *U. ruziziensis* seeds to other fungicides and doses.

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ACCELERATED AGING TEST IN UROCHLOA RUZIZIENSIS SEEDS SUBMITTED TO CHEMICAL TREATMENT FOR USE IN INTEGRATED SYSTEMS

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ABSTRACT

The aim was to test fungicides and doses in the *Urochloa ruziziensis* seeds treatment of low cultural value on the physiological effect caused after the use of the accelerated aging test. The experiment was developed at the Phytopathology Laboratory of the Federal University of Mato Grosso, Cuiabá, Brazil. The design used was completely randomized, with the treatments arranged in a double factorial scheme (3x4), with three active ingredients (*Carbendazim*; *Carbendazim* + *Tiram*; and *Carboxina* + *Tiram*) and four doses (0%; 50%; 100%; and 150% in relation to the manufacturer recommendation of each product) with four repetitions. The data collected were subjected to analysis of variance and regression at 5% probability. The treatment with *Carbendazim* + *Tiram* and *Carboxina* + *Tiram*, in the three doses evaluated, promoted greater germination to that obtained by the exclusive use of the active ingredient *Carbendazim*. *Carbendazim* promoted a higher abnormal seedlings percentage. The increase in doses, after accelerated aging, affected the *U. ruziziensis* seeds vigor, with a reduction in the first count.

Key words: abnormal seedlings; *Carbendazim*; physiological potential

INTRODUCTION

Urochloa grasses are prominent in the production process. The various species of this genus are internationally recognized for their contribution to the advancement of Brazilian livestock. Pasture, in addition to being the main source of bovine food, is also used in intercropping with grains (MATEUS et al., 2007). Among the prominent species, *Urochloa ruziziensis* is the most used grass in the No-Tillage System and in Integrated Production Systems (JAKELAITIS et al., 2004).

To ensure a prominent position, quality standards for forage seeds, recommended by different laws and standards, must be met for commercialization, such as purity and germination (MAPA, 2008). However, sustainability in the production of these seeds is threatened by the high fungi incidence (VECHIATO et al., 2010).

Thus, the use of pesticides in seed treatment provides the plant with defense conditions, allowing greater potential for the initial development of the crop (CASTRO et al., 2008). In addition, the seeds treatment with fungicides provides satisfactory conditions for them to reach their maximum productive potential, being used, mainly, with the purpose of allowing the expression of the germinative capacity of infected seeds, controlling pathogens transmitted by the seed and protecting them from the soil fungi (RAMIRO et al., 2019).

The seed physiological quality is routinely assessed by the standard germination test, which conducted under optimal environmental conditions provides the maximum germination potential by establishing the limit for the performance of the herd after sowing. However, due to its limitations, mainly regarding the lower sensitivity for the differentiation of quality and the frequent discrepancy in the results, the results obtained in the vigor tests are also necessary.

Among the various vigor tests, the accelerated aging test is one of the most used to assess the physiological potential (TEKRONY, 1995). This test has as principle the considerable increase in the seeds deterioration rate due to their exposure to high levels of temperature and relative humidity of the air, considered the main factors in the intensity and deterioration speed (OHLSON et al., 2010).

However, for the pathogens control in forage grass seeds, one of the major obstacles refers to the information scarcity in the literature on chemical control and its effect on physiological quality, especially after the accelerated aging test. Thereby, studies should be carried out aiming at guiding the management program in forage grass seeds.

Thus, the aim was to test different fungicides and doses in *Urochloa ruziziensis* seeds of low cultural value on the physiological effect after accelerated aging test.

MATERIAL AND METHODS

The work was developed at the Phytopathology Laboratory of the Faculty of Agronomy and Animal Science, Federal University of Mato Grosso, Cuiabá, Brazil. A batch of *U. ruziziensis* seed with 48% cultural value was purchased from a commercial forage seed company. The batch used came from seed production fields of the 2018 and 2019 crop, with 60.5% purity and 84% germination.

The design used was completely randomized in a double factorial scheme (3x4). The experiment consisted of 12 treatments, three fungicides (Carbendazim Nortox: a.i. *Carbendazim*; Derosal: a.i. *Carbendazim* + *Tiram*; Vitavax Thiram: a.i. *Carboxina* + *Tiram*), and four doses (0%; 50%; 100%; 150% of the manufacturer recommendation of each product) with four repetitions.

The seeds were initially submitted to the accelerated aging test in a Gerbox box with mesh. 40 mL of distilled water was added and the seeds were packed evenly under the screen, in a single layer of the seeds. Then the box remained in biological oxygen demand (B.O.D.) for 5 days at 41 ºC, with total light absence. Subsequently, the seeds were separated into sub-samples of 50 grams of pure seeds, submitted to treatments in a transparent plastic bag and homogenized.

The germination test was carried out with four repetitions of 50 seeds, sown on two sheets of germitest paper moistened with distilled water, in an amount equivalent to 2.5 times the mass of the dry paper, inside Gerbox boxes (11 x 11 x 3.5 cm). The boxes were kept in B.O.D. at 22 ºC and 12 light hours photoperiod. The test lasted seven days for the first count and 21 days for the final germination (BRASIL, 2009). The results were expressed as germination and abnormal seedlings percentage.

The seedling length was obtained from the seedlings of the first count (7 days), five of each repetition, removed at random, obtaining aerial and root length (mm) (NAKAGAWA, 1999). The seedling dry mass was verified from the seedlings used in the length evaluation. The material was placed in paper bags and taken to a regulated oven at 55 ºC, until a constant mass was obtained.

The data were subjected to analysis of variance and regression at 5% probability. The analyzes were performed using the RStudio statistical software, version 1.1.463.

RESULTS AND DISCUSSIONS

There was an interaction effect ($P<0.05$) between the fungicidal and dose factors on the germination (%) and abnormal seedlings (%), and isolated effect of both factors on first count (%) and aerial part length (mm). The root length (mm) variable there was an effect only from the fungicide factor.

The treatment with *Carbendazim* + *Tiram* and *Carboxina* + *Tiram*, in the three doses evaluated, promoted germination higher than the mean obtained by the exclusive use of the active ingredient *Carbendazim* (Table 1). In addition to less germination, the treatment with *Carbendazim* promoted a higher abnormal seedlings percentage in relation to the other fungicides, a condition that suggests attention to the possible recommendations or use of this active ingredient in crops intercropped with forage.

Table 1. *U. ruziziensis* seeds germination and abnormal seedlings submitted to seed treatment with different fungicides and doses after the accelerated aging test.

Fungicide	**Dose (%)**			
	0	**50**	**100**	**150**
		Germination (%)		
(a.i. *Carbendazim*)	44.00	3.00 b	11.50 b	15.00 b
(a.i. *Carbendazim* + *Tiram*)		39.00 a	30.50 a	34.00 a
(a.i. *Carboxina* + *Tiram*)		29.50 a	28.50 a	27.50 ab
		Abnormal seedlings (%)		
(a.i. *Carbendazim*)	5.50	35.00 a	25.00 a	22.50 a
(a.i. *Carbendazim* + *Tiram*)		7.50 b	6.50 b	6.50 b
(a.i. *Carboxina* + *Tiram*)		10.00 b	4.00 b	6.00 b
Variable		Fungicide		
		Carbendazim	*Carbendazim* + *Tiram*	*Carboxina* + *Tiram*
First count (%)		7.50 B	20.16 A	13.16 A
Aerial part length (mm)		28.92 A	21.92 B	21.30 B
Root part length (mm)		16.30 B	24.22 A	22.67 A

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ significantly by Tukey test at 5% probability. a.i.: active ingredient.

The abnormal seedlings appearance by the use of *Carbendazim* does not corroborate with observations by Brites et al. (2011). Evaluating different tropical forage species, the authors observed higher abnormal seedlings percentage values attributed to the seeds that have not undergone any chemical treatment, especially with regard to the *Urochloa* genus.

There was a negative and positive quadratic effect ($P<0.05$) within the fungicide *Carbendazim* on the *U. ruziziensis* germination (a) and abnormal seedlings (b) (Figure 1), respectively. The same behavior was not observed by the use of *Carbendazim* + *Tiram* and *Carboxina* + *Tiram*.

The lowest germination was verified using the 84.73% dose of the recommendation. Conversely proportional, the highest abnormal seedlings percentage was obtained by dose 94.43% of the recommendation.

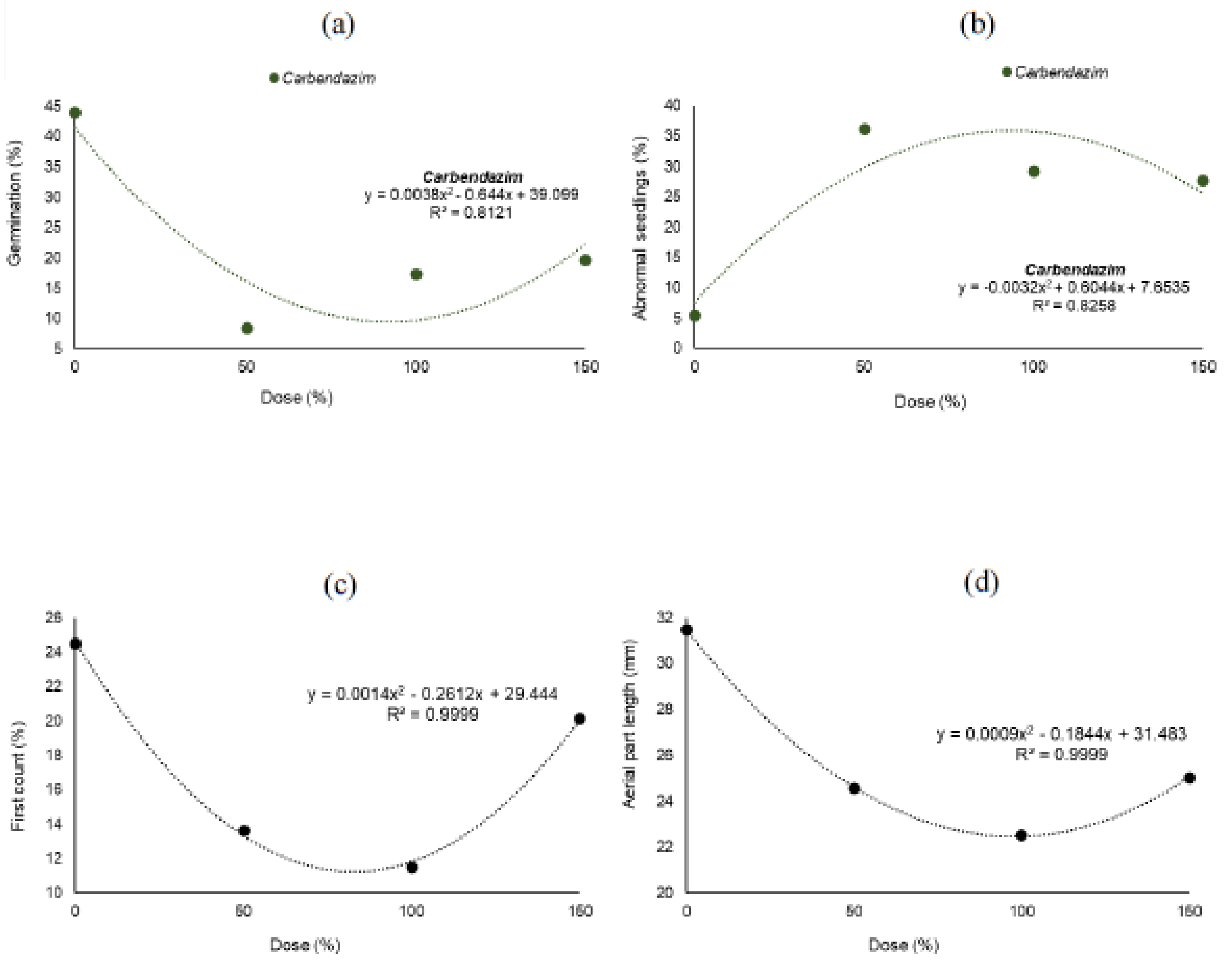

Figure 1 Split of the dose effect within fungicide on the germination (a) and abnormal seedlings (b) percentage; and dose effect on the first count (c) and aerial part length (d) of *U. ruziziensis* seeds of low cultural value submitted to the accelerated aging test.

The fungicides *Carbendazim* + *Tiram* and *Carboxina* + *Tiram* promoted a higher seed germination percentage and root length of seedling (Table 1). At the same time, these fungicides were responsible for the shortest air length. The same behavior was reported by Faria et al. (2003) working with cotton seeds.

The increase in doses, after accelerated aging, affected the *U. ruziziensis* seeds vigor, promoting a reduction in the first count (c), presenting an absolute minimum point in 93.28% of the dose (Figure 1). The high seeds moisture content when removed from the aging chamber, tends to make them more subject to injuries and deterioration by chemical treatment (BINOTTI et al., 2008), a condition that may have influenced the seeds germination.

The same trend was observed for the aerial part length (d), so that the increase in doses promoted a reduction in length in relation to the mean obtained by seeds that did not receive treatment.

CONCLUSIONS

The *U. ruziziensis* seeds treatment with *Carbendazim* + *Tiram* and *Carboxina* + *Tiram* allows better germination percentages.

Treatment with *Carbendazim* makes it possible to have plants with little root development and a higher abnormal seedlings percentage.

The recommended dose of *Carbendazim* promotes a reduction in the germination percentage and an increase in the abnormal *U. ruziziensis* seedlings appearance after an accelerated aging test.

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SOYBEAN HEIGHT AND YIELD IN AND INTEGRATED SYSTEM WITH EUCALYPTUS

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ABSTRACT

The integration is a sustainable production strategy that unites agricultural, livestock and forestry activities, thus the aim was to evaluate the effects of different integration systems on soybean height and yield. The experiment was conducted at the Brazilian Agricultural Research Corporation (Embrapa), Beef Cattle in Campo Grande – MS, Brazil. Randomized block design was adopted with four repetitions. The treatments were agro-forestry-pasture (ICL); agro-forestry-pasture system with inter-row distance of 28 m ($ICLF_{28}$); agro-forestry-pasture system with inter-row distance of 22 m ($ICLF_{22}$). The results obtained were submitted to analysis of variance, and when significant, the Tukey test was applied at 5% probability. There was a significant effect for plant height in different days after emergence. The ICL presented the lowest plant height, showing that the tree component harmed the $ICLP_{28}$ and $ICLF_{22}$ systems. The ICLP showed the highest grain yield, but in the $ICLP_{28}$ and $ICLP_{22}$ systems sampling sites B, C, and D showed the highest yield. The sampling sites away from the rows in the $ICLF_{28}$ and $ICLF_{22}$ systems improved the grain yield and the ICL system, although it had the lowest plant height, had the highest yield.

Key words: *Glycine max*; *Eucaliptus*; shading

INTRODUCTION

Brazil has presented a new concept in production units of goods and services based on the crop integration that aim to improve the production system. Currently, the search is to establish a sustainable agriculture, based on the maintenance of the yield, reduction of production costs and environment preservation (CARVALHO, 2006).

The integration Crop-Livestock-Forest (ICLF) use is a sustainable production strategy that integrates agricultural, livestock and forestry activities carried out in the same area. Thus, it encompasses diversified productive systems for the production of food, fiber, energy, timber and non-timber products, besides bringing benefits to the soil, potentiating the use of the area without harming natural resources (BALBINO et al., 2011; ALVARENGA et al., 2010).

Soybean is the most cultivated agricultural crop in the Brazil, for having great economic importance, high productive potential, nitrogen fixing capacity, reducing the need for mineral nitrogen input in the system (SALTON et al., 2013).

In ICLF systems, as the trees grow, there is a reduction in the light incidence under the understory, causing shading and influencing the production of the system as a whole. However, the trees shade can favor the crops present in the understory, providing a harmonious relationship between the cultivated species, reducing the environment temperature and thermal stress (OLIVEIRA NETO, 2010; PORTIRIO-DA-SILVA, 2012).

Thus, the aim was to evaluate the effects of different integration systems on soybean height and yield.

MATERIAL AND METHODS

The experiment was developed at the Brazilian Agricultural Research Corporation (Embrapa), Beef Cattle Unit, located in Campo Grande – MS, Brazil (latitude 20º 27' S; longitude 54º 37' W; 530 m altitude).

The climate is in the transition zone between Cfa (humid mesothermal without drought) and Aw (humid tropical), with an average annual precipitation of 1,560 mm with a rainfall regime defined in the hottest period of the year and drought in the coldest months. The average temperature in the period was 25 °C, with maximum and minimum temperatures of 31.3 °C and 20.8 °C, respectively.

The experiment area has been used with a succession cycle since 2008, using pasture in the winter period since the beginning and occurring crop variation in summer, where in 2008 soybeans and sorghum were grown, and in the following year eucalyptus was introduced in the area. In the years 2012 and 2018 soybeans were grown in the area and in the years 2010, 2011, 2013, 2014, 2015, 2017 and 2019 the pasture was the crop used in the summer, in addition in the years 2016 and 2017 a pruning and thinning was performed, respectively of eucalyptus.

A randomized block design was used in a banded experimental scheme with four repetitions. The main treatments were arranged in subdivided plots, being agroforestry (ICL) with full sun cultivation; agroforestry-pasture system with 28 m distance between eucalyptus rows ($ICLF_{28}$); agroforestry-pasture system with 22 m distance between eucalyptus rows ($ICLF_{22}$). The subplots were composed of the sampling sites, five sites equidistant between rows of eucalyptus trees (ICLF). These sites were demarcated on a transect perpendicular to the tree rows (east-west direction).

The sampling sites (north-south direction) were identified by the letters A; B; C; D and E, with the following distances from the nearest tree row: for $ICLF_{28}$, 7 m (A), 10 m (B), 11 m (C), 9 m (D) and 4 m (E). In the $ICLF_{22}$ system the sampling sites were 3 m (A), 7 m (B), 10 m (C), 7 m (D) and 3 m (E). In both systems 1 m distance between the rows of eucalyptus and soybean was respected.

The soil of the experimental area was classified as Red Dystrophic Latosol of clayey texture. Soil was collected from 0 to 20 cm depth for chemical analysis. In the area of full sun (ICL) the analysis revealed the following values: pH ($CaCl_2$) = 5.36; P (Melich) = 4.91 mg dm^{-3}; K (Melich) = 8.52 mg dm^{-3}; Ca = 2.33 $cmol_c$ dm^{-3}; Mg = 1.49 $cmol_c$ dm^{-3}; Al = 0.01 $cmol_c$ dm^{-3}; S = 4.05 $cmol_c$ dm^{-3}; V = 46.46%. In the understory ($ICLF_{22}$ and $ICLF_{28}$) the following values were found: pH ($CaCl_2$) = 5.08; P (Melich) = 11.03 mg dm^{-3}; K (Melich) = 148.68 mg dm^{-3}; Ca = 2.05 $cmol_c$ dm^{-3}; Mg = 1.19 $cmol_c$ dm^{-3}; Al = 0.07 $cmol_c$ dm^{-3}; S = 3.72 $cmol_c$ dm^{-3}; V = 41.69%.

Soybean crop management in the experimental area was initiated by desiccation of the total area with the use of non-selective herbicides of systemic and contact action known as glyphosate (Roundup®) and paraquat (Gramoxone®) in amounts of 1,225 g and 440 g of a.i. per hectare respectively.

Sowing was performed on straw mulch in November 2017 with the soybean cultivar TEC7849 iPRO from Bayer. The cultivar's cycle is characterized as late, 7.8 maturity group, medium/high plant stature of indeterminate growth. The seeding rate used was 14.7 seeds per linear meter. Seeds were treated with biological peat inoculant Adhere® 60 - 1.5 g m^{-1} (5x109 CFU g^{-1}), liquid inoculant Masterfix® - 4.5 mL kg^{-1} seed (1.4 million bacteria per seed) and insecticide Standak Top® at a concentration of 2 mL kg^{-1} seed.

Fertilization was performed in two applications, the first of 100 kg ha^{-1} in the field at the end of October and the second of 150 kg ha^{-1} in the sowing furrow, according to soil analysis. During the development of the crop applications of insecticides to control pests and fungicides to control diseases were made.

The main crop stages were observed according to the phenological scale proposed by Ferh and Caviness (1977) at 10; 19; 25; 33; 42 and 52 days after emergence (DAE) until the crop reached the reproductive stage (R1). During field collection, plant height was measured, taking the distance from the base of the plant to the end of the main stem, considering four plants per sampling site in the monitored treatments.

At the moment the soybean crop reached physiological maturity (R8), the plants present in a useful area of two 2.0 m rows at a spacing of 0.50 m were harvested by hand. The harvested plants were grouped into bundles, labeled and manually threshed. Grain yield (kg ha^{-1} was obtained from weighing the properly cleaned grains. The values obtained were corrected to 13% moisture.

The results obtained were submitted to variance analysis using SISVAR 5.7 software and when the F test was significant the Tukey test was applied, adopting a probability level of 5%.

RESULTS AND DISCUSSIONS

There was a significant effect for for soybean plant height in the evaluated systems in different days after emergence (Table 1). The ICL system differed from the others, presenting the lowest plant heights, when compared to ICLF$_{28}$ and ICLF$_{22}$, showing that the tree component affected plant growth.

Table 1. Mean of soybean plant height (cm) on different days after emergence in the integrated systems.

System	Days after Emergence (DAE)					
	10	19	25	33	42	52
ICL	6.31 b	10.48 b	16.00 b	24.89 b	38.97 b	64.54 b
ICLF$_{28}$	7.86 a	13.01 a	18.31 a	27.66 a	39.24 b	75.54 a
ICLF$_{22}$	8.35 a	13.30 a	18.63 a	27.87 a	58.72 a	76.53 a
[1]CV (%)	4.34	2.53	3.61	3.70	4.98	3.82

ICL: Integration Crop-Livestock; ICLF$_{28}$: Integration Crop-Livestock-Forest with 28 m distance between eucalyptus rows; ICLF$_{22}$: Integration Crop-Livestock-Forest with 22 m distance between eucalyptus rows. [1]CV: coefficient of variation. Means followed by the same lowercase letter in the column do not differ by the Tukey test (P>0.05).

In shaded environments the growth efficiency is very important, so the legumes in low light intensity conditions have a strategy to increase their height in search of greater light uptake (SCALON et al., 2002). Soybeans, when shaded, tend to raise their height, which occurs due to the stretching performed by the plant seeking to increase light absorption (CARVALHO, 2015).

Table 2. Soybean yield at the sampling location of the integrated systems under study.

System	Sampling Location				
	A	B	C	D	E
ICL	4,069.2 Aa	3,679.2 Aa	3,795.0 Aa	4,180.2 Aa	4,006.2 Aa
$ICLF_{28}$	1,957.2 Bc	3,561.0 Aa	3,069.0 Bab	3,379.2 Ba	2,524.2 Bbc
$ICLF_{22}$	1,777.2 Bb	2,578.2 Ba	2,929.2 Ba	2,607.0 Ca	2,176.2 Bab

ICL: Integration Crop-Livestock; $ICLF_{28}$: Integration Crop-Livestock-Forest with 28 m distance between eucalyptus rows; $ICLF_{22}$: Integration Crop-Livestock-Forest with 22 m distance between eucalyptus rows. Means followed by the same lowercase letter in the row and uppercase in the column do not differ by the Tukey test (P>0.05). CVa: 16.30% CVb: 12,46%.

ICL showed the highest grain yield, however in the $ICLF_{28}$ and $ICLF_{22}$ systems the sampling points B, C and D showed the highest yield. The sampling point within the ICLF systems influences grain yields, showing that sampling points A and E, closest to the rows are the most affected due to the high shading. This same effect is not observed in the ICL area due to the absence of trees.

Although the ICL system presented the lowest plant height in different days after emergence, this did not affect soybean yield. On the other hand, even though the soybean plant height in the $ICLF_{28}$ and $ICLF_{22}$ systems were greater, there was a high reduction in yield within these systems, with the mean being 3,845 kg grain ha^{-1} (ICL) and 2,656 kg grain ha^{-1} (ICLF).

The same effect was observed by Carvalho (2015), where shaded plants showed lower yield than unshaded plants. Thus despite the plant ability to adapt to shading, it was not enough to supply the light incidence required by soybeans, thus affecting their yield.

CONCLUSIONS

The sampling sites further away from the rows in the $ICLF_{28}$ and $ICLF_{22}$ systems positively influenced soybean yields.

The ICL system, despite having a lower plant height, had the highest soybean yield among the systems evaluated.

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LOSSES IN THE SILAGE OF PARTS OF MAIZE IN SINGLE CROP AND INTERCROPPED WITH RUZIZIENSIS GRASS (UROCHLOA RUZIZIENSIS) IN INTEGRATED SYSTEMS

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ABSTRACT

The aim was to evaluate the dry matter losses in the silage of parts of the maize plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*) in integrated systems. The experiment was carried out in the municipality of Colorado do Oeste – RO, Brazil. The randomized block design was adopted, with five repetitions. The treatments were arranged in 2x4 factorial scheme, being: two crop modalities (single, intercropped) and four maize plant parts (whole plant, half plant, plant without ear and ear with straw). Low gas losses were quantified in the silage fermentation, with a mean of 1.07% of DM. The mean value obtained from effluent losses was 33.03 kg ton^{-1}of green mass. The silage dry matter recovery was higher in the whole plant and the ear with straw silage, indicating lower losses during the fermentation process of this silage. It can be recommended the whole plant, half plant, plant without ear and ear with straw ensilage in single crop or intercropped.

Key words: Crop-livestock integration; Forage; *Urochloa ruziziensis*

INTRODUCTION

The maize plant has desirable characteristics for silage, which encompass since its yield in the field, nutritional value and substrates for its fermentation (ALLEN et al., 2003). In addition to these factors, there is still the flexibility to harvest maize for forage or grain, as well as providing plant fractionation options for the different silages production (BERNARDES and RÊGO, 2014). For this, technologies have been developed, such as processors and specialized equipment that allow the fractional harvesting maize plant for the different silages types production, such as snaplage (FERRARETO et al., 2018).

A very important factor to obtain high quality silage is the correct harvest point determination (Mittelmann et al., 2005). In the maize case, it is recommended to harvest when the dry matter content is between 33% and 37% (DOURADO NETO; FANCELLI, 2000). However, Cruz (1998) stated that the ideal dry matter content would be between 28% and 33% and Bal and Shaver (1997) determined that between 30% and 35% should be the correct time to harvest maize for silage. According to Moraes et al. (2013) the quality and nutritional value of the silage material can be influenced by the maize plants structural composition and by the grain, leaf and straw production. Thus, the aim was to evaluate the losses in the silage of the maize plant parts in single crop or in intercroppedwith ruziziensis grass (*Urochloa ruziziensis*) in integrated systems.

MATERIAL AND METHODS

The experiment was carried out in the municipality of Colorado do Oeste – RO, Brazil (13° 07' latitude S; 60° 31’ longitude W). We used the randomized block design with five repetitions. The treatments were arranged in 2x4 factorial scheme, being: two crop modalities (single maize and maize intercropped with ruziziensis grass) and four maize plant parts (whole plant, half plant, plant without ear and ear with straw). The *U. ruziziensis* cv. Kennedy was used for the intercropped, at a seeding rate of 3.25 kg ha^{-1} pure and viable seeds, which is characterized by its rapid growth in the rainy season, high potential for seed production, ease of establishment and desiccation by herbicides. The maize plants harvest was carried out manually at the stage of the meal grain, at the height of 0.2 m and 1.0 m above the soil surface. For the treatments of ear silage with straw, the ears were detached from the plant manually. The forage was crushed in a stationary mincer, reducing the particle size between 2 and 3 cm.

To produce the silage, the plots were made up of experimental silos (glass pots), with a volume of 3.0 L, equipped with a threadable lid and adapted with a "siphon" valve, which allows the exit and prevents the entry of gases inside the silo. At the bottom of each experimental silo, 600 g of sand was placed, separated from the forage by a nylon tulle fabric, in order to collect and quantify the effluents produced.

The experimental silos were filled with forage by manual compaction, obtaining the green mass density of 556.68 kg m^{-3}. After filling, the silos were closed and sealed with polyvinyl chloride (PVC) film on the edges of the lid in order to maintain the environment in anaerobiosis. The "siphon" valves were completed with water, making the entry of gases impossible. The silos remained closed for 135 days, sheltered in an airy place with no direct incidence of luminosity.

To determine losses and dry matter recovery, we used equations adapted from Jobim et al. (2007).

The data were submitted to analysis of variance and Tukey’s range test, at 5% probability.

RESULTS AND DISCUSSIONS

Was possible to verify the isolated effect for the plant parts for losses by gases (GasL) and dry matter recovery (DMR, P<0.05) (Table 1).

Table 1. Analysis of variance for dry matter losses in the silage of maize parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*) in integrated systems

		Effect				
Variable	**Mean**	**Modality (M)**	**Plant parts (P)**	**M x P**	**Block**	**CV (%)**
GasL	1.07	ns	*	ns	*	17.59
EfL	33.03	ns	ns	ns	ns	35.74
DMR	97.36	ns	*	ns	ns	1.06

GasL: Gas loss (%). EfL: Effluent losses (kg ton^{-1} GM). DMR: Dry Matter Recovery (%). *: Significant to 5% probability of error. ns: Not significant. CV: Coefficient of variation.

The lowest GasL were observed in a plant without ear and whole plant (Table 2). The GasL is an important form of DM loss during fermentation, intermediated by undesirable microorganisms that use carbohydrates as substrate. A point that favors the high GasL is the oxygen presence inside the silo. However, the proportion the GasL obtained in the present study was small mean of 1.07% DM, although greater for losses by gases have been associated with the type of fermentation that took place inside the silo (PAULA et al., 2020).

Table 2. Gases Losses (GasL) and dry matter recovery (DMR) in the silage of the maize plant parts in a single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

Modality	**Maize plant parts**				**Mean**
	Whole plant	**Half plant**	**Plant without ear**	**Ear with straw**	
			GasL (%)		
Single	0.81	1.24	0.80	1.18	1.01
Intercropped	1.14	1.31	0.70	1.35	1.12
Mean	0.98 b	1.28 a	0.75 b	1.26 a	
			DMR (%)		
Single	97.18	97.85	95.47	97.91	97.10
Intercropped	98.06	97.13	97.09	98.19	97.62
Mean	97.62 a	97.49 ab	96.28 b	98.05 a	

Means followed by the same letter do not statistically differ by Tukey test at 5% probability. The mean value obtained for EfL of silage was 33.03 kg ton^{-1} of green mass or 10.74% of DM.

However, Vilela et al. (2008) observed that the highest percentage of DM (34.8%) of the ensiled plants from the maturation stage of the grains to ensilage (milk line in 1/2 of the grain) was not detected effluent losses. The small losses of DM by effluent are due to the appropriate silage process of the original material, which is influenced mainly by the DM content, by the physical processing of the forage, by the type of silo and by the compaction degree (VILELA et al., 2008).

It is worth noting that the effluent has a large amount of organic compounds such as sugars, acids, protein and minerals, being an undesirable loss, but that can be avoided as the DM content of the forage is appropriate. On these aspects, no considerable EfL values were not observed.

The DMR from silage was higher in the whole plant silage and in the ear with straw (snaplage) (Table 2). According to Paula et al. (2020), higher rates DMR indicate lower losses during the silage fermentation process. The lower stalks proportion in the half-plant forage and the ear absence may favor a lower ensiled mass density, increasing the total silage losses of these plant parts.

It is noteworthy that the mean DM content of 33.73% forage is considered ideal for favoring adequate lactic fermentation, combined with adequate compaction (556.68 kg m^{-3}), positively influenced the DMR.

The relatively high DMR values obtained in this study may be related to low gas loss and effluent during fermentation process, which, according to Pedroso et al. (2005), may represent up to 98.4% of dry matter loss, mainly by undesirable fermentation, where there is the CO_2 formation.

CONCLUSIONS

The gas losses are reduced in the whole plant and in the plant without ear ensilage, although, in the of the other parts of the maize plant ensilage there are no significant losses. The greatest dry matter recovery occurs in the silages of the whole plant and ear with straw silages.

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CROP-LIVESTOCK-FOREST INTEGRATION: SUSTAINABLE TECHNOLOGY FOR AGRICULTURAL SCHOOLS IN TOCANTINS

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ABSTRACT

The presence of practical spaces such as forest nurseries, integrated crop-livestock-forest system (ICLFS) modules, community gardens and other initiatives in school environments, provide students with greater knowledge and serve as a practical field for teachers to offer part of their subjects. The objective of the work was to train and integrate the student community through forest nurseries and ICLFS modules in the state of Tocantins. The project was developed in three months of work, and the process of development of the activities had several phases: initial visit, communication with school managers, capacitation and practical training of students through the insertion of forest nurseries and ICFLS modules. In the period of three weeks, forest nurseries with a total area of 656 m² were implanted, produced over 10,000 forest seedlings, and a module of 1.5 ha of ICFLS was implanted. Thus, with the activities developed, they stimulated greater environmental awareness in agricultural schools, there was also identified opportunities for the development of sustainable practices and provided exchanges of experiences between the 3 schools participating in the project.

Key words: ICLFS; forest nurseries; native trees

INTRODUCTION

Tocantins has 277,620 km², which represents about 3.3% of the national territory and 7.2% of the North Region (SEPLAN, 2017). The state has 139 municipalities with a total of 1,383,445 inhabitants. 78.81% of the population live in the urban area and 21.19% live in the rural area. According to IBGE (2021) the entire agricultural sector plays an important role in the sustainability of the Tocantins economy. While the gross value added of agriculture has a 5.6% share in the total gross value added of the Brazilian economy, in Tocantins, this participation reaches the 20.6% mark. According to the IBGE (2021), there are 7.5 million hectares occupied by livestock and 700 thousand hectares occupied by agriculture, leaving, therefore, 5.7 million hectares for future expansion of the Tocantins agricultural frontier.

For the development of agriculture and settlement of populations, the first measure taken is the deforestation of the area, which often occurs with minimum criteria when it comes to ecological importance. Cattle breeding also contributes significantly to deforestation, as the latter in its search for food ends up trampling the plants and compacting the soil, making it difficult for sprouts to germinate and for water and air to infiltrate the soil (MACHADO, 2012).

Balem and Machado (2019) highlights the primordial role of rural extension with an emphasis on ecological soil management; animal welfare; health practices based on homeopathy and herbal medicine; respect for the humanity-nature relationship and social reproduction, and the production of knowledge must consider the wisdom of local actors.

For Caldart (2015), bringing agroecology to rural schools represents a broad movement of social transformation and requires us to “swim against the tide”, as we will not be able to go deeper into these relationships without understanding them and without knowing why it is necessary to fight to build them.

Therefore, agroecology follows a path towards the autonomy of each one in the production of their food in a healthy way, which involves ecological and also social aspects. From that aspect the integrated crop-livestock-forest systems (ICLFS) seek to conserve agrobiodiversity, promote sustainable practices and innovations through conscious use of the soil. The objective of this work is to present the tools used in the transfer of technology, structuring and implantation of ICLFS modules and the construction / reform of forest nurseries in agricultural schools in the State of Tocantins.

MATERIAL AND METHODS

The work was developed in the State of Tocantins, in three rural schools in the municipalities of São Salvador, Esperantina and Colinas, located respectively in the South, Center and North of the State. The main activity developed in these locations was the structuring of schools with forest nurseries, tools and equipment and training of young people to implement ICLFS, either in the school itself, in their family properties, or in the application of the system after agricultural technician training.

The project was carried out in axes, such as: the training of students and teachers on opportunities, benefits and challenges in the implementation of ICLFS; construction / renovation of a nursery for the production of forest seedlings; production of native seedlings for future implementation of ICLFS by the school itself; acquisition of equipment, tools and supplies for work in the field and production of forest seedlings and attendance to gender equality.

The collaborative work was inserted in three rural schools: Colégio Família Agrícola Jose Porfirio de Souza (São Salvador / TO), Escola Família Agrícola do Bico do Papagaio Padre Josimo (Esperantina / TO) and Escola Família Agrícola Zé de Deus (Colinas / TO). The first stage of the project was to conduct a visit to understand the reality of the school in the following areas: infrastructure, tools, inputs and other previously unidentified demands.

Subsequently, the project had its activities defined among with the school team. It is worth mentioning that in all activities women were prioritized as field and operational leaders, trying to meet gender equality, which is one the goals of the project, that also meets with the objective of sustainable development goals (SDG) 5, aiming to achieve equality and empowerment of all women and girls.

In this stage, areas and nurseries were visited to understand the best strategy to be developed by the school. The counterparts for the schools were to maintain the commitment to involve as many students as possible in the training, construction and production of the seedlings defined together and to provide technical staff of committed teachers and monitors for the practical operation of the project, in addition to offering food, accommodation and transport for these students, whose participants must be at least 50% female though all stages.

After this stage and definition of the team involved in each school, a working group was created, which operated substantially via Whatsapp®, with the objective of speeding up the communication and progress of the project. The activities of understanding which tools and equipment each school needed, listing and budgets were carried out mainly through this platform, with the aid of a Microsoft Excel spreadsheet. Parallel to this stage, the design of each nursery was prepared, meeting the specificities of each school, containing the quantification of materials and supplies needed to make the nursery of each school functional.

The activities planned for each school are described in table 1.

Table 1. Activities carried out in each of the 3 agricultural family schools participating in the project.

School's Name	City	Nursery Area (m²)	Seedling Production	ICLFS Module	ICLFS Area (ha)	Number of People
Colégio Família Agrícola José Porfirio de Souza	São Salvador/TO	81	2,500	No	-	30
Escola Família Agrícola do Bico do Papagaio Padre Josimo	Esperantina/TO	200	3,500	No	-	30
Escola Família Agrícola Zé de Deus	Colinas/TO	375	5,000	Yes	1.5	200
TOTAL	3	656	11,000	1	1.5	260

RESULTS AND DISCUSSIONS

For technology transfer, the main objective of the project, the team that coordinated the activities with the schools were two civil and environmental engineers, and a forest engineer. These professions are closely linked to sustainable use of soil. Thus, the understanding of the challenges, opportunities and experiences obtained with the realization of this project were debated and systematized.

Amid the success of the activities with the agricultural family schools, we were able to observe and summarize the scenarios below:

- Colégio Família Agrícola José Porfírio de Souza – São Salvador/TO: The 81m² nursery was built in 3.5 days with an average of 20 people involved daily. In addition, about 2,500 seedlings of native species were produced, such as cashew, cajá, mangaba, jatobá, yellow ipe, copaiba, cedar, cega-machado, angico and tingui. One of the things that made it more difficult to start the activities was the change of location of the nursery where the foundation had to be built, in addition to installing an irrigation system, adding 150m of buried irrigation due to the location of the water tank, in addition to acquiring new materials. Another factor of additional difficulty was the implementation of the project during the holiday season at the end of the year. To overcome this difficulty it was essential to engage the technical staff of the school, composed of the principal, coordinator, teachers and members of the community composed of volunteers parents of students actively participating in the training and the task force for the construction of the nursery and production of seedlings.
- Escola Família Agrícola do Bico do Papagaio Padre Josimo – Esperantina/TO: The 200 m² nursery already had a metallic structure and a mounted foundation, with a small part of the shade installed and was taken up by tall grass inside and outside the entire structure. All the work on renovating the nursery and producing native seedlings was carried out in 4 days, with an average of 15 people involved daily. About 3,500 seedlings of native species were produced, such as cashew, cajá, mangaba, jatobá, yellow ipe, copaiba, cedar, cega-machado, angico and tingui. A difficulty factor during the construction of the nursery and production of seedlings was the distance from the school structure to the location of the nursery, requiring a great effort to transport the seedlings, search for equipment / materials, access to bathrooms and food and other activities. In addition, the teaching staff was absent, which caused many implementation difficulties such as low student engagement and lack of materials such as available soil for preparing the substrate of the bags. Also, the existing metallic structure of the nursery is not a common structure for works in that region, which are generally constructed from treated wood.
- Escola Família Agrícola Zé de Deus – Colinas/TO: The 375 m^2 nursery already had a wooden structure assembled with shade in very bad conditions. The first difficulty faced was due to the great damage in the wooden structure when compared to what had been verified during the school's reconnaissance visit, requiring the exchange of some beams and the application of terminicide. All the work to leave the nursery in operation was carried out in 2.5 days, with an average of 60 people involved daily. In addition, about 5000 seedlings of native species were produced, such as cashew, cajá, mangaba, jatobá, yellow ipe, copaiba, cedar, machado-cego, angico and tingui.

A factor of difficulty during the construction of the nursery and production of seedlings, was the low participation of the school team in the activities carried out.

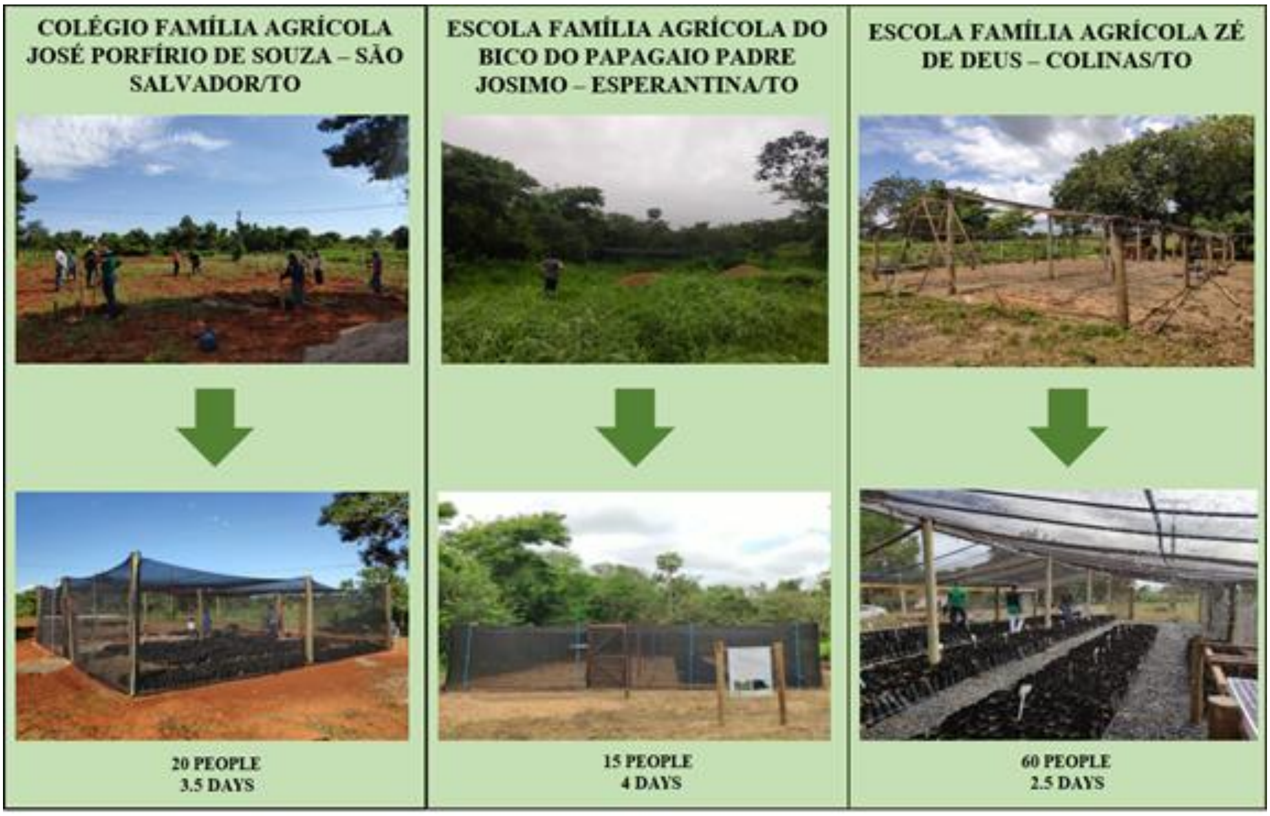

Figure 1. Before and after the construction / renovation of the nurseries.

Regarding the engagement of the technical staff, which was the most critical factor for success according to the professionals involved in the project, it is possible to highlight an excellent engagement at the São Salvador School, an average engagement at the Colinas school, and low engagement at Esperantina school.

It is important to highlight that all schools faced difficulties in finding budgets for local acquisition of tools and equipment, materials and supplies needed to enable autonomy in the implementation of ICLFS modules by schools and construction of the nursery, given that the choice of local stores was prioritized to purchase these items, it is clear that the school with the highest engagement of teachers, students and the community, was the one that was most agile in acquiring the items, being the first school to effectively build the nursery. At the rural school in the municipality of Esperantina, where a poor relationship between students / teachers and managers was observed, the process of implanting the nursery was noticeably more difficult to be conducted.

It was also possible to notice that the two schools with the lowest engagement of the school team were also the ones that students presented low performance, making it evident that the success of the project is directly related to the participation and engagement of the school in the whole process.

And even with all the difficulties, during the daily activities of building the nurseries and implementing the ICLFS module, we can observe how transforming these activities were for the students. This can be seen most successfully where the relationship between teachers and students was closer, respectively, São Salvador / TO and Colinas / TO. This demonstrates what Tristão (2002), in the context of environmental education, affirms that it is a transformative practice: it must be committed to the formation of critical citizens and co-responsible for a development that respects the most different forms of life and performance. That is, the greater the engagement of teachers, the greater the engagement of students, therefore, the greater the transformative action.

It was also possible to observe the interest of some students / teachers and monitors in the activities that can be carried out in these environments during the school year, and the benefits that the nursery can bring to the school.

Due to the collective construction of the nurseries, among with students, teachers, volunteers and monitors, everyone involved in the training had the opportunity to acquire more knowledge in the areas of working with wood for rural buildings, irrigation, seedling production, seed collection, seed processing, the role of the tree components from the ICLFS module, and the importance of planning, proactivity, and collaborative work.

CONCLUSIONS

The activities developed in all schools for the implantation of nurseries for the production of forest seedlings aimed to train everyone involved in the process, as well as to teach them about the various aspects related to their future professions. The three nurseries, executed and completed, now serve as laboratories for the day-to-day classes of these schools and training in seedling production, in addition to enabling the implementation of the tree components in ICLF systems.

For similar and future projects, it is important to rethink strategies for teacher engagement, expanding the transforming actions of the project, as well as including operating visits to the nurseries, so that the life of the nursery and the gains from its operation are permanent and understood as an ongoing process by the schools and communities involved.

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SILAGE OF MAIZE PLANT PARTS IS POSSIBLE DESPITE THE CROP CULTIVATION MODALITY

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ABSTRACT

Aimed to evaluate whether the bromatological composition of maize silages is influenced by the parts of the ensiled plant and by the intercrop with ruziziensis grass. The maize used in the experiment was the hybrid Galo and, for the intercrop, ruziziensis grass was used. The experimental silos were filled with forage by manual compaction. After filling, the silos were closed and sealed, remaining stored for 135 days. The contents of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and mineral matter (MM) of forages and silages were evaluated. The DM content of the forage and silage of ear with straw was higher than the other maize plant parts, regardless of the cultivation modality, and a lower DM value was found in the plant without ears. The opposite happened to the MM content. The CP content of the silage was higher for half plant and plants without ears, presenting lower value for ears with straw. The NDF content of the forage was higher when there was the single crop of maize combined with the plant without ears, and the silage showed higher NDF content for plants without ears, regardless of the cultivation modality. The chemical composition of maize forage and silage is influenced by the different plant parts and by the cultivation modality.

Key words: integrated crop-livestock system; tropical forage; *Urochloa ruziziensis*

INTRODUCTION

Among the most used forage for silage, maize (*Zea mays* L.), the sorghum (*Sorghum bicolor* L.), the sugarcane (*Saccharum officinarum* L.) and tropical grasses stand out. The high nutritive value of the maize plant, characterized by high digestibility and energy density, qualifies the silage of this forage as a great option for animal production systems (CALIXTO JR. et al., 2017).

In addition to the plant characteristics, the way silage is carried out can change the quality and nutritive value of the silage due to the losses that occur during the fermentation process. An alternative that has been gaining prominence in ruminant nutrition is the production of silage using different parts of the maize plant, like the maize ear silage (EUKEN, 2018), the whole plant silage added to the maize ears, the maize silage without the ear (FERREIRA et al., 2005) and the ear with the straw silage, known as Snaplage (AKINS; SHAVER, 2014).

Besides the effect on the nutritional quality of silage from different parts of the maize plant, there is also the possibility of growing maize intercropped with grasses in integrated crop-livestock system. According to Ceccon et al. (2010), the maize and tropical forage intercrop aims to produce straw to cover the soil and to produce forage for animal feed. The difference between one aim and the another consists, fundamentally, in the population and distribution of plants. The intercrop of perennial forages with maize is an alternative for establishing pastures or crops to cover the soil; this is possible due to the difference in growth of both species (SEREIA et al., 2012).

Species of the genera *Urochloa*, because they have a vigorous and deep root system, present high tolerance to water deficiency and nutrients absorption in deeper soil layers, developing under unfavorable environmental conditions for most grain-producing crops and species used for soil cover (BARDUCCI et al., 2009). Thus, these species are excellent alternatives for intercropping with maize.

Aimed to evaluate whether the bromatological composition of maize silages is influenced by the parts of the ensiled plant and by the intercrop with ruziziensis grass (*U. ruziziensis*).

MATERIAL AND METHODS

The experiment was carried out on the rural property Nossa Senhora Aparecida, located in the municipality of Colorado do Oeste – RO, Brazil (Latitude 13°07' S; Longitude 60°31' W). The climate of the region, according to the Köppen-Geiger classification, is of the type Awa, hot and humid tropical, presenting two well-defined climatic seasons: the summer from May to September, when the lowest rainfall is observed, around 750 to 810 mm; and winter from October to April, when the greatest rainfall occurs between 1,470 and 1,500 mm.

Randomized block design was adopted with five repetitions, arranged in a double factorial scheme (2x4), the first factor being the cultivation modality (single maize and maize intercropped with ruziziensis grass) and the second factor the maize plant parts (whole plant, half plant, plant without ears and ears with straw).

The area preparation began in October 2019. The maize used in the experiment was the hybrid Galo. For the intercrop, *U. ruziziensis* cv. Kennedy was used, at a sowing rate of 3.25 kg ha^{-1} of pure and viable seeds (PVS).

The plants were harvested manually when the maize reached the farinaceous stage. According to the treatment, the harvest height was 0.2 m and 1.0 m above the soil surface, simulating the harvesting heights of the platform of a mechanized silage plant. For the ear silage treatments with straw, the ears were simply removed from the plant manually. The forage was ground in a stationary chipper, reducing particle size between 2 to 3 cm.

To proceed with the silage production, the plots were constituted of experimental silos (glass pots) with volume of 3.0 L, equipped with screw cap and adapted with "siphon" valve, which allows the outlet and prevents the entry of gases inside the silo. At the bottom of each experimental silo, 600 g of sand were placed, separated from the forage by a nylon tulle fabric, in order to collect the effluents produced.

The experimental silos were filled with forage by manual compaction, obtaining the real density of green mass of 556.68 kg m^{-3}. After filling, the silos were closed and sealed with polyvinyl chloride film (PVC) at the edges of the cover in order to maintain the anaerobic environment. The "siphon" valves were completed with water, making it impossible for gases to enter. The silos remained stored for 135 days, sheltered in a ventilated place and without direct incidence of light.

At the time of ensiling, a sample of the chopped green forage was collected, homogenized and packed in plastic bags that were stored under freezing. Samples of silage were also collected at the opening of the experimental silos. The forage and silage samples were sent to the Animal Nutrition Laboratory and the Forage Laboratory of the Federal University of Mato Grosso to proceed with the analyzes. The pre-dried forage and silage samples were ground in a Willey stationary mill, in sieves with 1 mm mesh, being taken to drying in a drying oven at 105 ºC for 8 h (AOAC, 1990), obtaining the dry matter (DM) contents. Through the methodology proposed by AOAC (1990), the contents of crude protein (CP) and mineral matter (MM) were determined. For the neutral detergent fiber (NDF) analysis the solution described by Van Soest et al. (1991), autoclave extraction according to Pell e Schofield (1993) was used, which is carried out with TNT bags (non-woven fabric).

The data were subjected to analysis of variance and when the F test was significant, the Tukey means comparison test was carried out at the level of 5% probability of error.

RESULTS AND DISCUSSIONS

Table 1 presents the summary of the variance analysis for the forage and silage characteristics of maize plant parts in single crop or intercropped with ruziziensis grass. For the forage characteristics, an effect of interaction between the factors for NDF was observed. On the other hand, there was an isolated effect of the modality and of the plant parts for the DM content and an isolated effect of the plant parts for MM ($P<0.05$), with no significant effect for the CP content. As for the silage characteristics, an isolated effect of both factors was observed for the variable DM, CP and NDF. The MM variable had a significant effect only for the maize plant parts ($P <0.05$).

Table 1. Summary of analysis of variance for forage and silage characteristics of maize (*Zea mays* L.) plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

Variable	**Mean**	**Effect**				**CV (%)**
		Modality (M)	**Plant Parts (P)**	**M x P**	**Blocks**	
			Forage			
DM	33.73	*	*	ns	*	8.76
CP	7.73	ns	ns	ns	ns	5.53
NDF	41.52	ns	*	*	ns	9.49
MM	4.47	ns	*	ns	ns	15.83
			Silage			
DM	36.05	*	*	ns	*	6.99
CP	7.32	*	*	ns	ns	4.09
NDF	30.60	*	*	ns	ns	6.13
MM	4.09	ns	*	ns	*	11.48

DM: Dry matter (%). CP: Crude protein (% DM). NDF: Neutral detergent fiber (%). MM: Mineral matter (%).
*: Significant at 5% probability of error. ns: Not significant. CV: Coefficient of variation.

The forage was harvested when the maize plants were in the appropriate stage for ensiling, with a mean content of 33.73% DM, which contributed to the DM content in silages were found within the quality standard fermentation. According to Santos (2020), the ideal fermentation in the silo is expected when the forage dry matter content to be ensiled reaches approximately 33%, indicating, therefore, the adequacy of the mean DM contents obtained in the present study, this variable being influenced isolated by the crop modality and the maize plant parts (Table 2).

During silage, part of the forage protein is transformed into soluble nitrogenous compounds, such as ammonia, nitrates, nitrites, free amino acids and peptides. Protein solubilization occurs due to the activity of plant enzymes (proteases) that are released when cell walls are broken during harvesting and chipping, which may have occurred in all forage treatments.

It was observed a higher value for the NDF contents in the maize plants without ear in single crop (64.11%), although this variable has presented statistically equal values, regardless of the crop modality, except when in intercropped crop of the plant without ear. Such values are in accordance with the data reported by Zebeli et al. (2012).

Table 2. Mean bromatological composition of forages and silages of maize (*Zea mays* L.) plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

Modality	**Maize plant parts**				**Mean**
	Whole plant	**Half plant**	**Plant withot ear**	**Ear with straw**	
			Forage		
			DM (%)		
Single	31.09	32.91	24.73	40.15	32.22 b
Intercropped	34.90	37.49	29.09	39.42	35.23 a
Mean	33.00 B	35.20 B	26.91 C	39.79 A	
			NDF (%)		
Single	37.17 aB	37.32 aB	64.11 aA	29.22 aC	41.96
Intercropped	40.70 aB	39.56 aB	57.63 bA	26.46 aC	41.09
Mean	38.94	38.44	60.87	27.84	
			MM (% DM)		
Single	3.84	4.12	7.53	2.04	4.38
Intercropped	5.08	4.07	7.24	1.86	4.56
Mean	4.46 B	4.09 B	7.39 A	1.95 C	
			Silage		
			DM (%)		
Single	30.95	34.09	28.20	46.29	34.88 b
Intercropped	31.72	37.20	32.89	47.06	37.21 a
Mean	31.33 C	35.64 B	30.54 C	46.67 A	
			CP (%)		
Single	7.50	7.58	7.88	7.31	7.57 a
Intercropped	7.09	7.20	7.22	6.77	7.07 b
Mean	7.30 AB	7.39 A	7.55 A	7.04 B	
			NDF (%)		
Single	32.55	27.82	50.49	15.03	31.47 a
Intercropped	31.59	25.56	48.47	13.25	29.72 b
Mean	32.07 B	26.69 C	49.48 A	14.14 D	
			MM (% DM)		
Single	4.18	3.92	7.01	1.46	4.14
Intercropped	4.38	3.47	6.84	1.48	4.04
Mean	4.28 B	3.70 B	6.93 A	1.47 C	

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ statistically by the Tukey test at 5% probability.

The cultivation modality provided a higher DM content of the silage and, when it comes to the maize plant parts, a higher value was found for the ear silage with straw, whereas the half plant silage showed intermediate value and the plant silages whole and plant without ear had lower dry matter content. The superiority found in the DM contents for ear with straw silage (snaplage) and maize silage intercropped with ruziziensis grass can be attributed, in part, to the fact that the ear fraction, rich in starch, makes up a considerable part of the dry matter of silages produced with maize.

The CP content of the silage was higher in maize silage in single crop and in half plant and plant without ear silages. Variations in crude protein content in maize silages have been reported in several studies (FIGUEIREDO et al., 2018; SANTOS et al., 2020; ALMEIDA et al., 2021). The reduction in crude protein content of silages produced in intercropped cultivation is possibly related to competition for environmental resources. Works carried out by Alves (2013) and Silva et al. (2013) found that when maize is submitted to an intercrop with ruziziensis grass, there is a reduction in the maize development, especially in the off-season, a season characterized by lower light incidence, low temperatures and less water availability.

The satiety effect can be expressed in terms of NDF, since the determination of food intake units is highly correlated with the plants cell wall concentration (VALENÇA et al., 2016). It is important to note that, in foods with contents above 60% of NDF in dry matter there is a limitation in intake due to the physical effect of filling the rumen, therefore, the results presented in this work are satisfactory in order to minimize this effect.

Higher MM content was found for plant silages without ears, while ear with straw silage showed lower mineral content, with whole plant and half plant silages having intermediate values. The lowest contents of mineral matter observed in ear with straw silages may be due to the absence of other plant structures.

In view of the research already carried out, it is noticeable that there are several possibilities for ensiling the maize plant, knowing the characteristics of the food when subjected to the ensiling process of different portions of the plant and its results are still very varied, however the adaptation of ensilage in harvest heights allows the use of silage by farmers, provided they have such compatibility of machinery, leaving material remaining in the area that will act as soil cover.

CONCLUSIONS

The bromatological composition of forage and maize silage is influenced by the different plant parts and by the cultivation modality.

Ensilage of whole plant, half plant, plant without ear and ear with straw in single crop or intercropped with ruziziensis grass can be recommended, considering the appropriate values of the variables evaluated about the bromatological composition, with the adequacy or choice of the modality be adopted for the purpose of the farmer and the studies of other variables such as fermentation pattern, economic viability and fermentative losses in the silage.

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DIGESTIBILITY AND TOTAL DIGESTIBLE NUTRIENTS OF SILAGE FROM MAIZE PLANT PARTS IN SINGLE CROP OR INTERCROPPED WITH RUZIZIENSIS GRASS

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ABSTRACT

The aim was to evaluate whether the digestibility and the total digestible nutrients content of maize silages is influenced by the parts of the ensiled plant and by the intercrop with ruziziensis grass. The maize used in the experiment was the hybrid Galo and, for the intercrop, ruziziensis grass was used. The experimental silos were filled with forage by manual compaction. After filling, the silos were closed and sealed, remaining stored for 135 days. The contents of total digestible nutrients (TDN), digestibility of dry matter (DDM) and organic (DOM) of forages and silages were estimated. The ear forage in single or intercropped crop showed higher TDN, DDM and DOM values, followed by half plant forages in single or intercropped crop, whole plant in single or intercropped crop and, finally, plant without ear, this time, showing superiority when intercropped with ruziziensis grass. As for silages, the contents of TDN, DDM and DOM were higher for the ear with straw silage, regardless of the cultivation modality. Considering the digestibility of dry and organic matter and the value of total digestible nutrients, the silages of maize plant parts in single crop or intercropped with ruziziensis grass showed good nutritional value for feeding ruminants.

Key words: integrated crop-livestock system; nutritive value; *Urochloa ruziziensis*

INTRODUCTION

Ensilage is a forage/grain conservation process that occurs through acidification of the mass as a result of microbial fermentation under anaerobic conditions (NOVAES et al., 2004). Its fundamental principle is the fermentation of sugars by bacteria, through the organic acids production and consequent lowering of the pH of the ensiled mass. In this process, there is a notoriety for lactic acid that keeps microorganisms with low activity during the storage time (OHMOMO et al., 2002).

Although there are several forages, annual and perennial plants suitable for silage production, maize (*Zea mays* L.) has a prominent place and is considered a reference, due to the adequate soluble carbohydrates contents found in the plant, which lead to lactic fermentation, promoting the conservation of a food of high nutritional value, easy to prepare and of great acceptance by the animals, with great green mass production and adequate dry matter content (OLIVEIRA et al., 2010).

Several studies are being carried out, increasing the possibility of ensiling maize in different ways, performing ensilage of parts of the maize plant. Moraes et al. (2013) state that the quality and nutritional value of ensiled material can be influenced by the structural composition of maize plants and by the grains production, leaves and stems. Paziani et al. (2009) also comment that the quality of the silage is influenced by the structural composition of the plant, and should be a criterion to be considered when choosing the hybrid, as well as its total mass production.

Besides the effect on the nutritional quality of silage from different parts of the maize plant, there is also the possibility of growing maize intercropped with grasses in integrated crop-livestock system. According to Ceccon et al. (2010), the maize and tropical forage intercrop aims to produce straw to cover the soil and to produce forage for animal feed. The difference between one aim and the another consists, fundamentally, in the population and distribution of plants. The intercrop of perennial forages with maize is an alternative for establishing pastures or crops to cover the soil; this is possible due to the difference in growth of both species (SEREIA et al., 2012).

Species of the genera *Urochloa,* because they have a vigorous and deep root system, present high tolerance to water deficiency and nutrients absorption in deeper soil layers, developing under unfavorable environmental conditions for most grain-producing crops and species used for soil cover (BARDUCCI et al., 2009). Thus, these species are excellent alternatives for intercropping with maize.

Therefore, the aim was to evaluate whether the digestibility and the total digestible nutrients content in maize silages are influenced by the parts of the ensiled plant and by the intercrop with ruziziensis grass (*U. ruziziensis*).

MATERIAL AND METHODS

The experiment was carried out on the rural property Nossa Senhora Aparecida, located in the municipality of Colorado do Oeste – RO, Brazil (Latitude 13°07’ S; Longitude 60°31’ W). The climate of the region, according to the Köppen-Geiger classification, is of the type Awa, hot and humid tropical, presenting two well-defined climatic seasons: the summer from May to September, when the lowest rainfall is observed, around 750 to 810 mm; and winter from October to April, when the greatest rainfall occurs between 1,470 and 1,500 mm.

Randomized block design was adopted with five repetitions, arranged in a double factorial scheme (2x4), the first factor being the cultivation modality (single maize and maize intercropped with ruziziensis grass) and the second factor the maize plant parts (whole plant, half plant, plant without ears and ears with straw).

The area preparation began in October 2019. The maize used in the experiment was the hybrid Galo. For the intercrop, *U. ruziziensis* cv. Kennedy was used, at a sowing rate of 3.25 kg ha^{-1} of pure and viable seeds (PVS).

The plants were harvested manually when the maize reached the farinaceous stage. According to the treatment, the harvest height was 0.2 m and 1.0 m above the soil surface, simulating the harvesting heights of the platform of a mechanized silage plant. For the ear silage treatments with straw, the ears were simply removed from the plant manually. The forage was ground in a stationary chipper, reducing particle size between 2 to 3 cm.

To proceed with the silage production, the plots were constituted of experimental silos (glass pots) with volume of 3.0 L, equipped with screw cap and adapted with “siphon” valve, which allows the outlet and prevents the entry of gases inside the silo. At the bottom of each experimental silo, 600 g of sand were placed, separated from the forage by a nylon tulle fabric, in order to collect the effluents produced.

The experimental silos were filled with forage by manual compaction, obtaining the real density of green mass of 556.68 kg m^{-3}. After filling, the silos were closed and sealed with polyvinyl chloride film (PVC) at the edges of the cover in order to maintain the anaerobic environment. The “siphon” valves were completed with water, making it impossible for gases to enter.

The silos remained stored for 135 days, sheltered in a ventilated place and without direct incidence of light.

At the time of ensiling, a sample of the chopped green forage was collected, homogenized and packed in plastic bags that were stored under freezing. Samples of silage were also collected at the opening of the experimental silos. The forage and silage samples were sent to the Animal Nutrition Laboratory and the Forage Laboratory of the Federal University of Mato Grosso to proceed with the analyzes. The pre-dried forage and silage samples were ground in a Willey stationary mill, in sieves with 1 mm mesh, being taken to drying in a drying oven at 105 ºC for 8 h (AOAC, 1990), obtaining sample dried in an oven. The contents of total digestible nutrients (TDN), digestibility of dry matter (DDM) and digestibility of organic matter (DOM) were estimated through equations proposed by Cappelle et al. (2001).

The data were subjected to analysis of variance and when the F test was significant, the Tukey means comparison test was carried out at the level of 5% probability of error.

RESULTS AND DISCUSSIONS

Table 1 presents the summary of the analysis of variance for the forage and silage characteristics of maize plant parts in single crop and intercropped with ruziziensis grass. For the forage characteristics, an interaction effect between the factors for TDN, DDM and DOM was observed. On the other hand, there was an isolated effect of the plant parts for the TDN, DDM and DOM contents of the silages ($P<0.05$).

Table 1. Summary of the analysis of variance for the digestibility and total digestible nutrients of forages and silages of maize (*Zea mays* L.) plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

Variable	**Mean**	**Effect**				**CV (%)**
		Modality (M)	**Plant parts (P)**	**M x P**	**Blocks**	
			Forage			
TDN	63.88	ns	*	*	ns	2.35
DDM	66.66	ns	*	*	ns	1.98
DOM	61.34	ns	*	*	ns	2.08
			Silage			
TDN	66.67	ns	*	ns	*	0.85
DDM	69.12	ns	*	ns	*	0.72
DOM	63.72	ns	*	ns	*	0.76

TDN: Total digestible nutrients (%); DDM: Dry matter digestibility (%). DOM: Digestibility of organic matter (%). *: Significant at 5% probability of error. ns: Not significant. CV: Coefficient of variation.

For maize silages, both for TDN and for DDM and DOM were influenced by the plant parts, with higher value for the ear with straw silage (snaplage), followed by silage of half plant, whole plant and, finally, plant without ear. It is important to note that DDM and TDN, as indicative of the nutritional value of the food, undergo small changes with the evolution of physiological maturation. This fact can be explained by the participation of each plant component in the initial stages of maturation, when there is less energy density and less dry matter content, and at the time of harvest, when there is an inversion of these factors.

Table 2. Means of digestibility and total digestible nutrients of forages and silages of maize (*Zea mays* L.) plant parts in single crop and intercropped with ruziziensis grass (*Urochloa ruziziensis*).

Modality	**Maize plant part**				**Mean**
	Whole plant	**Half plant**	**Plant without ear**	**Ear with straw**	
			Forage		
			TDN (%)		
Single	65.06 aB	66.01 aAB	54.62 bC	68.40 aA	63.52
Intercropped	63.68 aB	65.67 aB	57.80 aC	69.76 aA	64.23
Mean	64.37	65.84	56.21	69.08	
			DDM (%)		
Single	67.70 aB	68.54 aAB	58.52 bC	70.64 aA	66.35
Intercropped	66.48 aB	68.23 aB	61.32 aC	71.84 aA	66.97
Mean	67.09	68.39	59.92	71.24	
			DOM (% DM)		
Single	62.35 aB	63.16 aAB	53.44 bC	65.20 aA	61.04
Intercropped	61.17 aB	62.86 aB	56.15 aC	66.36 aA	61.64
Mean	61.76	63.01	54.80	65.78	
			Silage		
			TDN (%)		
Single	65.87	67.85	60.73	71.59	66.51
Intercropped	66.25	68.36	60.79	71.94	66.83
Mean	66.06 C	68.10 B	60.76 D	71.77 A	
			DDM (%)		
Single	68.42	70.16	63.89	73.45	68.98
Intercropped	68.74	70.60	63.95	73.75	69.26
Mean	68.58 C	70.38 B	63.92 D	73.60 A	
			DOM (%)		
Single	63.04	64.73	58.65	67.92	63.58
Intercroped	63.36	65.16	58.71	68.21	63.86
Mean	63.20 C	64.94 B	58.68 D	68.06 A	

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ statistically by the Tukey test at 5% probability.

It is already a reality among Brazilian cattle ranchers to use plants without ears for animal feed. According to Pereira et al. (2006), the plants present several variations in the bromatological composition due, mainly, to the existing varieties associated with other factors, such as, place and time of crop, age, and time of harvest, sowing density, which, probably, will cause a great variation in silage quality.

Adopting such a practice, the quality of the chemical, physical and microbiological attributes will provide adequate conditions for the growth and plants development and for the diversity maintenance of the organisms that inhabit the soil. However, in view of the high exports of nutrients and the intensive use of the agricultural area in the integrated crop-livestock systems with silage production, it is also important to verify the efficiency of these productive systems in order to preserve the attributes of the soil that are paramount in crop production.

CONCLUSIONS

Considering the digestibility of dry and organic matter and the value of total digestible nutrients, the silages of maize plant parts in single crop or intercropped with ruziziensis grass showed good nutritional value for feeding ruminants.

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6. Microclimate, landscape and biodiversity

BIODIVERSE RURAL LANDSCAPES: AGROFOREST SYSTEM IN PAMPA’S BIOME

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ABSTRACT

The current economic model has provided the design of rural landscapes that foster environmental impact processes. It is a reflection of history that sees society and nature as different elements. Agriculture is considered to be the cause of ecosystem destruction in the name of agricultural-technological intensification. The southern region of Brazil stands out as a thruster of initiatives to implement productive systems of biodiversity, such as agroforestry systems. Especially in the Pampa domain area, standing out for the inadequate use of the soil, requiring studies that promote restorative production systems and combine biodiversity conservation and income generation. Thus, possibilities of composition are generated between the activities managed by pampean family producers with production systems that promote the permeability of the local landscape. In this perspective, under the agroecological basis of local knowledge, the use of native species groups of economic return is a strategic technology for landscape management. This work aims to conceptualize and typify agroforestry systems in the Pampa territory, based on agroecological knowledge.

Key words: Agriculture; Southern Brazil; Pampa

INTRODUCTION

The current economic model has provided the design of rural landscapes that fosters/instigates/stirs ongoing processes of environmental impacts. This reality is a reflection of history that sees society and nature as different elements, this point of view is supported by preservationist models which accept conservation islands surrounded by anthropized areas (CURTIN, 1993). Agriculture is considered as one of the main potential causes of ecosystem destruction (KLANDERUD et al., 2010). In tropical regions in particularly, because of agriculture development, becomes the biggest cause of biodiversity loss (PERAL & GARCÍA-BARRIOS, 2010). This reality sets a divergent model of territorial organization, once it opposes to a type of reality that tries to build spaces where conservation, production, and nutritional and food sovereignty of the local population coexist. (GARCÍA-BARRIOS et al., 2009). Reinforcing the necessity of territorial convergence, Perfecto & Vandermeer (2010), highlight important characteristics that should be maintained and/or built at the rural landscape. The most important are 1) the agrosilvopastoral matrix should be of a high quality to preserve the wild flora and fauna; 2) development of a diverse agriculture, cattle raising and forest production and 3) Increase the social distribution of basics products and services.

For that matter, the word landscape is defined as ‘a determined part of one place’ so “the result of a dynamic combination, therefore instable, of physical, biological and anthropic elements that, dialectically react on top of each other turn the landscape into an unique and indissociable set, always in progress” (BERTRAND, 2005:141), thus, it can determines populations and consequently territories, besides constitute the basis to the spatial and temporal analysis at the rural areas (FAJARDO, 2010). The challenge to the scientific community is to promote a resilient and adapted agricultural activity, using logical and accessible strategy to maintain all the ecosystem’s function and services (LIN, 2011). To conserve nature in anthropized areas is essential to invest in quality, functionality, and permeability in agrosilvopastoral’s matrix, that surrounds less disturbed native habitats (PERFECTO & VANDERMEER, 2010). Furthermore, it is crucial to organize and balance the interests and needs in the area, looking through an agricultural view of rural life and conservation.

In this context, the south region of Brazil stands out as a thruster of implementation of biodiversity productive systems, especially in small farms areas. Among all the diverse productive types, the Agroforestry System sticks out, because it is a technological opportunity to foment diverse and integrated systems, especially in Pampa's biome, which suffered with an inadequate use of soil. By this reason, the landscape composition in the Pampa's biome needs studies that guides instruments, provide restorative and productive systems, and conserve the biodiversity and generate income. Thus, possibilities of composition are created among the activities commonly managed by Pampean family producers with productive systems that promote permeability of the local landscape. With this perspective, under the agroecological basis of local knowledge, the use of groups of native species to make money is a strategical technology in landscape management. The objective of this paper is conceptualizing and typify agroforestry system in Pampa's biome, based on the agroecology knowledge.

MATERIAL AND METHODS

The methodology of this paper is a theoretical experiment, because this type of research considered more than just theorical reviews in the literature but also express reflexions and interpretations resulting by the authors dialectic. Used all the available information about this topic, trying to incorporate new approaches and knowledge to agroforest system in Pampa's biome (GIL, 2007; MANEGHETTI, 2011).

RESULTS AND DISCUSSIONS

Concepts and types of agroforestry system

Agroecology has as organization unit, the agroecosystem, that could be defined as a system in the delimited space that shares nature resources from the ecosystem in which is inserted and has as a purpose agrosilvopastoral production adequate to local resources and knowledge. Under this perspective, the agroforestry systems are productive arrangements with balance between the nature resources and local knowledge, promoting biodiversity from the use of botanical species, perennial or not, with the possibility of adding animals in the system.

Among the agroforestry systems recognized in the scientific literature, there are three types of organization: agrosilvopastoral, silvopastoral and silviagricola. These types of systems are defined by the current components on the productive system, in other words, agricultural cultivation, forestry, and livestock. So, in these systems there is a concomitant productive planning of production, in a biodiverse regime. One constant thing in those three systems are the perennial species, usually forestry, with the possibility to use timber species or not. In addition, with this perennial component, there is the possibility to produce grain products, green stuff, fruits, milk, meat and eggs in agrosilvopastoral; milk, meat and wool in silvopastoral and grain products, green stuff, and fruits in silviagricola.

Agroforestry systems in Pampa

The Pampa biome represents a biodiverse vegetation aggregation that encompasses the territory of Brazil, Uruguay and Argentina. It has in its genesis a process strongly linked to the dynamics of disturbance, whether in remote times, with large herbivores, or in the current time, with the economic dynamics centered mainly on cattle and sheep farming. Thus, there is evidence that the current predominant physiognomy of the countryside has an extraordinarily strong relationship with this historical characteristic of management of the fields for more than twelve thousand years. However, if it were not for historical human management, a large proportion of the Pampa would be covered by forests.

The region exhibits an immense cultural heritage associated with its biodiversity, which contributes to the formation of an identity aimed at the miscegenation of cultures. In its landscape, the fields predominate, interspersed with savanoid environments, capons of forest, riparian forests, and wetlands. Thus, it is a mosaic of different types of vegetation with a landscape of 60% of the countryside type and the rest designed by environments of shrub and forest phytophysiognomy (CHOMENKO & BENCKE, 2016) with its own flora and fauna (QUADROS et al., 2009). It has a unique biodiversity that, in addition to guaranteeing numerous ecosystem services, is a unique natural, genetic, and cultural heritage of regional, national, and global importance.

The observer of the Pampean landscape identifies an accentuated cultural mark in the green, greenish, and yellowish fields occupied for about 350 years by extensive livestock, and today, by the large monocultures that shape this landscape (CRUZ & GUADAGNIN, 2015). Both the look and the vegetation are shaped by the effect of these economic activities. The increase in the number of animals per hectare has put pressure on pasture production capacity, resulting in the selection of species with low nutritional content and the extinction of species with high quality. Since, due to cultural practices forged by pressure from the economic model, the heritage of nature in Pampa has been neglected and forgotten by the inhabitants of the territory, which results in obstacles to the conservation of the identity of its people and of the biodiversity intrinsic to its Ecosystems.

In this sense, to improve adaptation and mitigate the effects of climate variability on agricultural production, there are initiatives to include perennial tree and shrub species in the Pampean agroecosystems, with the purpose of protecting animals and mitigating the effect of thermal stress caused by climate variability. However, the arrangement used is called an island, in which the grove of exotic species is installed in the middle of an area of native countryside, but this grove does not result in an integrated system, nor does it use native perennial tree species. Thus, there is a disregard for the potential of the silvopastoral system for the pampa biome, which is an integrated productive system in which it uses species adapted to the ecosystem in order to increase the productive diversity of the agroecosystem, resulting in wood and non-wood products.

Socio-ecological interactions in the Pampa landscape

Under the perspective of sustainability, agroecosystems have interactions that involve the economic, social, cultural, and ecological dimensions. These interactions are complex and can be expressed in a synergistic or competitive way. Synergistic relationships are positive and competitive, negative for one and positive for the other. The competition dynamics reveals a conflicting demand, that is, the same resource is disputed and generates a usage conflict, commonly called a trade-off. Pampa clearly bears the mark of its evolutionary history, both biological and cultural, which has built a landscape of low resilience that traditional trade-offs emerge. In this sense, we can highlight two conflicts visible in the Pampean territory, one that is related to the dynamics of the landscape and the other to the processes that occur in the soil, both already registered in several landscapes where there is the strengthening of agricultural intensification in the world.

Landscapes have a strategic role in offering ecosystem services and maintaining biodiversity. Human demands on landscapes are multiple and create competition for the same space (VERHAGEN et al., 2018). Monocultural agricultural landscapes have often been optimized to the detriment of biodiversity, which generates a trade-off between the decline in biodiversity and increased demand from agriculture (MEYFROIDT, 2018; SMITH et al., 2012). The main impression vectors of this conflict are the conversion of land use, where the natural biodiversity of ecosystems has been reduced to monocultural systems, without respecting the capacity and aptitude of land use. In the Pampa, this reality is built on the mosaic of the landscape with rice production in the lowlands, soybean, and silviculture in areas of deeper sandy soils.

Still, especially in shallow soils, the overgrazing system in the livestock production of native fields, has led to a decrease in native countryside diversity due to the negative selection pressure and the contamination of waters and soils due to the strong demand for anti-parasitic control.

In the composition of the landscape, soils play a strategic role as the system's organizer. They are non-renewable natural resources of great importance for life on Earth, both for the ecosystem services they provide, and for being the source of food for most living beings, including humans (CABRERA-DÁVILA, 2014; FAO & GTIS, 2015). The biological diversity existing in the soil, called edaphic fauna, induces its functioning, that is, it offers conditions for the maintenance of ecosystem services inherent in the soil. In this sense, soil functionalities can have a double classification, that is, it can be both a support service, because of the nutrient cycling process, as well as provision, due to the promotion of productivity. Research is demonstrating that the decrease in soil organic carbon, the reduction of microbial biomass and nutrient cycling, resulting from the predominant model of agricultural intensification, has exhausted the soil's ecosystem services, including generating a disservice to the system (GARCIA et al., 2018; WILLIAMS & HEDLUND, 2014).

Under this view, it is highlighted that in agricultural intensification systems under the technological focus, a trade-off is reported between support and provision services, that is, as there is an increase in productivity there is a decrease in the capacity of soil cycling. Biodiverse systems offer a path that combines ecological synergy and economic benefits as they promote the functioning of the agroecosystem, guaranteeing essential ecosystem services, such as soil fertility, productivity and resilience. In this sense, they are systems where the increase in productivity does not occur at the expense of soil support services or the depletion of landscape biodiversity.

Scientific and political initiatives need to consider ecological and agronomic perspectives under the management approach of agricultural landscapes, considering the functional relationships between biological diversity and agricultural productivity (MASTRANGELO & GAVIN, 2012) promoting agricultural intensification under an ecological approach. Williams & Hedlund (2014) highlight that the most prevalent factor in productivity is the heterogeneity of the landscape. Thus, it is highlighted that with the SAFs there is an opportunity to promote synergies especially from the promotion of biodiversity and local knowledge for adaptation to the territory.

CONCLUSIONS

As you understand how this system can work as synergic method using the agroecology as knowledge resource, there is the perception that all the comprehension in ethnoecological is organized by productive agroecosystems. In this way, all the popular knowledge about the management in pasture, livestock rearing, soils and weather in Pampa biome represent the democratization of the agroecosystem’s biome. The intense ecological work that promotes a dialogue between the theoretical and practices could be intensify in agroforestry, that enhance the animal welfare and reduce the antiparasites in the livestock management, promote an autonomous operation from the fruitful systems, in addition new designs more compatible to soya and silviculture. One of the hindrances that should be overcome, is the energy that demands in the reorganization of systems, that now are too simple to complex systems. All this effort is to reorganize and regroup the current knowledge, and also promote the present design transition to a stable one.

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WCCLF 2021
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THE POTENTIAL OF NATURAL SHADING PROVIDED BY BRAZILIAN SAVANNA TRESS FOR THE THERMAL COMFORT IN AGROFORESTRY SYSTEMS

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ABSTRACT

The concern of climate change effects to the ecosystems and livestock activities increases the mitigating tools search, as the agroforestry systems, aiming to better understand the thermal comfort provided by trees shading in different ecosystems. Therefore, this study estimated the potential of thermal comfort by four different Brazilian Savanna native tree species and the association between physiological responses to the environment, as the leaf temperature. Evaluations were carried out in 2020 summer, with collection of microclimate variables, which, the Mean Radiant Temperature (TMR, °C) was calculated from the shading and unshaded place, to estimate the thermal comfort index, Radiant Heat Load (RHL, W m^{-2}). Solar radiation was estimated by the sum of direct, diffuse, and reflected components (W m^{-2}). The shading of species reduced the values of meteorological variables as dry bulb and black globe temperatures, to values under the thermal comfort, with average reduction respectively equal to 1.3°C and 6.4°C, with significant difference in unshaded place and between species ($P<0.05$), reflecting TMR and RHL lower values in shading provided to animals, with respective reductions of 27,4% and 15,4%. These results demonstrate the potential of native tree species from Cerrado to provide adequate levels of thermal comfort in agroforestry systems.

Key words: Agroforestry; native trees; Cerrado

INTRODUCTION

Climate change is one of the biggest current concerns in livestock production as well as the effects on health, well-being, and productivity (LACETERA, 2019). As the world population grows, estimated to reach 9 billion people by 2050, the production of animal protein will have to increase by more than 200 million tons per year according to data from the United Nations (UN) and the United Nations for Food and Agriculture (FAO) (FAO, 2016), and consumer pressure for animal welfare and conservation of the environment must be considered together. In view of this, meeting these pressures and demands becomes one of the main challenges, with an increase in the search for systems such as agroforestry and outdoor animal husbandry systems, due to their potential to reconcile sustainable development and productivity (BROOM, 2017).

However, in these systems, animals are more likely to suffer from variations by meteorological parameters such as temperature and relative humidity, solar radiation and wind speed. These when at their extremes take homeothermic animals (which must maintain their body temperature relatively constant in the face of environmental fluctuations), to thermal stress conditions, which negatively affect health and welfare, which in turn compromises productivity and the quality of life (COLLIER and GEBREMEDHIN, 2015; GONZALES-RIVAS et al., 2019). For this reason, it is necessary to provide shade and adequate shelter for the animals, especially in regions of tropical climate where the incident solar radiation regime is rigorous throughout the year (DA SILVA and MAIA, 2013), as observed in Brazil, one of the largest animal protein producers and exporters in the world (ZIA et al. 2019). The production of these animals is developed in different Brazilian ecosystems, where most of them are raised on pasture (MILLEN et al., 2011). The regions of Brazil with the highest animal production in pastures occupy the territory of the Cerrado, the 2nd largest biome in the country, which ends up causing deforestation in part of its areas (FAUSTO et al., 2014). Given this scenario, it is essential to adopt measures and systems that contribute to the recovery of degraded lands and atmospheric carbon sequestration, thus reducing the impacts and pressure of animal production on the Cerrado, which leads to measures such as the use of native trees in productive systems. Studies conducted by Karvatte Jr. et al. (2016), Oliveira et al. (2017), and Mós et al. (2020) in agroforestry systems reported that the native tree species from Cerrado provides better thermal comfort to animals compared to systems without the use of others shading resources. However, they did not describe the effects of different species of trees on the thermal comfort of these animals and did not characterize their effects on soil temperature, along with the biophysical parameters of native species.

Therefore, it is essential to evaluate the potential of native Cerrado trees not only as a source of shading for animals but also for their derived products, especially when considering the climate projections that they estimate increases in air temperature, declines in precipitation and longer periods of drought, which will consequently impact animal production (COLLIER et al. 2019). Given these statements, this study aimed to assess thermal comfort from different native tree species from Cerrado and its potential to provide a better microclimate to animals and promote their selection and incorporation into livestock systems.

MATERIAL AND METHODS

The experiment was conducted in the conservation experimental area from *Água Limpa Farm* of the University of Brasilia (UnB) where is present an agroforestry system. In the sector, four native trees of the Brazilian Savanna were evaluated and selected by crown shape, as previously described by Da Silva e Maia (2013): Gomeira (*Vochysia thyrsoidea*) – inverse conic crown, Pequi (*Caryocar brasiliense*) – lentil-shaped, Lobeira (*Solanum lycocarpum*) – lentil-shaped and Sucupira (*Pterodon emarginatus*) – spherical crown. From each native tree species was measured the physical dimensions to estimate trees shade area and proportion, from proposed formulas by Silva (2006), recommended to arboreal species from tropical regions, in the year months at midday.

The evaluations were conducted between spring and summer, in 10-minute intervals from 09:00 a.m. to 04:30 p.m. with the collection of the dry, wet bulb (°C), and black globe temperatures from the shade of the trees and in the sun (°C) with the aid of a black globe thermometer (model Protemp-2, Criffer) in 80cm above ground. The relative humidity (RH, %) was calculated from the wet and dry-bulb temperatures. The wind speed (U, m s^{-1}) and short-wave radiation (SR, W m^{-2}) were collected by the automatic weather station (Vaisala, RW1200).

The soil temperature covered by those trees (°C) and soil temperature exposed to the sun (°C) were measured with the aid of an Infrared Thermometer (model TD-960, ICEL), as well as the temperature of adaxial and abaxial sides of leaves (ºC) and characterized with the aid of a Thermographic Camera (Testo, Number 865) each 30 minutes intervals. From the black globe temperature, the Mean Radiant Temperature (TMR, °C) derived from selected trees and in the sun was calculated, from this the thermal comfort index, Radiant Heat Load (RHL, W m^{-2}) were calculated. The data were submitted to statistical analysis with the aid of the SAS program (Statistical Analysis System version 9.2) according to Littell et al. (1991). This enabled the best distribution of data related to the normal pattern, organization of files and statistics of analysis of variance, dispersion, association, and central tendency, based on the method of least squares (HARVEY, 1960). The significant averages were developed by the Tukey test, at 0.05 level of significance. The analysis of variance was performed using the statistical model:

$$Yijk = \mu + Di + Sj + Tk + eijk$$

Where Yijk is the ith observation of the meteorological variables studied; μ is the parametric mean; Di is the effect of the ith day (i =1,…, 11); Sj is the effect of the -jth schedule (j =8,…, 16); Tk is the effect of the kth tree (k = Pequi, Gomeira, Sucupira, Lobeira); and eijk is the random error.

RESULTS AND DISCUSSIONS

The mean air temperature (Tar, °C) observed under the shade of the trees was 29.12 °C, and its highest values were observed at 11:30h, 13:00 and 14:00, (30.78 ± 0.21 °C, 30.06 ± 0.04 °C and 29.71 ± 0.03 °C, respectively), which corresponds to the thermoneutrality zone of a great part of homeothermic mammals and birds according to Riek and Geiser (2013) and Scanes (2015), with an upper critical temperature average fluctuating from 29.0 to 33.7 °C. The air temperature of the species *C. brasiliense* was the lowest compared to other tree species, with an average of 27.4 °C ($P<0.05$). The mean values of relative humidity (RH, %) observed in the shaded microclimate from *V. thyrsoidea*, *C. brasiliense*, *P. emarginatus* and *S. lycocarpum* were respectively 67.40 ± 0.38%; 50.00 ± 0.53%; 65.00 ± 0.37% and 64.92 ± 0.38%, described as optimal values for thermal comfort as described by the National Research Council (2011), that indicates a range between 30 and 70%. The shade projected by the different tree species showed a statistical difference ($P<0.05$) on RH, between *V. thyrsoidea* (67.4%) and *C. brasiliense* (50%). The mean RH observed in the unshaded microclimate was 39.16%. The variation in RH throughout the day was inversely proportional to the air temperature.

It was observed that *C. brasiliense* was able to keep the TMR stable throughout the day, showing no statistical difference in relation to the evaluated schedules ($P>0.05$). There was no statistical difference ($P>0.05$) between the other species in relation to TMR, presenting higher values in comparison to *C. brasiliense*, which may be associated with the morphological characteristics such as a higher leaf density, which results in lower temperatures, a parameter also observed by Karvatte Jr. et al. (2016) and Oliveira et al. (2017), in other tree species from Cerrado. Figure 1A. presents the means of Mean Radiant Temperature and Radiant Heat Load from the shading by native tree species and in unshaded place among the hours. The most unfavorable thermal conditions were observed between 11:00h and 14:00h.

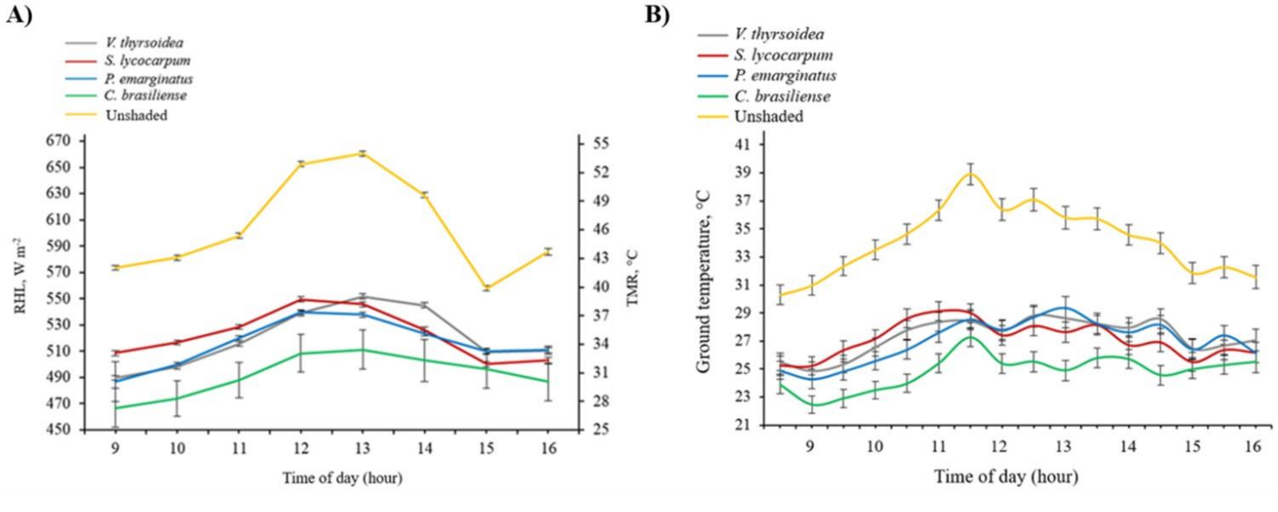

Figure 1. (A) Averages of Radiant Heat Load (±SE, W m^{-2}) and Mean Radiant Temperature (TMR, °C) from the unshaded and in the shaded place by native tree species of Brazilian Savanna (*C. brasiliense*, *V. thyrsoidea*, *P. emarginatus*, *S. lycocarpum*) and (B) the temperature from shaded by each species and unshaded soil (°C), along the experimental hours, from 9:00 h. to 16:00 h.

The average solar radiation observed was 1170.89 W m^{-2}, which exemplifies the significant amount of radiation that the animals are susceptible to when in unshaded place. There was a statistical difference for RHL between the days and schedules ($P<0.05$), with means observed in the shade and in unshaded place, respectively, of 503.61 ± 2.60 W m^{-2} and 595.13 ± 2.56 W m^{-2}, which results in an average RHL reduction by shading native species of 18.17%. In the *V. thyrsoidea*, *S. lycocarpum*, *P. emarginatus* and *C. brasiliense* tree species, the averages were equivalent to 509.17 W m^{-2}, 513.09 W m^{-2}, 505.47 W m^{-2}, 486.66 W m^{-2}, respectively. The RHL means from native tree species were lower at schedules of higher temperature with a value to 501.33 ± 15.47 W m^{-2} compared to the sun (657.07 ± 2.07 W m^{-2}), attenuating the incidence of RHL at these schedules in 31.06%, a similar value was reported by Karvatte Jr. et al. (2016) and Pezzopane et al. (2019). The RHL average observed in the shading from *C. brasiliense* was close to the value described by Mós et al. (2020) as ideal for the thermal comfort of sows in free-range systems of 491.93 ± 25.13 W m^{-2}.

A 17% decrease in the radiant heat load in an Integrated Crop-Livestock-Forest System as reported by Giro et al. (2019), allows cattle more rumination time, reduced body temperature and more idle time, associated with welfare condition. The mean temperature of the unshaded soil (°C) and the shaded soil (°C), by the tree species evaluated according to schedules are shown in Figure 1B. The mean temperature from shaded soil was 26.40 °C, reaching the highest value at mid-day. It was observed that the mean shaded soil temperature from *C. brasiliense* was the lowest among tree species ($P<0.05$). The unshaded soil temperature not showed statistical difference between the species ($P>0.05$), showing a high value, which can contribute to a thermal load on the animal in more than 400 W m^{-2} as described by Kelly and Bond (1971). The *C. brasiliense* had the highest unshaded soil temperature at midday with an average of 41.5 °C, while the shaded soil at the same hour we observed 27.2 °C, with a difference of 14.3 °C, which can allow the animal a longer period of rest and idle, for example, maximizing heat loss flows with the soil, what potentiate the conduction heat transfer mechanism.

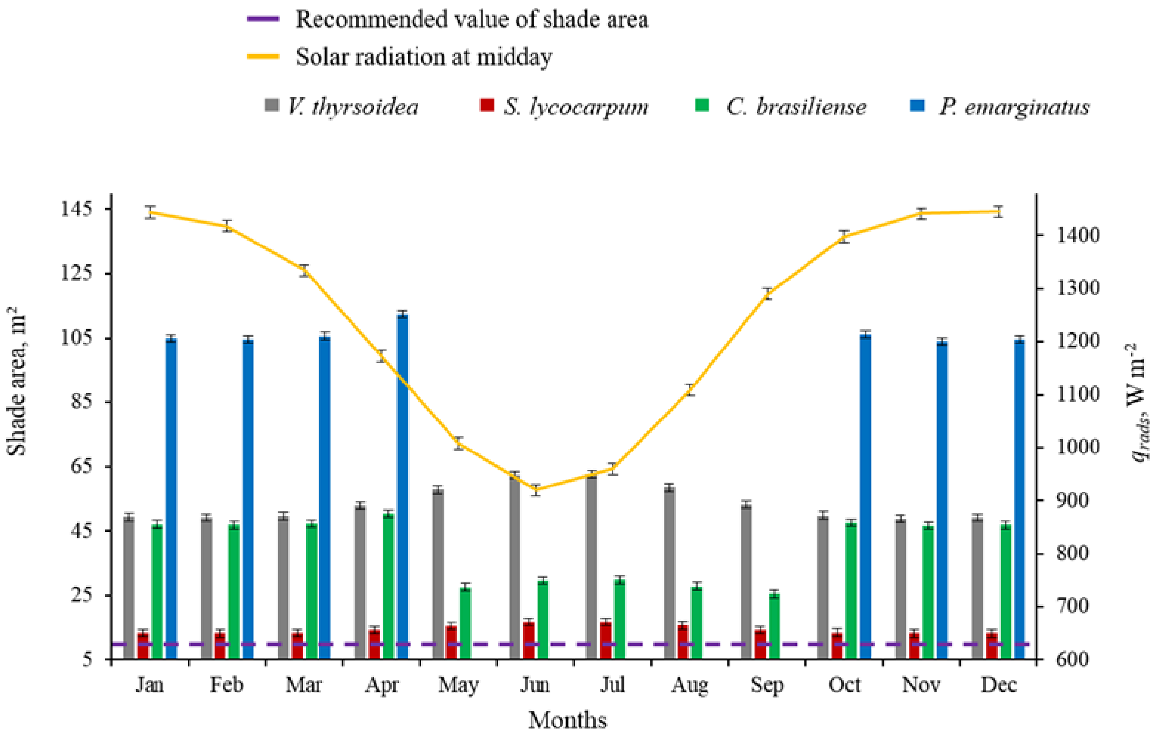

Figure 2. Solar radiation (q_{rads}, W m^{-2}) and estimated means of the shaded area from tree species (*V. thyrsoidea*, *C. brasiliense*, *S. lycocarpum* and *P. emarginatus*) with foliar phenology considered, at midday along the year months.

The abaxial leaf surface (intern) and adaxial leaf surface (extern) temperatures, with respectively means 26.6 °C and 26.8°C, did not show statistical differences ($P>0.05$) between trees species, schedules and days, their temperatures were maintained constant along the hours in all the species. The *V. thyrsoidea* adaxial leaf surface temperature at midday differed from the *C. brasiliense* and *S.*

lycocarpum ($P<0.05$). In qualitative aspects, the shade provided by those native tree species showed differences in the shade area and length, along with the phenology. The shade area average of *V. thyrsoidea*, *S. lycocarpum*, *C. brasiliense* and *P. emarginatus* was respectively (166.5 m^2, 22.3 m^2, 75.3 m^2 and 79.1 m^2). *C. brasiliense* and *V. thyrsoidea* did not differ in shading area ($P>0.05$). The *P. emarginatus* and *V. thyrsoidea* showed the highest values of shaded area with averages of 166.5 m^2 and 79 m^2 respectively, which allows more animals per shade area. Some authors recommended shading area values of 5.6 m^2 and 9.6 m^2 per animal to provide adequate space between animals and air movement (ALVES et al. 2015; SCHÜTZ et al. 2010). There was no difference ($P>0.05$) in the average temperatures of the leaf surfaces (abaxial and adaxial), between the tree species and evaluated days, and their temperatures were kept below the Tar. The temperatures from the adaxial surface of the leaf of *V. thyrsoidea* at midday only differed from the species *C. brasiliense* and *S. lycocarpum* ($P<0.05$), presenting a value near to Tar, possibly due to the stomatal closure at this time of high temperature, avoiding the loss of water to the environment by evapotranspiration (LAMBERS and OLIVEIRA, 2019). The shade provided by species showed differences in relation to the shading area and length, together with the phenology that allows adequate shading area throughout the seasons (Figure 2). Estimating the averages from shading area of *V. thyrsoidea*, *S. lycocarpum*, *C. brasiliense* and *P. emarginatus* over twelve months at midday (the time with the highest incidence of shortwave radiation), we obtained 53.61 m^2; 14.39 m^2; 51.10 m^2 and 114.02 m^2, respectively.

The trees *C. brasiliense* and *V. thyrsoidea*, with semi-deciduous phenology (partial loss of their leaves in winter) and perennial, respectively, do not differ in the values of shade area over the year months ($P>0.05$). *P. emarginatus* with the shape of the canopy being spherical showed the highest values of shaded area with averages at midday of 114.02 m^2, which allows a greater number of animals per shaded area; however, as it is a deciduous species, in the months corresponding to the dry winter season (May to September) loss the leaves, which is an unfavorable aspect, since even in these months high levels of solar radiation are observed. However, the *V. thyrsoidea* species, which presents a conical-inverse canopy, has an average shade area at midday of 53.61 m^2 throughout all months of the year, without losing of leaves, thus allowing constant shade, and revealing the importance of having different tree species in the same system. In contrast, *S. lycocarpum*, with a lentiform shaped crown, had a lower shaded area value compared to other species equal to 14.39 m^2, however, being a perennial species, it keeps its leaves throughout the year. Thus, showed that the use of species evaluated can provide adequate shade area along the year season to a certain number of animals.

CONCLUSIONS

This study, based on the microclimate data of four different native tree species from the Cerrado biome, during the summer season, demonstrates the potential of their shading, and parameters such as leaf temperature and shade area provided, to reduce variables such air temperature and the Radiant Heat Load, which indicates the importance of its conservation and implementation in extensive systems, especially in tropical climates, to provide thermal comfort to animals and adding welfare, besides being fundamental pieces for sustainability. The results also suggest a greater potential to provide thermal comfort from the species *C. brasiliense*, the Pequi, which obtained a greater difference between the other species in the reduction of average values of Radiant Heat Load, air temperature and soil temperature.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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MICROCLIMATE AND THERMOREGULATION OF LAMBS DORPER X SANTA INÊS RAISED IN TWO DIFFERENT PRODUCTION SYSTEMS: A CASE STUDY

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ABSTRACT

The objective of this research was to evaluate whether the silvopastoral system interferes in the microclimate and thermoregulation of Dorper x Santa Inês crossbreed lambs in subtropical climate. This study was conducted in an experimental station in humid subtropical climate. Sheep were evaluated during the months of January and February 2017 in two rearing systems: silvopasture (SP) and in open pasture (OP). Each environment had six replicates, totalling 12 animals. Temperature and relative humidity were recorded. From these variables, thermal comfort indexes were calculated. To evaluate thermoregulation, the variables measured were rectal temperature, mean surface temperature and respiratory rate. For the analysis of microclimatic data and thermoregulatory variables, mixed modelling was used. The silvopastoral system attenuated the air temperature in relation to the full sun (31.1 and 32 ºC, respectively), but in the hottest hours of the day the air temperature was above the thermal comfort zone for the lambs in both environments. There was a difference ($P<0.05$) between treatments for respiratory rate responses (98 and 128 mov. min. $^{-1}$) and rectal temperature (39.5 and 39.8 ºC), respectively. Despite the high temperatures in both production systems, the lambs kept in the silvopastoral system showed higher heat dissipation efficiency.

Key words: biometeorology; sheep production; welfare

INTRODUCTION

Regarding the animal production in extensive farming systems, one of the major obstacles are the climatic challenges to which animals are subjected. The thermal stress stands as one of the main limiting factors of sheep production, which results from the exposure of the animal to an unfavorable environment, causing damage to their homeostasis (AL-HAIDARY, 2014). In addition, this factor may negatively influence the food intake, weight gain, reproductive rates and production of milk and meat (NÓBREGA et al., 2011). In extreme weather situations such as, high air temperature and relative humidity and direct solar radiation incidence, sheep adopt adaptive measures to reduce the stress. Among these are physiological and behavioural responses to get thermal balance. Assess the physiological parameters, such as the respiratory rate, and rectal temperature, this might evidence the tolerance to the heat stress (ALMEIDA NETO et al., 2014). Thus, it is necessary to assess the black globe temperature and humidity index (BGHI) estimated by Buffington et al. (1981), because it expresses the combined effects of thermal energy and encompasses the radiative factor (SILVA, 2008). In addition, the radiant thermal load index (RHL) aims to evaluate the radiation heat exchange between the animal and the environment. In this context, the silvopasture system (SP) stands out compared to conventional systems, because it reduces the environmental impact, increases the diet of animals due to the greater amount of crude protein (BOLAÑOS et al., 2014) and reduces the environmental effects. Furthermore, the improvement of microclimate is observed, which reduces the temperature and increases the relative humidity of the air (MARECHA; ANGULO, 2012). The aim of this work was to assess whether the silvopastoral system influenced in the microclimate and the thermoregulation of lambs Dorper x Santa Inês.

MATERIAL AND METHODS

A trial was conducted between January and February 2017, in the experimental farm of Federal University of Technology – Dois Vizinhos Campus, located at the Southwest of Paraná State, Brazil. The predominant climate of the region is Cfa type – humid subtropical, according with Köppen, with lower temperatures between -3 and 18 °C (ALVARES et al., 2013). An adaptive period was considered in this study, 41 days before the trial beginning. Five microclimate and thermoregulatory trials of animals were realized, in random sequence of days, without rain.

Animals and treatments

Male uncastrated crossbreed Dorper x Santa Inês lambs (n = 12) was assessed in this study, with an average age of 4.5 months and average initial live weight of 20 kg. The animals were submitted to two treatments, corresponded to raising environment: silvopasture system (SP), with louro pardo (*Cordia trichotoma* (Vell.) Arrab. ex Steud.) and the second one was an open pasture (OP). Both treatments had experimental area divided in paddocks, tree equal parts of 400 m². The animals were kept in pasture (*Panicum maximum* Jacq cv. Aruana) in both treatments and supplemented with 1% of concentrated related to the live weight and received the same amount of mineral salt.

Microclimate assessment

The environmental microclimate of SP and OP was assessed through the measurement of the following variables: air temperature (Ta, °C), black-globe temperature (Tg, °C), wind speed (WS, m s^{-1}) and relative humidity (RH, %). These variables were measured in each minute interval, for 12 hours (7h00 to 19h00). These was registered by a U12 – 013 data logger (Onset Computer Corporation, Bourne, MA, USA) with two external channels. with the external used to couple a thermocouple cable with a black-globe probe. This device had a temperature range of -20 to 70 °C and relative humidity from 5 to 95%, with a precision of ±0.35 °C from 0 to 50 °C. For ambient relative humidity, the precision range was ±2.5% from 10% to 90% to a maximum of ±3.5%. Wind speed was measured using a portable digital propeller anemometer (model MS6252A, Mastech, Guangdong Province, China) with a precision of ±3% from 0.40 to 30.0 m s^{-1}.

Thermoregulatory variables

The thermoregulatory variables used in this study was the rectal temperature (RT, °C), hair coat surface temperature (ST, °C) and respiratory rate (RR, breaths per minute). These are measured in 9h00 and 15h00, approximately, during the trials.

The RT was measured through a clinical thermometer, introduced directly in the animal's rectum, kept for two minutes. The RR was determined by direct auscultation of bells for 30 seconds, with a flexible stethoscope, located at the laryngotracheal level and the result multiplied by two, which reflects the breaths per minute.

For the ST measurement, an infrared thermometer with laser sight. To obtain a straightforward measure of ST, this was measured in five distinct points in the animal's body surface (head, neck, back, ribs and legs). After this procedure, an average of these temperatures was obtained, to resume in the hair coat surface temperature.

Thermal comfort indexes

After these measures, the black globe temperature and humidity index (BGHI) was calculated, using the equation according with Buffington et al. (1981):

$BGHI = Tg + 0.36 \times To + 41.5$

Tg – black-globe temperature (ºC).

To – dew-point temperature (ºC).

The radiant heat load index (RHL) was determined using equation proposed by Esmay (1978):

$$RHL = \sigma (MRT)^4$$

RHL = determined in W m^{-2}

σ = Stefan-Boltzman constant (5.67 x 10^{-8} W m^{-2} K^{-4})

MRT = mean radiant temperature, K.

The MRT can be obtained through the following equation (Bond et al., 1954):

$$MRT = 100.\left\{\left[2.51.\sqrt{WS}.(Tg - Ta)\right] + \left(\frac{Tg}{100}\right)^4\right\}^{1/4}$$

MRT is given by K and wind speed (WS) in m s^{-1}.

Statistical analysis

The experimental design used in this study was the split-plot design. The daily hours were considered the main plot and the treatments as subplot. Mixed models were used for each one of the variables. The daily hours and treatments were considered fixed effects and random effects the interaction with days and daily hours. The models were adjusted using the software R and the lme4 package (BATES et al., 2015).

RESULTS AND DISCUSSIONS

The results of air temperature and relative humidity in both studied environments are expressed in Table 1.

Table 1. Average values (mean ± SE) of air temperature (Ta), relative humidity (RH), black globe temperature and humidity index (BGHI) and radiant heat load index (RHL) between the farming systems (OP – open pasture; SP – silvopasture system) throughout the daily periods.

Hours (h)	Ta (°C)		RH (%)		BGHI		RHL (W m^{-2})	
	SP	OP	SP	OP	SP	OP	SP	OP
9:00 – 11:00	24.8±0.5Bb	26.7±0.3Ab	77±1.6Aa	71±1.6 Ba	75±0.6Bb	82±0.6Ab	472.4±2.9Bb	576.0±10.6Ab
14:00 – 16:00	31.1±0.8Ba	32.0±0.8Aa	58±3.7Ab	55±3.8 Bb	83±1.1Ba	87±1.3Aa	542.9±16.7Ba	631.1±28.7Aa

Means followed by same letters, lowercase in columns and uppercase in rows, do not differ by Tukey test at 5% probability.

There was a variation in air temperature between the periods of morning in the two systems animals in silvipastoril system (SP) and animals in open pasture (OP). The air temperature in OP was higher in relation to the SP, also within the periods. The relative humidity was higher in the morning, in the two systems evaluated ($P<0.05$). The incidence of solar radiation influences the temperature and air humidity in an open pasture. However, this can also be influenced in shaded environments.

The BGHI values was different between the treatments at silvipastoril and full sun ($P<0.05$), greater in shaded environment (SP) in the mornings, with BGHI equal to 83. However, in the OP, such BGHI values were higher to the SP in both periods of the day (morning and afternoon). The increase in air temperature directly influenced the values of BGHI.

According with Andrade (2006), under environments with BGHI's values nearby 85.5, the Santa Ines' lambs did not showed problems regarding thermal stress, since these animals have great adaptability to harsh conditions. However, in this present study, the BGHI value in OP systems reached 87 and probably these animals were in intense thermal stress (Table 1).

The average values of the radiant thermal load index (RHL) were higher in the afternoon on both treatments. The RHL features to heat exchange between the animal and the environment, which involves the average radiant temperature based in a uniformly black body, to eliminate the effect of reflection (BAÊTA; SOUZA, 2010).

We observed lowest RHL in the silvipastoril system, when compared to OP during the daily period (morning and afternoon). However, despite the shade of the trees protect animals from direct sunlight, heat load received by animal can be significant and should be investigated even in shaded environments (SILVA, 2000).

Leitão et al. (2013), when assessed comfort and thermal stress of sheep in the North of Bahia state, found RHL of 540 W m^{-2} during the hottest period of day (12h00 – 15h00). This value is similar to our findings, during afternoon in SP (542.87 W m^{-2}). In this case, the silvopastoral system was characterized as a comfortable environment for lambs during harsh periods, when compared with open pasture. The presence of trees, joint with pasture, reduced the heat load in the ground, as well as the thermal radiation by surface, thus, resulted in lower RHL values.

Regarding the values of the hair coat surface temperature (ST) and respiratory rate (RR), differences between both groups was observed ($P<0.05$) (Table 2).

Table 2. Average values (mean ± SE) of respiratory rate, rectal and hair coat surface temperature between the farming systems.

Farming systems	**Respiratory rate (breaths min.$^{-1}$)**	**Rectal temperature (°C)**	**Hair coat surface temperature (°C)**
Silvopasture	98±7.3 b	39.5±0.1 b	34.7±0.5 b
Open pasture	128±8.1 a	39.8±0.1 a	36.9±0.7 a

Means followed by same letters, lowercase in columns and uppercase in rows, do not differ by Tukey test at 5% probability.

The highest values were observed in full sun, where the animals were exposed to direct sunlight. The exhibition of sheep under high temperatures increases heat dissipation through the skin through sweating and through dyspnea (MARAI et al., 2007).

The rectal temperate was higher for lambs kept in OP, when compared with SP ($P<0.05$). The rectal temperature represents the average body temperature, higher when the animal is exposed to high radiation environment.

CONCLUSIONS

Based on the results of this study, for subtropical climate regions, we concluded that the silvopastoral system provided better thermal conditions for Dorper x Santa Inês lambs, which showed less thermoregulation efforts to keep in thermal comfort during the hottest periods of summer.

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SHADING EFFECTS ON PHYSIOLOGICAL AND BEHAVIORAL RESPONSES OF SOWS IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEM

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ABSTRACT

This work aimed to compare the shading effects on the sows' responses, through behavioral observation, shading evaluation, meteorological and physiological analysis. In November 2019, sows were evaluated at *Água Limpa* Farm from the University of Brasilia, Brazil. The natural shading from native trees was compared with 80% cloths of black polypropylene, heat-reflective, and both associations, where the dry, wet-bulb, and black globe temperature, relative humidity, wind speed, were collected at one-minute intervals. The soil temperature was measured every 30 minutes. The Mean Radiant Temperature and Radiant Heat Load were calculated. An ethogram was elaborated considering the females' place, posture, and the activity performed. The vaginal and body surface temperatures were measured every minute and ventilation every 20 minutes. The data were statistically analyzed using the least-squares method. The black cloth presented better thermal comfort than trees at some hours, and the cloths association at all ones, which influenced the frequency of use of the artificial shadings which was greater than the use of trees. The soil temperature showed a statistical difference between cloths (P<0.01), with differences of up to 2ºC. The ventilation ranged from 19 bpm to 80 bpm. The females' body surface temperature remained close to 37ºC. The vaginal temperature was constant (37.5ºC) with a slight increase throughout the day. The results demonstrate that the shadings influenced the sows' physiological and behavioral responses.

Key words: Alternative system; swine; tropical climate

INTRODUCTION

The free-range system is an alternative for swine breeders, which can ensure better welfare, once the animals can express their natural behavior (MACHADO FILHO and HOTZEL, 2000). In these systems, the animals are directly exposed to environmental variations, so it is necessary to offer shading structures to avoid stress provoked by extreme conditions. As an option, we have agroforestry systems, which have trees as natural shading for animals (BALBINO et al., 2011).

The swine, being homeothermic animals, depend on an environment with temperature within the limits of thermoneutrality (HANNAS et al., 2000; BÍCEGO and GARGAGLIONI, 2020). In free-range systems, there is a greater difficulty in achieving this requirement, due to the constant direct radiation in animals and the breeding environment. Therefore, natural or artificial shading structures must be provided so that the animals do not undergo thermal stress.

In previous studies, Mós et al. (2020) realized that DanBred sows in free-range systems in the Cerrado, preferentially use the shading of native trees. However, in the hottest hours, the authors noticed an increase in the use of artificial shading, demonstrating that the type of shading influences the choice of animals due to the thermal comfort it provides.

Researches related to the effects of shading on animal behavior in free-range systems are mostly focused on cattle farming (OLIVEIRA et al., 2014; BROWN-BRANDL et al., 2017; OLIVEIRA et al., 2019). However, due to the increase concern about animal welfare, free-range swine systems have growth potential in Brazil, so, there is a need to understand the thermal conditions this type of system and shading structures provided for these animals. Based on this information, the objective of this work was to evaluate the effects of different shading on the behavioral and physiological responses of sows in free-range systems, exposed to tropical environments.

MATERIAL AND METHODS

The project was approved by the Animal Use Ethics Committee of the University of Brasília (protocol nº107/2019 CEUA). The experiment was conducted from November to December 2019 at the *Unidade Demonstrativa de Suínos Criados ao Ar Livre* (UDCAL) of the *Água Limpa* Farm from University of Brasília (Latitude 15º47' S, longitude 47º56' W and altitude of 1080m), located in Vargem Bonita, DF, Brazil.

In the sector, six females were distributed in a double 3 x 3 Latin square design, housed in paddocks in the gestation sector, where each paddock has an area equal to 1000m². The sows received concentrated and balanced feed, pasture, and water ad libitum, in addition to shading structures to protect the incidence of direct solar radiation.

For the evaluation of the shading structures were compared the natural shading of native trees, artificial structures constructed with black polypropylene cloths with 80% shading; meshes of heat reflective material with 80% shading; and the association of both (BLC + HR) built at 2 meters high with measures of 4 meters wide by 4 meters long; and the outdoor environment with direct radiation on animals. For this comparison, the behavior of the animals, the frequency of use of artificial shading and natural shading, as well as the thermal comfort provided by these structures were evaluated. The temperature of the soil exposed to the sun and covered (ºC) by the shade of the structures with the aid of a thermographic camera (model 854, Testo), at 30-minute intervals.

The following meteorological parameters for the characterization of the environment from 8 am to 4 pm every minute were measured throughout the research: dry and wet bulb temperature (ºC); the relative humidity (RH, %); the wind speed (U, m s^{-1}); the temperature of the black globe (Tgn, ºC) in the sun and the shade of each shading structure and the solar radiation (qrads, $W.m^{-2}$). From the temperature of the black globe, the Mean Radiant Temperature (MRT, K) and the Radiant Heat Load (RHL, W m^{-2}) were calculated. From the dry and wet bulb temperature, the pressures were calculated: partial (Pp, kPa) and saturation vapor pressures of the atmosphere (Ps, kPa).

As to evaluate the behavior of the females, an ethogram was elaborated, including the animals' place of staying: 1) in the sun; 2) using natural shading or 3) artificial shading; body posture: 1) standing and 2) lying down, and the activity they were performing: 1) grazing; 2) resting; 3) taking a mud bath; 4) rooting; 5) drinking water; 6) feeding; or 7) rubbing, using the behavioral sampling method.

For the physiological evaluation, ventilation (VT, $breaths.min^{-1}$) was collected, measured by counting the flank movements for 60 seconds with intervals of 20 minutes; surface temperature (Tsur, ºC) from an Ibutton (Model DS1921G, Thermochron) positioned and protected from direct radiation on the animals' back; and vaginal temperature (Tv, ºC) with the aid of a T-cent (Model DST-Centi, StarOddi), placed internally in the sows' vagina.

The data were analyzed statistically with the aid of the program "Statistical Analysis System" (SAS, version 9.2). The analysis of variance (ANOVA) of meteorological variables was performed using the following statistical model:

$$Yijkm = \mu + Si + Dj(i) + Hk + eijk$$

Where Yijkm is the o-th observation of the meteorological variables studied; S is the fixed effect of the i-th site (i=natural shading, HR, BLC, HR+BLC or sun); D is the random effect of the j-th day of collection within the i-th management (i=shading and j=1, …, 18 i=sun and j=1, …, 18); H is the effect of the k-th class of collection hour (k=8, …, 16); μ is the parametric mean and eijk is the random error.

The ANOVA of physiological variables was performed using the following statistical model:

Yijk = μ + Si + Dj + Hk + eijk

RESULTS AND DISCUSSIONS

The average air temperature ranged from 25.56ºC in the coldest hours (8 am) to 29.57ºC in the hottest hours (between 12 and 01 pm) regardless of the shading evaluated. At the hottest time analyzed (01 pm), the natural shading - which differed significantly ($P < 0.05$) from all other shadings, except for the artificial shading constructed with the association of the heat reflective cloths (HR) with the polypropylene (BLC) ($P > 0.05$) - showed a reduction in air temperature of up to 3ºC. Karvatte Jr. et al, in 2016, found similar behaviors in forestry livestock integration systems, with a reduction of up to 8.9ºC in air temperature when native Cerrado trees are used. Despite that, when we compare the MRT of the shading, which represents the thermal sensation of the animals (DA SILVA and MAIA, 2013), it is possible to notice that the structure built with the association of the heat reflective and polypropylene cloths (HR + BLC) reduced approximately 3ºC, decreasing up to 20ºC when compared to animals exposed directly to the sun, while the tree reduced around 16ºC (Figure 1). This shows that, in isolation, the air temperature does not fully characterize the thermal conditions that the different environments provide, requiring parameters that take into account the wind speed, radiation, and relative humidity, such as the RHL calculated from the MRT (DA SILVA and MAIA, 2013). As well as the thermal sensation, the RHL of the HR + BLC shading obtained the best results (457.14 W m^{-2}; Fig. 1), which reduced by up to 31.1% of the load at times of higher temperature (01 pm), demonstrating better comfort to animals.

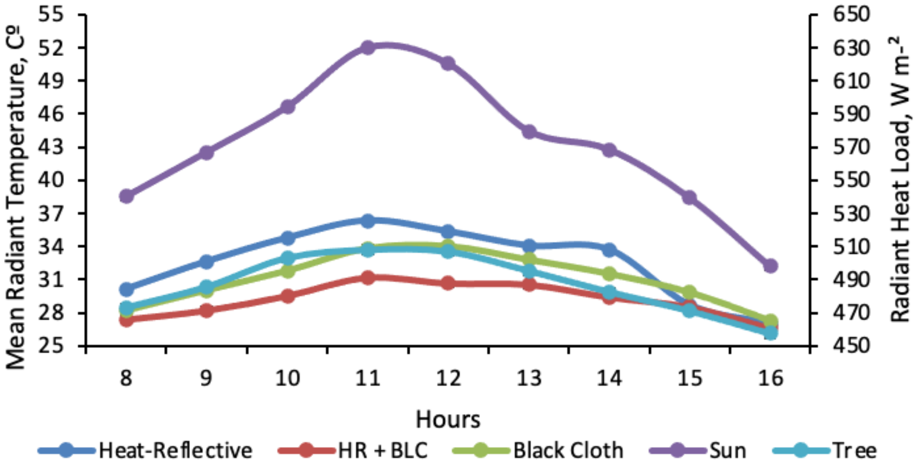

Figure 1. Averages of Mean radiant temperature (TMR, ºC) and Radiant Heat Load (RHL, W m^{-2}).

The average short-wave radiation regardless of the time evaluated, ranged from 218.44W m^{-2} on the mildest days to 640.45W m^{-2} on the hottest days, which indicates a situation of extreme discomfort for animals exposed to the sun. It is important to highlight that during the day temperatures and solar radiation occurred much higher than the average values used, such as in the hottest periods (12 and 01 pm) where the radiation reached 815.43W m^{-2}, and therefore it is necessary to promote some type of shading structure in these systems.

The difference between Ps and Pp ranged from 0.87kPa at milder hours to 1.85kPa at warmer ones. The ventilation of the females followed these results, where the mean VT was 19 breaths min^{-1} in the initial periods, exceeding 80 breaths min^{-1} at noon. The greater the difference between the pressures, the lower the air relative humidity and, with this, the greater the ease for the animals to dissipate heat by latent flows with the increase of the respiration rate and cutaneous evaporation, and for that reason at the hottest hours females likely used more respiratory evaporation in an attempt to lose heat. The wind speed during the days varied from 0 m s^{-1} to 4.4 m s^{-1}, this variation is since the environment is open, where the animals are subject to wind gusts which affect directly the heat transfer by convection. However, in tropical environments, convection becomes inefficient for the thermal balance of pigs due to the high energy gain from short and longwave radiation (MAIA et al., 2005).

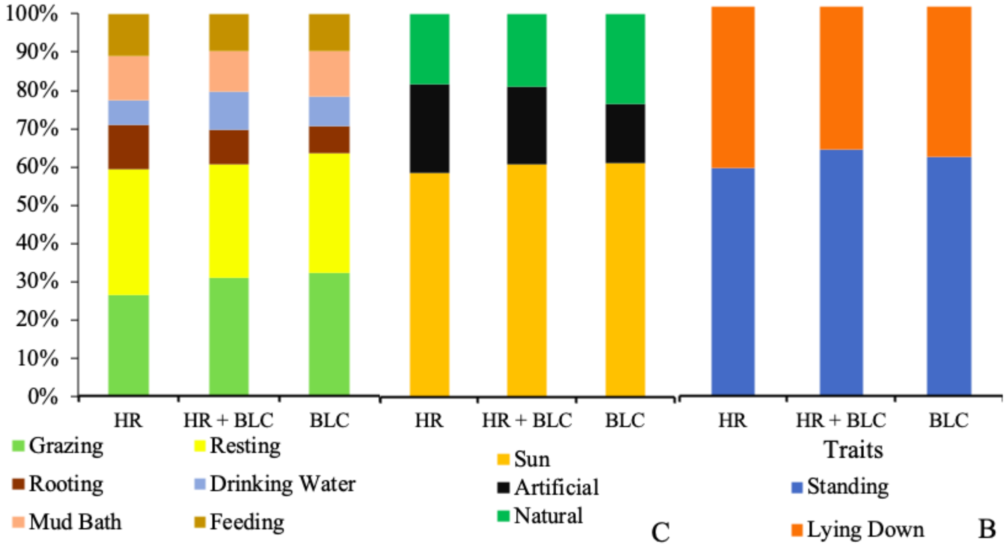

Figure 2. A. Behaviors obtained by the research ethogram; B. Body posture; C. Preferred place of the sows.

Although the pigs have keratinized sweat glands (Ingram, 1965), the presence of the mud helps heat dissipation by cutaneous means. This was observed in the HR shading, which presented the highest MRT values (~36.5ºC), and due to the surface temperature of the females under this treatment be lower (35.85ºC), the long-wave radiation became a way of heat gain, making the balance inefficient, even with heat dissipation by other sensitive flows (convection and conduction) at certain hours. Therefore, the sows spent most of the time lying in a mud bath (Fig. 2A), probably in an attempt to ease this heat loss through skin evaporation to feel more comfortable.

Even with the thermal sensation and RHL values outside those considered ideals according to the estimate made by Mós et al. (2020) in previous studies (Above 32.04ºC and 491.93W m^{-2}), in treatments with HR cloth shading, there was a greater demand for this resource (Fig. 2C) due to the radiative characteristics of the material due to its lighter color, it has a higher radiation reflectance value (DA SILVA, 2008), which favors the dissipation of diffused light and provides a milder soil temperature for places under its shade. This was observed when the temperatures of the exposed and covered soil by the structures were compared, where the HR provided a lower temperature of the soil covered by its shade (26.67ºC), with differences ($P<0.05$) of up to 2ºC concerning the BLC treatment (28.64 ºC). That is why, in HR, the sows were more concerned with the need to dig through the soil more frequently (Fig. 2A) in an attempt to dissipate heat by conduction through the contact of the snout with the milder temperature soil. It was also possible to notice that the females remained most of the time at rest, consuming little pasture during the day, and for this reason, they appeared to be feeding ration more often.

Most of the sows regardless of the day analyzed, appeared more often standing (56%) (Fig. 2B), due to the activities they performed (Fig. 2A). However, the females housed in the paddocks with the HR treatment appeared lying down (41%) more often than the females of the BLC and HR + BLC treatments (36% and 38%, respectively). This behavior was promoted by the lower temperature of the soil under this structure in an attempt to lose heat, since the average surface temperature of all sows was close to 37ºC, which indicates the possibility of dissipating heat by conduction to the soil that was with lower temperature (~26ºC), thus avoiding the activation of mechanisms that demand greater energy expenditure, such as respiratory evaporation.

The BLC structure also showed MRT and RHL values outside the ideal condition range for sows, and therefore, there was little demand for artificial shading by females, with greater use of natural shading. Although BLC absorbs a greater amount of energy due to its dark coloring (DA SILVA and MAIA, 2013), in free-range systems in tropical conditions and with high loads of direct radiation in the environment, these cloths accumulate a large amount of heat, and subsequently release it to the breeding place, increasing the temperature of the environment, and for that reason, animals tend to choose to remain at rest under the shade of the trees that provide greater thermal comfort.

In the paddocks with the structure built from the association of the two cloths (HR + BLC), the sows spent less time at rest and in mud baths (27.89% and 10.16%, respectively; Fig. 2A), and consequently, more time standing in the sun (63.35%; 60.76%; Fig. 2B; 2C). These behaviors were probably due to the thermal sensation of this structure being better, so animals need less time under this structure to feel comfortable dissipating energy, and with this, they can perform more proactive activities such as grazing during the day even under unusual ideal conditions for sows.

The vaginal temperature, which can be equated to rectal temperature (VICKERS et al., 2010) was constant with a slight increase throughout the day (37ºC), regardless of the air temperature variation, which shows that even under extreme temperature conditions, the organism of the sows remains within the expected normality but growing throughout the day. This demonstrates that the females were not under thermal stress, since the expressive increase in the internal temperature in the animals indicates that the heat dissipation flows are insufficient to maintain the homeothermy (FERREIRA, 2012), which was not observed in this trial.

CONCLUSIONS

Preliminary results demonstrate that the different shadings influenced the physiological and behavioral responses of the sows, with emphasis on nets association structure, which showed better thermal conditions than the native tree. The heat-reflective net showed the greatest reduction in soil temperature, and consequently, the animals remained more frequently lying under their shade.

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SELECTION OF SPECIES FOR IMPLANTATION IN LOW-CARBON TECHNOLOGY IN THE BRAZILIAN ATLANTIC FOREST

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ABSTRACT

The Atlantic Forest has a history of agricultural occupation and expansion that changed the original ecosystem, increase loss of native vegetation and degraded areas. By adopting low-carbon technologies, producers can promote food security and contribute to mitigate climate change. This type of technology is practicable through projects such as Sustainable Rural. The success of this type of project is related to the appropriate choice of species for different environmental conditions. Thus, the objective of this work was to identify, from trained specialists and rural producers, the main species for implantation of different low-carbon technologies in the Atlantic Forest, being: Agroforestry Systems (AFS), Recovery of Degraded Area with Pasture (RDAP), Recovery of Degraded Area with Forest (RDAF), Forest Planting (FP) and Management of Native Forest (MNF). 2,020 properties were supported with the technologies, and 376 species of interest were identified. The RDAF and MNF had the greatest diversity of species group. AFS and RDAP concentrated on one main species, Theobroma cacao and Avena spp. respectively. Thus, it is found a listing of species with potential for projects with different low-carbon technologies in the Atlantic Forest, which are adapted to the local market and with economic and environmental benefits.

Key words: climate change; sustainable rural development; sustainability

INTRODUCTION

The Atlantic Forest is an important biome for Brazil, both for being a biodiversity hotspot and for the economic and social function of the region. It is the most populous biome in the country, with 145 million inhabitants (72% of the population), occupying more than 1.3 million km^2 in 17 states (SOS Mata Atlântica, 2019). Despite this, due to its history of agricultural occupation and expansion, there are still continuous trends of alteration of the original ecosystem, marked by deforestation and the degradation of areas (ALVES-PINTO et al., 2017).

After centuries of exploration, only 12.4% of the native vegetation of this biome remains intact, in the form of small forest fragments isolated in the highly anthropized landscapes (SOS MATA ATLÂNTICA, 2019). Therefore, sustainable land use is essential to overcome many sustainability challenges, rural poverty, food security, water use, ecosystem degradation, loss of biodiversity and climate change (ALVES-PINTO et al., 2017; FAO, 2014).

Rural producers can contribute to food security and mitigate climate change, through forest restoration and the adoption of low-carbon technologies with the sustainable intensification of their production (SAGASTUY and KRAUSE, 2019).

There is a need to disseminate the benefits of low-carbon technologies, such as the provision of ecosystem services, so that investors and decision makers can support projects aimed at implementing those systems on rural properties (SILVA et al., 2018). An example of those projects is the Sustainable Rural, carried out in the Amazon and the Atlantic Forest, with the aim of promoting the adoption of low-carbon technologies, through technical assistance, financial incentives and training for rural producers, selection of species and appropriate technologies (ASSAD et al., 2019).

Although there are several studies on the economic and environmental benefits of low-carbon technologies (CARRER et al., 2020), few report the species implanted in these systems, as a way of directing technical assistants and rural producers at the time of choice.

Thus, the creation of a species database can accelerate the success of these projects, especially when the choice is made by specialists, whose training allows the choice of species under different environmental conditions, increasing the success of programs when selecting most suitable species.

In this sense, species were identified for implantation in different low-carbon technologies in the Atlantic Forest, from trained specialists and rural producers.

MATERIAL AND METHODS

The study area is based on the Phase I Sustainable Rural Project (PRS I) carried out with rural producers in the Brazilian Atlantic Forest biome, in 40 municipalities in four states: Minas Gerais, Bahia, Paraná and Rio Grande do Sul. Details of the project can be checked on the website http://mata-atlantica-amazonia.ruralsustentavel.org/ and in the book by Assad et al. (2019).

One of the actions of the project was to identify, support and financially encourage the implementation of low-carbon technology in properties of small (modules less than or equal to 4) and medium (modules between 4 and 15) rural producers. Fiscal module is a unit of measure, in hectares (ha), which the value is fixed for each municipality, taking into account several factors, such as the type and income of predominant activity and others. The supported technologies were: Agroforestry Systems (AFS); Recovery of Degraded Areas with Pasture (RDAP); Recovery of Degraded Areas with Forest (RDAF); Plantation of Commercial Forests (FP) and; Sustainable Management of Native Forests (MNF). Each producer could choose the technology that would be best for their reality, being able to choose the implementation of more than one.

It contemplated 2,020 properties, and the main species of interest for implementation for each technology (AFS, RDAP, RDAF, FP and MNF) were identified according to the purpose of the producer. This choice was made through a participatory methodology, based on the scientific knowledge of Technical Assistance Agents (TAA) trained in low-carbon technology by the PRS team and the perception of the producer involved. Taking into account their knowledge, local market, resources available on the property for proper management and economic and environmental benefits.

It was made a list of species or group of species with the highest frequency for each technology, then, a chi-square analysis was performed to check the significance through the p-value using the R-software.

RESULTS AND DISCUSSIONS

With the project's actions, 2,488 interventions were carried out with the implementation of the AFS, RDAP, RDAF, FP and MNF technologies. But the total of properties were 2,020, thus, the same producer could implement more than one low-carbon technology in his property, in a total area of 10,010 hectares.

The total number of species chosen in all the five technologies was 376, and the main species or group of species most frequently presented in Table 1, which did not present a significant difference (p-value> 0.05) between them.

Table 1. Main species and purposes for the different technologies of the Atlantic Forest biome.

Technology	**Species**	**Frequency**	**Purpose**	
AFS p-value < 2.2e-16	*Theobroma cacao*	859	Almond	Seed
RDAP p-value < 2.2e-16	*Avena* spp.	203	Dairy Cattle	Pasture
RDAF p-value = 0.08699	*Cedrela* spp.	59	Timber	Protection and PPA recovery
	Inga Mill.	56	Environmental conservation	Reforestation
	Swietenia macrophylla	56	Timber	Protection and PPA recovery
	Theobroma grandiflorum	55	Fruit	Reforestation
	Eucalyptus spp.	54	Timber	-
	Tabebuia spp.	43	Timber	Environmental conservation
	Anadenanthera spp.	40	Timber	Reforestation
	Paubrasilia echinata Lam.	39	Protection and PPA recovery	Timber
	Persea spp.	39	Fruit	Protection and PPA recovery
	Hymenaea courbaril	38	Environmental conservation	Timber
	Spondias mombin L.	38	Fruit	Protection and PPA recovery
FP p-value = 0.1011	*Eucalyptus* spp.	28	Timber	-
	Syzygium aromaticum	17	Seed	Grains
MNF p-value = 0.2019	*Anadenanthera* spp.	38	Beekeeping	Timber
	Eugenia spp.	38	Fruit	Seed
	Campomanesia spp.	36	Fruit	Beekeeping
	Araucaria angustifolia	27	Seed	Fruit
	Ilex paraguariensis	23	Fruit	Timber

In the AFSs, it was verified that cacao (*Theobroma cacao*) was the most representative species, being chosen from 859 properties, for the personal use or trade of the fruit and seed (Table 1). The cultivation of oats (*Avena* spp.) was widely indicated as forage for RDAP, being represented by 203 producers to pastures formation, mainly for dairy cattle.

The cacao tree is generally used in agroforestry systems shaded with other perennial and annual crops, and the fruit, seed or wood can be commercialized (SOMARRIBA and BEER, 2011). This species can store high amounts of carbon in its biomass, and carbon credits can be sold (SOMARRIBA et al., 2013), if the carbon market policy becomes strengthened.

The *Avena* spp. is a species widely used for animal feed, especially in the dry season (winter), as it is an alternative to improve the cattle productivity, mainly in southern Brazil (PEREIRA et al., 2020). Supplementation with oat silage is also an alternative when the pasture dry mass productivity is limited and to conserve pasture conditions in the dry season (BURBANO-MUÑOZ et al., 2018).

The two species most used in FP were eucalypts for timber purposes and the clove tree of India (*Syzygium aromaticum*) for the commercialization of its seeds. In RDAF, the group of significant species was more heterogeneous when compared to other technologies, presenting a greater variety. The purposes were diverse too, including wood and fruit, but the main objective was environmental conservation, recovery and protection of Permanent Preservation Areas (PPA).

As in FP, eucalypts (*Eucalyptus* spp.) were one of the most chosen species in RDAF (Table 1). With the RDAF technology it is possible to restore areas, with the establishment of new forest plantations in an already open, unproductive, and degraded areas (BRANCALION et al., 2014). The mixed planting of native forest species is efficient for the recovery of degraded areas, mainly with regard to the accumulation of biomass and carbon stock (SOUZA et al., 2020).

Cedar and Ipe were also species used by producers to recover degraded areas with FP. In a study in the Atlantic Forest, it was observed that these species *Cedrela fissilis* and *Tabebuia impetiginosa* obtained positive responses to fertilization and pest management, promoting positive impacts on the recovery of degraded areas (CAMPOE et al., 2014). It is important to use forest species for the protection and recovery of headsprings and PPA areas for the environmental regularization of properties, and species such as Ingá and Angico (*Anadenanthera* spp.), can be used to this purpose, mainly because of their rusticity (BAGGIO et al., 2013).

On the other hand, eucalypts can serve as a “savings account” due to the commercialization of wood, because this forest species is capable of producing woody biomass quickly and on a large scale (MCMAHON et al., 2019). *Eucalyptus* productivity in Brazil increased as a result of intensified management, improved cultivation practices and the development of fast-growing genotypes (BINKLEY et al., 2017).

In the MNF, the species that stood out, had the purpose of beekeeping, fruits, seeds and wood. Species such as Angico (*Anadenanthera* spp.) and Guabiroba (*Campomanesia* spp.) were used for beekeeping, and araucaria (*Araucaria angustifolia*) for the extraction of their seeds. Others were fructiferous trees, making economic exploitation by the producer possible through the sustainable management of the native forest (Table 1).

The MNF aims to produce material and immaterial goods constantly and continuously over time, with economic benefits for producers and society, allowing to conserve forests and achieve sustainable exploitation (ANDRAE et al., 2018). *Araucaria angustifolia* was one of the native species most used by the project's producers, which is widely exploited in the states of the southern region of Brazil, due to its excellent technological and ecological value, with the commercialization of its seeds (FIGUEIREDO FILHO et al., 2011).

In addition, in the MNF there is the possibility of the sustainable exploitation of fruit trees, as in the case of *Eugenia brasiliensis*, which allows the commercialization of its fruit (LAZARINI et al., 2018). The availability of food and the sustainable use of natural resources are two inseparable themes in the focus of traditional and contemporary societies. That is why rural producers in some regions of the Atlantic Forest consume and commercialize their native fruits, such as pitanga (*Eugenia* spp.) and guabiroba (*Campomanesia* spp.) (SOUZA et al., 2018).

CONCLUSIONS

It was found 376 species in the 2,488 implanted technologies in more than 10 thousand hectares in the Atlantic Forest biome. It was possible to obtain a list of species with high potential for projects with low-carbon technologies in the Brazilian Atlantic Forest. Those species are adapted to the local market and available for the small and medium producers. When using proper management, those species can bring economical and environmental benefits.

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EFFECT OF THE ARBOREAL COMPONENT ON RAINFALL INTERCEPTION IN A SILVOPASTORAL SYSTEM

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ABSTRACT

The use of silvopastoral system has become a viable alternative to agricultural producers as a means of sustainable animal production, and as in every supply chain seeks to achieve maximum productivity with a lower consumption of natural resources. Thus, the objective was to evaluate rainfall interception by the *Eucalyptus grandis* tree component in a silvopastoral system in the northwestern region of the state of Paraná (lat 23º 41' 33" S, long 52º 53' 27" W). Five weather stations were installed at different points in the silvopastoral system: full sun (FS), representing monoculture; C20 and C30 (center of the inter-rows at 20 and 30 m, respectively) and S20 and S30 (positioned below the canopy). Rainfall data were collected for a 29-month period from December 2016 to April 2019. The data were divided into 10-day period and classified as rainy and dry, and then subjected to t-test statistics at 5% significance level. Significant interference of the tree component was observed only in the 10-day period when precipitation was greater than 40 mm, i.e., in the occurrence of heavy rainfall; there was no interference of the different spacing between rows of trees with precipitation less than 40 mm for the northwestern region of Paraná

Key words: Microclimate; Agrosilvopastoral; Thermal comfort

INTRODUCTION

The silvopastoral system allows a safe and sustainable agricultural production, allowing the intensive use of areas and the maintenance of natural resources. It is a management strategy that has been spreading and has proven to be very efficient, especially when well planned, allowing each component (agricultural, livestock, and forestry) to express its best potential for production and profitability, bringing benefits to the environment as a result of diversification, consortia, and rotation (VIARO and CAVICHIOLI, 2017; PORFÍRIO-DA-SILVA, 2015; MICCOLIS et al., 2016; SCHEMBERGUE et al., 2017).

The presence of the forest component, besides carrying out the decomposition and mineralization of organic residues, allows an increase of the organic matter levels of the soil and consequently improvement of its quality. In recent times it has been used as a strategy to reduce deforestation and as an alternative tool in carbon consumption, helping to control the emission of greenhouse gases (CASTRO NETO et al., 2017; TORRES et al., 2014).

Other advantages of its use are related to the reduction of wind speed and evapotranspiration, which provides greater animal welfare as a result of a better acclimatization of the environment (BALBINOT JUNIOR et al., 2018). On the other hand, as the growth and development of trees, there is a gradual reduction in the availability of the system's luminosity, requiring the use of forages that present a greater tolerance to this condition (SILVA et al., 2020).

Thus, there is no ideal type of forest species to be used in the silvopastoral system; it is known that these should be chosen based on the objective and profitability of the producer, in addition to meeting the local edaphic-climatic demands. However, because of the adaptability to the tropical climate and the wide availability of genotypes, the use of *Eucalyptus spp* has stood out mainly for having wide applications (production of fence posts, struts, energy, Sawmill, Coal etc.) and for having and fast growth in a short space of time (DE DEUS RIBEIRO et al., 2017; CORDEIRO et al., 2015; DOS REIS et al., 2020).

In addition to shading capacity another important factor to be considered in the formation of the forest component is its potential for retention and interception of rainfall by the canopy, so that water is lost to the atmosphere before it even reaches the ground (DE ALMEIDA et al., 2019). According to Groppo et al. (2019), the tree canopies of forests formed by Atlantic Forest have higher retention efficiency than forests composed of eucalyptus. However, Galzerano and Morgado (2008), discuss that eucalypts in silvopastoral system are an optimal regulator of the flow of water resources and maintenance of soil moisture, but highlights that in a period of six months, trees can intercept approximately 14% of the average 85% effective rainfall (TONELLO et al., 2014).

Thus, considering the competition for water throughout the silvopastoral system, the work aimed to evaluate the interception of rainfall, by means of the arboreal component of *Eucalyptus grandis* in silvopastoral system in the northwestern region of Paraná.

MATERIAL AND METHODS

The study was conducted in the municipality of Tapejara, northwest region of the state of Paraná, located at latitude 23º 41' 33" S, longitude 52º 53' 27" W and an altitude of 445 m. Climate classified as Cfa, according to Köppen, and soil as Argissolo.

The experiment was conducted from December 2016 to April 2019 (29 months), in a total area of 13 ha of silvopastoral system. The forest used consists of *Eucalyptus grandis*, cultivated since 2007 in simple rows with spacing of 1.5 m between plants and 20 to 30 m between lines accompanying the terraces, at an arboreal density of 333 to 222 ha^{-1} trees. The forage species present in the area was *Megathyrsus Maximus* (Mombassa grass), in a continuous system of grazing of Brown Swiss dairy cattle.

To capture and quantify the interception of rainfall by trees, the TE52MM-L rainfall sensor was installed in five automatic weather stations ref. Commercial Campbell Scientific®. One of them was located in pasture exposed to full sun (FS), characterizing the conventional system of cattle ranching in monoculture. And the other four arranged in shaded pasture, 20 and 30 m between the lines of trees respectively and positioned in the center of the between lines (C20 and C30) and below the canopy (S20 and S30). Stations C20 and S20 were positioned in cross-section to the tree lines whose distance was 20 m, while stations C30 and S30 the distance between the lines was 30m.

At each of these stations, daily accumulated rainfall data were collected every 10 seconds, stored in a datalogger, archived every 15 minutes, and transmitted by GPRS signal every 1 hour. For analysis of the intercepted rainfall data, they were filtered into groups and different time scales. The repetitions of the treatments were the time scale used (10-day period), of which for accumulated rainfall (P), two groups were considered, rainy and dry. Rainy when the 10-day period had $P \geq 40$ mm and dry when $P < 40$ mm. With this, after applying the filters and separating the analysis groups, the results were submitted to the t-test at 5% significance, with the help of the Statistica® program.

RESULTS AND DISCUSSIONS

Figure1 presents the variation of accumulated rainfall (P) in millimeters, for the dry and rainy 10-day period during the 29 months of evaluation of the five stations installed throughout the silvopastoral system.

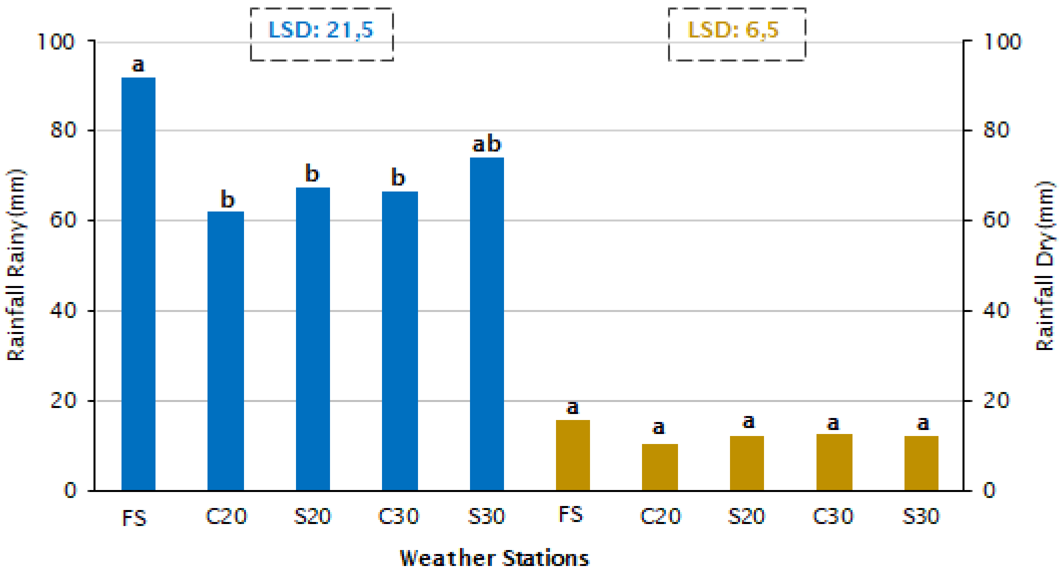

Figure 1. Cumulative rainfall (P), in mm, on the 10-day period scale between the rainy (P≥40 mm) and dry (P<40 mm) weather stations, Tapejara - PR, Brazil by the t- test at 5% significance. * LSD = Least Significant Difference

It was found that there are significant differences only when 10-day period rainfall greater than 40 mm (P≥40 mm) occurred, in the rainy cluster with a maximum reduction of 32.9%. For the dry cluster the results did not show significant differences between the weather stations. That is, there was interference of the tree component in the interception of rainfall only in more intense rainfall, in this case, above 40 mm per 10-day period, indicating that for lower decadal rainfall the tree component does not intercept significant amounts.

For the rainy group, there was a significant difference between the values obtained at weather station FS (full sun) and all the others, except for those recorded at S30 (17.9 mm or 19.4%). It is also observed that there was no significant difference for the 10-day period rainfall between the weather stations located below the canopy and in the center of the between tree rows, C20 x S20 and C30 x S30, respectively, i.e., for the conditions studied, the spacing between tree rows did not interfere in rainfall interception. The lower availability of water in forested systems may also result from the loss by raindrops intercepted by the canopy, which run off the trunks and branches or are evaporated and result in significant water losses (GYENGE et al., 2002; DOUGLAS et al., 2006).

Studies comparing effective rainfall in forest systems in relation to rainfall without interception (Tonello et al., 2014) in *Eucalyptus cloeziana*, *Pinus caribea var. hondurensis* and Semideciduous Seasonal Forest, showed interception of 13.8, 15.0 and 22.8%, respectively, showing similarity with those obtained by this work. In the same line, the estimated interception was 14.5% of precipitation in eucalyptus forest in the southern region of Brazil (SARI et al., 2016).

CONCLUSIONS

The tree component *Eucalyptus grandis* integrated with *Megathyrsus maximus* (Mombasa-grass) in the silvopastoral system caused interception of rainfall only in conditions of intense rainfall, i.e., above 40 mm per 10-day period. There was no interference between the different tree spacing's in the tree rows in rainfall periods of less than 40 mm in northwestern Paraná.

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MAXIMUM TEMPERATURE EFFECTS CAUSED BY THE FORESTRY SYSTEM IN NORTHWESTERN PARANÁ

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ABSTRACT

With the increase in temperature as a result of global warming, rural producers have been looking for more sustainable production alternatives, such as systems that integrate vegetal and animal production. In view of this, the effects on the maximum air temperature in a silvopastoral system composed of *Eucalyptus grandis* forests and *Megathyrsus maximus* forage (Mombasa grass), in a continuous grazing system by Brown Swiss cattle in northwestern Paraná were evaluated. An experiment was developed in the municipality of Tapejara (lat 23º 41' 33" S, long 52º 53' 27" W) over a 29-month period where three weather stations were installed at different points in the silvopastoral system: OS (full sun), C20 (cross section at a spacing of 20 m between rows) and C30 (cross section at a spacing of 30 m between rows). For analysis the data were divided into warm and mild days, and then the results were submitted to statistical t-test at 5% significance level. We observed higher average maximum temperature values for the grouping of warm days, but there was still a reduction of this in areas with higher concentrations of trees. Showing a reduction in the average maximum air temperature in the silvopastoral system in northwestern Paraná

Key words: Microclimate; Thermal comfort; Animal production

INTRODUCTION

In recent times climate change and its negative effects promoted by human action, has been the agenda of great controversy and discussion by all economically productive sectors, but it is in the agricultural sector that has felt the greatest consequences and impacts on the quality and viability of production. With the expected increase in the earth's temperature, there has been an increase in the search for sustainable alternatives by producers and ranchers in an attempt to minimize these effects (CASTRO, 2014; ARTAXO, 2014; SILVA and GUETTER, 2015).

Thus, the implementation of silvopastoral systems in agriculture and livestock has become an important tool for sustainable and effective management in an attempt to counteract the negative effects of climate change. The cultivation of trees of economic interest, associated with animal and forage production, allows the intensive use of the same area providing benefits to soil quality and preservation and a better control of the local microclimate (CZEKOSKI et al., 2017; ARANHA et al., 2019).

According to Silva et al. (2015), it is expected for the state of Paraná an increase trend in temperature extremes, with forecasts and expectations of an increase of up to 0.02 ºC in the heating pattern of the annual averages of minimum and maximum temperatures for the coming years. It is known that high temperatures affect the animal productive performance, since as a strategy to circumvent the heat, their metabolism tends to decrease food intake and focus only on reducing the sensation of heat resulting in reduced weight gain, being this one of the main effects of animal discomfort (ARANHA et al., 2019; OLIVEIRA et al., 2018).

Based on this assumption, the importance of the arboreal component in the system is emphasized mainly in tropical regions. Shade production avoids exposure of animals to sunlight, improves the nutritional value of pastures and allows a better maintenance of moisture in the system, providing a better animal welfare. In addition, at the end of the productive cycle of the trees they can have their wood destined for different profit purposes (ALVES et al., 2017; ALMEIDA et al., 2014; SANTOS, 2019)

In the search to improve the effects of climate change on animal production and temperature control in silvopastoral systems, this work aims to evaluate the effects of variations in the average maximum temperature of the environment caused by silvopastoral systems in the northwestern region of Paraná.

MATERIAL AND METHODS

The experiment was carried out in the municipality of Tapejara, northwest region of the state of Paraná, located at latitude 23º 41' 33" S, longitude 52º 53' 27" W and altitude of 445 m. With climate classified as Cfa, according to Köppen, and soil as Argissolo. In the period from December 2016 to April 2019 (29 months), in a total area of 13 ha of silvopastoral system, with forest formed by *Eucalyptus grandis*, cultivated since 2007 in simple rows with spacing of 1,5 m between plants and 20 to 30 m between lines accompanying the terraces, at an arboreal density of 333 to 222 ha^{-1} trees. The forage species present in the area was *Megathyrsus Maximus* (grass-Mombasse), in a continuous system of grazing of Swiss brown cattle for milk production.

To quantify the effects of the maximum temperature on the silvopastoral system, the temperature sensor CS215 at 2 meters of ground height was used, installed in three automatic weather stations ref. Commercial Campbell Scientific®. The OS station is placed in pasture exposed to full sun, as a witness, and the other two stations, C20 and C30, are placed in the shaded pasture in the center of the lines for two distances between the trees, 20 and 30 m, respectively. At each of these stations, data on the maximum temperature mean were calculated, collected every 10 seconds, stored in Datalogger, archived every 15 minutes, and transmitted by GPRS signal every 1 hour.

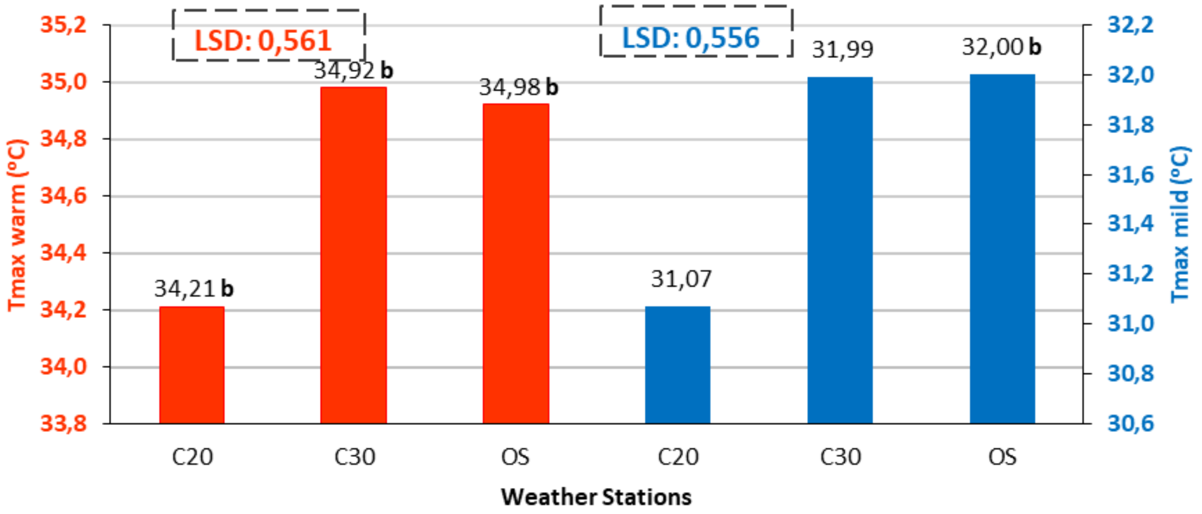
To perform the analysis of the maximum mean temperature, the data collected by the stations were filtered in groups and in differentiated time scales. The repetitions of the treatments being the temporal scales, of which for maximum temperature (Tmax) were considered two groups, Warm and mild. Warm when days showed Tmax greater than 33 oC in months that reached high temperatures, and mild when Tmax greater than 29 ºC and lower than 33 ºC (29 ºC Tmax 33 ºC) in months with mild temperatures.

Thus, after applying the filters and separating the analysis groups, the results were submitted to the t test at 5% significance, with the aid of the Statistica® program.

RESULTS AND DISCUSSIONS

The Figure 1 shows the maximum temperature variation of the air for warm and mild days during the 29 months of evaluation of the three stations installed throughout the silvopastoral system.

The stations in the warm day clustering denoted higher average maximum temperature (Tmax) when compared to the mild day stations, with the highest temperature recorded at station OS, which represents full sun conditions. The lowest mean maximum temperature value was recorded only at the C20 station of the mild day cluster located 20 m away from the tree stands.



* LSD = Least Significant Difference

Figure 1. Maximum air temperature variation (Tmax), in ºC in the warm and mild weather stations, Tapejara - PR, Brazil by t test at 5% of significance.

When the differences recorded for Tmax for the warm and mild clusters are analyzed, the values found at weather stations OS and C30 were not significantly different. Maximum reductions of 0.74 ºC and 0.93 ºC were observed in the warm and mild clusters, respectively.

The C20 station also shows no significant difference in conditions in the grouping warm days, but when compared to the group of mild days the Tmax recorded is higher. The C30 station located at 30 m between lines, however, does not present significant difference in both hot and mild days, but a higher average maximum temperature is recorded for the first group with a difference of approximately 2 ºC.

Even if it is not significant, the results indicate a small reduction in the average maximum temperature in area with a higher presence of trees. According to Roberto (2018) the shading trees in the silvopastoral system affects the local microclimate in different intensity and climatological parameters, but the most impactful is the reduction of temperature by the containment of long wave solar radiation and a greater maintenance of humidity in the environment. Other factors such as solar declination (seasons), tree arrangement and groove orientation may change the local temperature mainly the maximum air temperature values (BOSI, 2014).

Similar results are found by Da Silva et al. (2020), where they affirm that in silvopastoral environments there is a reduction in the maximum temperature as a consequence of the greater interception of solar radiation, even if in different positions of the system. However, they also claim that in points of full sun, due to a lower air movement, there may be an intervention in the air temperature values.

CONCLUSIONS

The use of forests formed by *Eucalyptus grandis* together with *Megathyrsus Maximus* (grass-Mombaça) in the silvopastoral system caused a reduction in the average maximum air temperature in the northwest of Paraná.

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SPATIAL VARIABILITY OF MAXIMUM TEMPERATURE AND CHLOROPHYLL IN AN INTEGRATED AGRICULTURAL-FOREST SYSTEM

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ABSTRACT

The objective of this work was to study the variability of maximum temperature and chlorophyll A in an agroforestry system using the geostatistics technique. This study was carried out in an area of 0.8 hectares with an integrated crop and forestry system managed by Embrapa Agrossilvipastoral in Sinop, MT – Brazil. Results from semivariograms models have shown that maximum temperature had no spatial dependence detected, problaby because of the small size area where this variable seemed constant. Conversely, Chlorophyll A has shown spatial dependence after semivariogram adjustments. It was observed that the highest values of chlorophyll A were located where there were no trees and the lowest maximum temperatures close to the pequi trees, likely due the solar energy availability.

Key words: Geoestatistics; Forestry agriculture system; chlorophyll

INTRODUCTION

The majority of agricultural integrated systems involve various combinations, basically working with the planting, during the summer, of annual crops (rice, beans, corn, soybeans or sorghum) and trees, associated with forage species (brachiaria or panicum). The possibilities of combining the agricultural, livestock and forestry components, result in different integrated systems, such as crop-livestock-forest (ILPF), crop-livestock (ILP), silvopastoral (SSP) or agroforestry (SAF). In this system, the producer benefits from the more efficient use of his resources, obtaining an improvement in the quality of the soil and water with the possibility of decreasing the amount of use of pesticides (BALBINO et al., 2011). However, intense research is being carried out in order to answer questions related to the association of different elements in the integrated systems. For example: Is there spatial temperature variability in systems integrated with the forestry component? Does the photosynthetic activity, which allows, among other issues, the aid in the prediction of nitrogen fertilization (ARGENTA et al., 2001) vary in integrated systems? In this context, the goal of this work is was evaluate the variability of maximum temperature and chlorophyll in an agroforestry systems using the geostatistics technique.

MATERIAL AND METHODS

This study was carried out in an area of 0.8 hectares with an integrated crop and forestry system managed by Embrapa Agrossilvipastoral in Sinop, State of Mato Grosso, Brazil (11°52'26.0"S, 55°35'50.7"W). For the thermal study, the FLIR i7® camera (FLIR, Wilsonville, OR) was used, obtaining thermal images (ºC) in corn plants in stage R4, Caryocar brasiliense (pequi) and mahogany trees, carried out on May 18 of 2017. For the corn samples, three images were captured covering the temperature from the underside of the plant to its canopy. In the mahogany,and pequi trees two images were captured, of the trunk and the top. Subsequently, the average of the measurements of each plant was estimated. All images were collected in the early morning, between 8:30 am and 10:30 am on sunny days. For the thermal image processing, the FLIR Quick Report software was used. A feature of this software allows an area represented by a square to be moved by the user to that area that best represents the target studied. Once the square was positioned, the maximum and minimum temperatures were available.

RESULTS AND DISCUSSIONS

The first step of the geostatistics analysis resulted in the estimation of semivariograms, which express the spatial dependence of the studied phenomenon. A trend was noticed at thesemivariogram estimated to chlorophyll A, after reaching the semivariogram, so the trend was withdrawn using the simplest surface, in this case the linear surface. The adjusted modelwith the least squares error was the exponential (15.8) in relation to the Gaussian (22.2) and the spherical (19.8). At the end of this process, the semivariogram settings were: Nugget effect: 17.3, range: 14.4 meters and 7.9 level. It was observed that the highest values of chlorophyll A were located where there were no trees and the lowest maximum temperatures close to the pequi trees. This result makes sense because where there was more availability of solar radiation, which means, there was conditions to more chlorophyll production. Regarding to the maximum temperature variable, it was observed that the data did not show spatial dependence, that is, the nugget effect was found. This case indicated the spatial random distribution, as the measure that increased the discontinuity at the origin of the semivariogram, the more random became the phenomenon that generated the variable under analysis (STURARO, 2015), making it impossible to apply geostatistics for this variable (Figure 1).

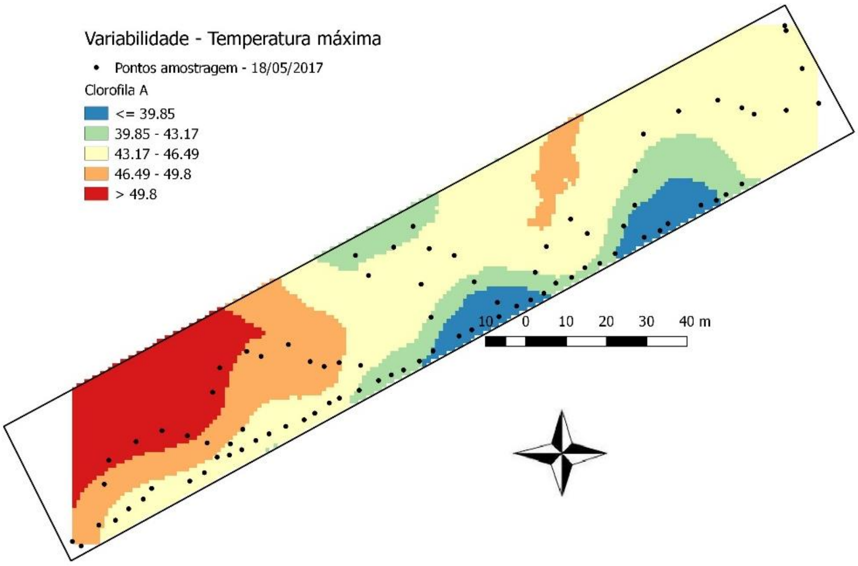

Figure 1. Spatial variability of chlorophyll A values using kriging technique performed by QGIS software.

CONCLUSIONS

The results of this study demonstrated that there was no spatial variability for the maximum temperature in the study area, suggesting that in the small size of the area the temperature remains constant. However, the variable chlorophyll A showed variability, found through the spherical model in the linear residue data. The highest estimated chlorophyll A values were located where there was more availability of solar radiation. For future work it is suggested to intensify the number of samples and that it be done in a predetermined random design, instead of zigzag, to better capture aspects of spatial dependence.

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ANALYSIS OF SOIL TEMPERATURE IN DIFFERENT COVERS OF SECOND CROP CORN IN TRANSITION AREA OF AMAZON AND CERRADO BIOMES

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ABSTRACT

The objective of this work was to evaluate the variation of the average, minimum and maximum temperatures in two (2) type of surfaces: soil with crop residues and straw of Brachiaria and the soil under it or bare soil in two experimental areas at Embrapa Agrossilvipastoral located in Sinop, MT. Those area were managed with conventional cultivation and corn and brachiaria intercropping. Thermal images and GPS locating were used to produce maps of variability using IDW metodology. As expected, results have shown that average and maximum temperatures on the surface with straw were higher compared to temperature under the straw. The difference between maximum temperatures reached 15.5 ºC.

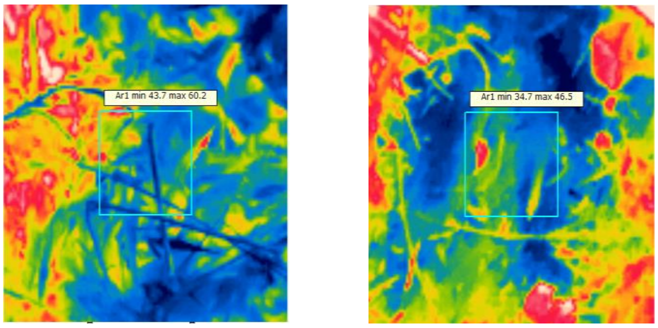
Key words: Agricultural cover; soil temperature; spatial variability

INTRODUCTION

Variations in soil temperature due to different types of agricultural management, such as conventional and no-tillage, affect the local sustainability of the soil. Regarding to soil management, the second crop of corn and *Brachiaria ruziziensis* aims to produce a greater volume of residues, which result in a greater amount of organic matter for biological activity and, consequently, an improvement in the cation exchange capacity (CTC). The CTC enhances the retention of fertilizers in the soil, avoiding its transfer to the water table (TRECENTI, 2011). Conversely, despite being widely used, the conventional system increases the mechanical strength of machines due to the increase in apparent density rates. Also, regarding to soil biology, Dong et al. (2013) study quantified a great diversity of nematodes in no-tillage systems when compared to a conventional corn planting system. Studies evaluating soil temperature are poorly documented, especially in tropical regions. The work of Monneveux et. al. (2006) carried out in Mexico, revealed that the peaks of temperature in the soil in the rainy and dry seasons were between 30 and 33 °C respectively. The objective of this work was to evaluate the variation of the average, minimum and maximum temperatures in two (2) type of surfaces: bare soil and soil with crop and *Brachiaria* residues in two experimental areas with conventional cultivation and corn and brachiaria intercropping.

MATERIAL AND METHODS

The thermal images used in this study were collected in the technological showcase area at Embrapa Agrossilvipastoral located in Sinop-MT (11°52'26.0"S, 55°35'50.7"W). The two experimenal areas encompassed 0.64 (Plot 1) ha and 0.4 ha (Plot 2), respectively, corresponding to conventional crop and forestry integration. The former crop planted in the areas was corn and brachiaria (Plot 1) and Corn (Plot 2). The data sampling was carried out on August 15 (142 samples collected from 2PM to 4PM), 2018; August 30 (216 samples collected from 8AM to 11 AM), 2018; and September 6, 2018 (139 samples collected from 2PM to 4PM). This approach corresponded to two days were sampled in the afternoon and one in the morning. This period in the north of Mato Grosso, still corresponds to the end of the dry period in the region. To acquire thermal images (° C), the FLIR i7® camera (FLIR, Wilsonville, OR) was used. For each chosen point, a thermal image was obtained on the straw surface, normally consisting of corn residues (leaves, trunks), and *Brachiaria. A*fter georeferencing the set of points with Etrex 30® Garmin GPS equipment, a second thermal image was obtained, at the same point, with the maximum exposure of the bare soil, obtained with the aid of a metal hoe. This procedure was performed taking care to not to disturb the physical structure of the soil, just cleaning the area. The samples were chosen on a zig zag path at random pattern. For the thermal image processing, FLIR Quick Report software was used. A feature of this software allows an area represented by a square, in the image, to be moved by the user in order to emphasize the studied target. Once the square is positioned, the system quantifies the maximum and minimum temperatures. Exploratory data analyses were performed. Figure 1 illustrates thermal images regarding the temperature on and under the crop residues and Brachiaria straw.



(a) (b)

Figure 1. Thermal images of one geographic point (a) with crop residues and (b) without crop residues and Brachiaria straw.

For each point, the minimum and maximum temperature were stored, and the average temperature was estimated in an Excel spreadsheet. For temperature analysis, the free software QGis Version 2.18.4 and the statistical environment R were used. The interpolation of the data was performed using the inverse distance to power (IDW) technique, which allowed the construction of maps for estimate unknown local temperature values across the study area. A limitation of this IDW interpolation technique lies in the fact that the decrease in the quality of the interpolation occurs when the distribution of the sampling points is irregular. In addition to the spatial positioning of the temperature variable, exploratory data analysis was carried out using histogram and boxplot graphs in the R environment.

RESULTS AND DISCUSSIONS

Considering all days of sampling, the temperature maps showed the average and maximum temperatures on the surface with straw higher than those without straw, or exposed soil, that is, solar energy heats predominantly to residues on the surface. The lowest average temperatures were located below the forestry component, as in the shade of medium and large trees such as cashew and Brazil nuts (Figure 2). The highest maximum temperature in the straw was 67.7 ^{o}C on 08/30/2018 in plot 2 (corn residue only) and the lowest minimum temperature of 24.1 ^{o}C also in the same day in plot 1 (corn and brachiaria residue). The difference between maximum temperatures reached 15.5 ^{o}C.

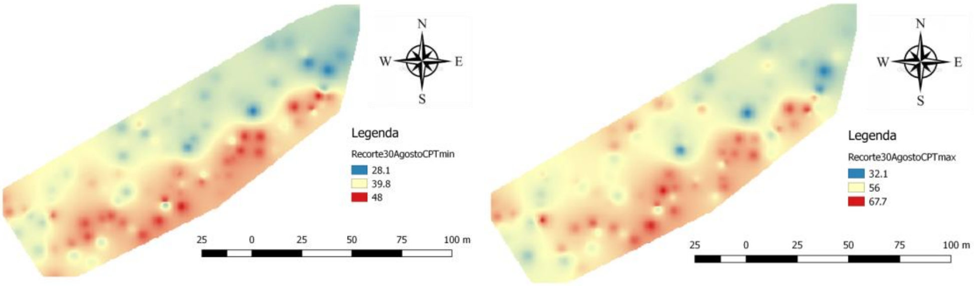


Figure 2. Spatial variability of minimum (a) and maximum (b) temperature at crop residues and soil under the brachiaria straw or crop residues.

CONCLUSIONS

The objective of this work was to evaluate the variation of the average, minimum and maximum temperatures of the exposed soil surface and at crop straw in two experimental areas with conventional corn cultivation and corn and brachiaria intercropping. Evaluating the temperature variation, it was concluded that the straw, whether only corn residues or brachiaria biomass, alleviates the temperature on the soil surface. Future work should correlate the effects of soil temperature with agricultural production.

ACKNOWLEDGMENTS

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INSECT RICHNESS IN DUNG PATCHES OF CATTLE RAISED IN TWO LIVESTOCK SYSTEMS

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ABSTRACT

The negative impact of livestock breeding on the environment has been mitigated through the combination of pastures and trees, characterizing the silvopastoral systems, an alternative to conventional pasture systems. The silvopastoral systems provide environmental services, particularly the recovery of degraded areas and carbon sequestration. Furthermore, the complexity of the silvopastoral systems can improve other environmental services, for example, enhance biodiversity and reduce pests through biological control. However, it is not clear the relationship between microclimate, pasture, trees, cattle, and invertebrate present in this environment. The purpose of this research was to characterize the richness and abundance of insects associated with dung patches of cattle raised in Integrated Livestock Forestry System (ILFS) and Conventional Pasture System (CPS) during one year in Brazil. The insect diversity associated with dung patches in the ILFS and CPS systems were respectively, 1.84 and 1.79. The morph species equivalent in the ILFS and CPS systems were 7 and 6 species, respectively.

Key words: Insect diversity; silvopastoral systems; integrated livestock forestry system

INTRODUCTION

The integrated livestock forestry system (ILFS) is a variation of silvopastoral systems which is an important socioeconomic component of the economies of countries of Tropical America. When implanted and well managed, they become key land-use systems for the provision of environmental services, particularly the recovery of degraded areas and carbon sequestration. Also, they can provide viable economic alternatives to farmers (AMÉZQUITA et al., 2004).

The ILFS combines trees (generally eucalyptus) with pasture and needs more labor and financial resource per hectare than existing technologies i.e. conventional pasture system (CPS); consequently, they have the potential of reducing the conversion of natural forestry to pasture (KAIMOWITZ and ANGELSEN, 2008). The combination of pastures and trees can contribute to mitigating the negative impact of livestock breeding on the environment.

The adoption of ILFS can favor adequate microclimate environmental conditions for cattle (PEZZOPANE et al., 2015), improve soil fertility and groundwater recharge, reduce erosion, improve water quality, sequester carbon, enhance biodiversity and consequently reduce pests and diseases (GUSMÃO et al., 2020).

Tropical climates favor the development of various ectoparasites that afflict cattle, especially the horn fly *Haematobia irritans*, the botfly *Dermatobia hominis* and the cattle tick *Rhipicephalus microplus* (GRISI et al., 2014). However, on the same climatic conditions, a diversity of invertebrate organisms living on ground soil and in dung patches can contribute to biological control of ectoparasites, maintaining its populations below the economic threshold (MENDES and LINHARES, 2002). The environmental services, as biological control, delivered from sylvopastoral systems, are described in the literature (NAVAS et al., 2008). However, the relationship between microclimate, pasture, trees, cattle, and invertebrate present in this environment is still not clear. The objectives of this study were the characterization of insect diversity associated with dung patches of cattle raised in ILFS and CPS systems.

MATERIAL AND METHODS

The study was conducted from August 2018 to May 2019 in São Carlos, São Paulo, Southern Brazil (22°01’ S, 47°53’ W, alt 860 m), where the climate is characterized as Cwa (Köppen), with a cool and dry season from April to September (mean air temperature of 19.9°C; and total rainfall of 250 mm), and a warm and wet season from October to March (mean air temperature of 23.0°C; and total rainfall of 1100 mm), according to Alvares et al. (2014).

The study included a 6-ha open pasture of the palisadegrass *Urochloa* (syn. *Brachiaria*) *brizantha* Stapf ‘BRS Piatã’, which was a CPS system, and a second 6-ha pasture, which contained the same palisadegrass with rows of *Eucalyptus urograndis* (*E. grandis* × *E. urophylla*) ‘GG100’, which was the integrated livestock forestry system (ILFS).

The trees in the silvopastoral system were planted in April 2011 and were arranged in simple rows, with an East-to-West orientation, with 15 m between rows, 2 m between trees within rows, and density of 333 trees ha^{-1}. In 2016 July was carried out thinning trees which result in a density of 166 trees ha^{-1}. In 2019 August was carried out thinning trees which result in a density of 83 trees ha^{-1}.

The herd consisted of male Nelore cattle, weaned at eight months of age. The cattle were submitted to rotational grazing, according to Euclides and Euclides Filho (1998). At the end of the seventh day of grazing, 15 recently dropped dung patches were selected randomly and covered by a trap (Figure 1) to evaluate the insects at the seven and 14 days after the trap installation. Then the insects collected through the trap were taken to the laboratory for the separation the morph-species (S) which were identified to the order *taxon*. The identifications to the family and specific *taxa* are still in course.

Figure 1. Trap for collecting insects associated with dung patches of cattle

The data of insect associated with the dung patches were analyzed from the number of individuals (n_i) of each morph-species (S), and the insect diversities related to the systems (ILFS and CPS) were determined by applying the Shannon index (H'), calculated in function of the relative abundance (proportion) (p_i) of morph-species (S_i) in the sample (N), where:

$$H' = -\sum_{i=1}^{S} P_i \times LN_{P_i}, \text{ with } P_i = \frac{n_i}{N}$$

Through the diversity index *H'*, the equivalent number of morph-species ($S_{H'}$) for each system was determined, given by the equation (ODUM, 1983; PIELOU, 1975).

$$S_{H'} = e^{H'}$$

RESULTS AND DISCUSSIONS

The solar radiation was lower in the ILFS in all seasons during the time evaluations, with the average value of 3.58 MJ m^{-2} day^{-1} in the ILFS, and 8.08 MJ m^{-2} day^{-1} in the CPS. Significant differences ($P<0.05$) were also observed for average maximum wind speed in the two systems, with means of 7.44 and 5.12 m/s for the CPS and ILFS, respectively (Table 1).

Average soil temperatures also differed significantly ($P<0.05$) between the systems, with values of 22.47±0.05 °C (CPS) and 21.67 °C (ILFS). However, did not observe statistical difference for air temperature and average relative humidity between the systems (Table 1).

The insect richness values (number of morph-species) for the ILFS and CPS in the seasonal periods were 16 and 15 morph-species in the winter; 17 and 16 morph-species in the spring; 18 and 18 morph-species in the summer and 16 and 11 morph-species in the autumn, respectively (Table 2). In the ILFS system were registered higher total richness (67) and abundancy (5,363) than in the CPS system with total richness (60) and abundancy (4,138) (Table 2).

The average diversity indices (H') for the ILFS and CPS were 1.84 and 1.79, respectively. The numbers of equivalent morph-species ($S_{H'}$) considering the diversity H' of each system were seven morph-species in the ILFS and six morph-species in the CPS (Table 3). These values represent the number of morph-species that would be expected in each system if all morph-species has the same abundance (maximum evenness).

Table 1. Meteorological parameters in area of the systems during the experimental period.

System	Season/year	Solar radiation	Average soil temperature	Average air temperature	Average relative humidity	Maximum wind speed
CPS	Winter/2018	7.11 b	19.18 f	19.38 e	66.50 b	7.63 ab
	Spring/2018	9.12 a	23.33 c	22.24 bc	76.83 a	8.29 a
	Summer/2019	9.12 a	24.95 a	23.34 a	76.46 a	7.26 bc
	Autumn/2019	6.97 b	22.43 d	21.50 cd	73.34 a	6.57 cd
	Mean	8.08 A	22.47 A	21.61 A	73.28 A	7.44 A
ILFS	Winter/2018	3.20 d	18.64 g	19.25 e	65.54 b	5.64 e
	Spring/2018	4.78 c	22.66 d	22.01 c	75.73 a	5.99 de
	Summer/2019	4.24 c	24.06 b	22.94 ab	77.22 a	4.72 f
	Autumn/2019	2.09 e	21.33 e	21.07 d	74.57 a	4.15 f
	Mean	3.58 B	21.67 B	21.32 A	73.26 A	5.12 B

Table 2. Richness and abundancy of insect associated with dung patches of cattle in the ILFS and CPS systems through the seasons.

System	Season/year	Richness	Abundancy
ILFS	Winter/2018	16	1,040
	Spring/2018	17	1,927
	Summer/2019	18	1,575
	Autumn/2019	16	821
	Total	67	5,363
CPS	Winter/2018	15	367
	Spring/2018	16	1,646
	Summer/2019	18	1,616
	Autumn/2019	11	509
	Total	60	4,138

Table 3. Insect diversity and equivalent morph species associated with cattle dung patches in the ILFS and CPS systems through the seasons.

Season/year	Diversity (H')		Equivalent morph species ($S_{H'}$)	
	LF	CP	LF	CP
Winter/2018	1.49	2.18	4	9
Spring/2018	1.69	1.45	5	4
Summer/2019	2.27	2.18	10	9
Autumn/2019	1.9	1.35	7	4
Mean	1.84	1.79	7	6

CONCLUSIONS

The presence of trees in pastures alters the environment, notably through the reduction of solar radiation, decrease in wind speed, attenuation of soil temperature, and diversification of food supply promoting insect richness in dung patches of cattle.

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SPATIOTEMPORAL THERMAL DISTRIBUTION IN AGROFORESTRY SYSTEMS IN THE TROPICS

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ABSTRACT

The objective was to verify the spatiotemporal distribution on infrared temperature inside agroforestry systems. The study was carried out between June 2015 and February 2016, during the months corresponding to the winter and summer seasons, respectively, in Brazil. The experimental area of Embrapa Beef Cattle is located in Campo Grande (Mato Grosso do Sul), coordinates 20º24'53" S, 54º42'26" W and 558 m altitude, and is composed of two agroforestry systems with different densities and arrangements trees, totaling 12 ha. Pasture temperatures were determined using an infrared thermography camera and the records interpolated by the natural neighbor method. Results show spatiotemporal variations in infrared temperature, and the system with the lowest shade availability has the greatest heat accumulation area. This means that the environment inside agroforestry systems is not homogeneously comfortable for cattle.

Key words: Animal welfare; geostatistics; microclimate

INTRODUCTION

In agroforestry systems, the combination of trees in different densities and spatial arrangements affects the thermal environment with a variety of processes and feedbacks, highly dynamic and correlated in space and time. By intercepting direct solar radiation, trees reduce heat load below the forest canopy, providing cooler environmental through evapotranspiration and shading (OLIVEIRA et al., 2017; KARVATTE JR. et al., 2020). In this sense, considering an animal as a thermodynamic system that continuously exchange energy with the environment, studies evaluating heat load in grazing systems are important to assess thermal environment available for farming animals (MAGALHÃES et al., 2020).

Indicators such as surface temperature of pasture are highly variable, requiring observations in both high spatial and temporal resolution. These temperature variations result from physical and biological interactions affected by leaf morphology and albedo, tree canopy position, radiation, wind and stomatal response to the environment, directly influenced by season and regional climate (GERSONY et al., 2016; KIM et al., 2016). In this sense, infrared thermography can be used to describe in detail the patterns of leaf thermal variations and their relationship with environmental variables that characterize microclimate in agroforestry systems, extending traditional measurements to a spatial and temporal scale because, regardless of the application, all collected data are influenced by atmospheric conditions.

Our hypothesis is that different shade availability can result in spatiotemporal variations in infrared temperature in agroforestry systems. Therefore, the goal of this study was to verify the spatiotemporal distribution of infrared temperature inside agroforestry systems.

MATERIAL AND METHODS

A trial was conducted at the experimental farm of the Brazilian Agricultural Research Corporation (Embrapa Beef Cattle), located in Campo Grande, State of Mato Grosso do Sul, Brazil (20º24′53″ S, 54º42′26″ W, average elevation: 558 m), between June 2015 and February 2016, covering a dry winter and a rainy summer season, respectively. Local climatic pattern is in the transition between warm temperate (Cfa) and humid tropical (Aw), with precipitation and average annual temperature of 1.560 mm and 23,0ºC respectively (KÖPPEN, 1948).

The experimental area, with 12 ha, is composed of two agroforestry systems (AS-1 and AS-2), both divided into four paddocks of 1.5 ha, established in 2008 with piatã grass (*Urochloa brizantha* cv. BRS Piatã). In the AS-1 system, the forest component used is eucalyptus (*Eucalyptus grandis* x *E. urophylla*, clone H 13; average height of 26 m during the experimental period), planted in simple line rows (22 m and 2 m; density of 227 trees ha^{-1}), with a displacement of −20.41°S and − 54.71°W, in relation to the East-West axis. The AS-2 system has native trees from the Brazilian Cerrado (*Dipteryx alata* Vogel and *Gochnatia polymorpha* Less), which have been preserved and have an approximate density of 3 trees ha^{-1}.

The evaluations were carried out during four consecutive days in each experimental month, simultaneously evaluating one paddock of each system per day. The data were recorded from 08:00 am to 04:00 pm (GMT -04:00, at hourly intervals). Infrared images of all systems were captured using a professional thermographic camera (Testo®, model 875 2i), according Karvatte Jr. et al. (2020). Subsequently, images were analyzed using the IRSoft® software (Testo), obtaining values of pasture temperatures ($T_{Pasture}$), at equidistant points in the shade projection (2.0 m, 4.0 m and 6.0 m) and in full sun (2.0 m, 4.0 m and 6.0 m), in relation to the lines of trees. $T_{Pasture}$ values (°C) were also obtained at equidistant points between tree rows (0 m, 3.6 m, 7.3 m, 11.0 m, 14.6 m, 18.2 m and 22.0 m), identifying the location of the trees in AS-2.

The thermographic records were interpolated by the natural neighbor method, using the free software QGIS (version 3.10) and presented in the form of spatiotemporal thermal distribution maps identified between the rows of trees and differentiation between full sun and shade.

RESULTS AND DISCUSSIONS

Spatiotemporal thermal distribution maps show higher infrared temperatures (IT) during summer, in both agroforestry systems (Figure 1). Despite the greater thermal area observed in the AS-1 system (IT $\leq$ 32 °C), greater IT were identified in the AS-2 system (IT $\leq$ 35 °C). The daytime variation (8 a.m. to 4 p.m.) shows minimum temperatures recorded at 8 a.m. (IT $\geq$ 25 °C) and maximum temperatures between 11 a.m. and 2 p.m. (IT $\leq$ 35 °C).

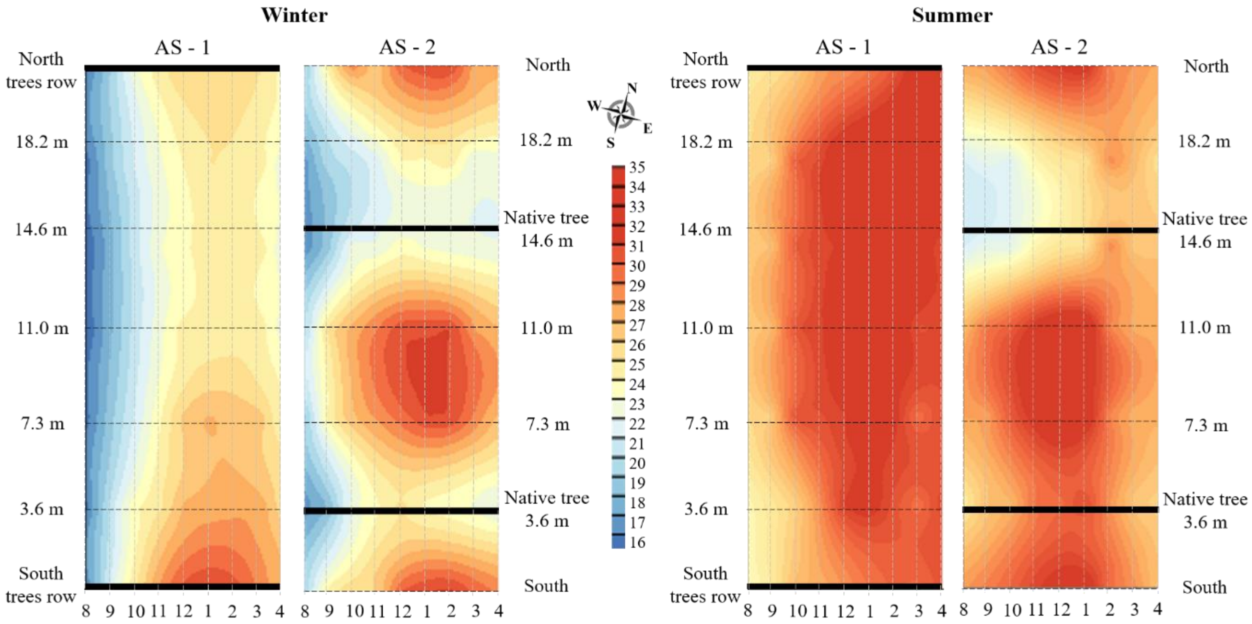

Figure 1. Spatiotemporal distribution of infrared temperature between rows of trees in agroforestry systems with eucalyptus (AS-1) and native trees (AS-2), during the winter and summer seasons.

Interactions found confirm the hypothesis of this study and show the differences in IT that represent the interface responsible for the spatiotemporal patterns of dissipation of daytime and seasonal pulses of solar energy that reach Earth's surface. In both systems assessed, during summer $T_{Pasture}$ was from 1.2 to 1.8 °C higher than the temperatures obtained in winter, possibly due to increase in solar radiation during the summer, which can reach up to 1000 W m^{-2}, according to Silva (2006). In fact, in this study, we observed that during winter, shade was projected in Southwest direction in the morning, characterizing a greater distribution of shade among tree rows in AS-1 system and wide individual shade projection in AS-2 system. In contrast, during summer, shade remained under canopy or a few meters from trees, projected Northwest in the morning in both systems. These results represent the effect of solar declination throughout the year and apparent solar movement further and corroborating with other similar studies (PEZZOPANE et al., 2017; MAGALHÃES et al., 2020).

Spatiotemporal thermal distribution for assessment sites reveals greater IT recorded in full sun (average variation of 26.5 ± 4.6 °C in winter and 31.2 ± 2.3 °C in summer, for AS-1 and 27.7 ± 5.3 °C in winter and 30.8 ± 3.3 °C in the summer, for AS-2) (Figure 2). However, the AS-2 system showed consistently higher temperatures throughout the experimental period and in both evaluated locals (average variation of 24.9 ± 8.1 °C for winter and 29.6 ± 4.5 °C for summer). Previous studies suggest that introduction of trees in pastures, in adequate density, acts as protection against thermal radiation load, since they reduce heat load associated with solar radiation (Karvatte Jr et al., 2016; Oliveira et al., 2017). In fact, our results show that in both seasons, forest canopy was effective in preventing extremes of thermal heating in the shaded environment (average IT reduction of 4.2 ± 2.0 °C in winter and 3.6 ± 1.0 °C in summer of AS-1 system and 5.5 ± 3.5 °C in winter and 2.3 ± 1.4 °C in summer, of AS-2 system).

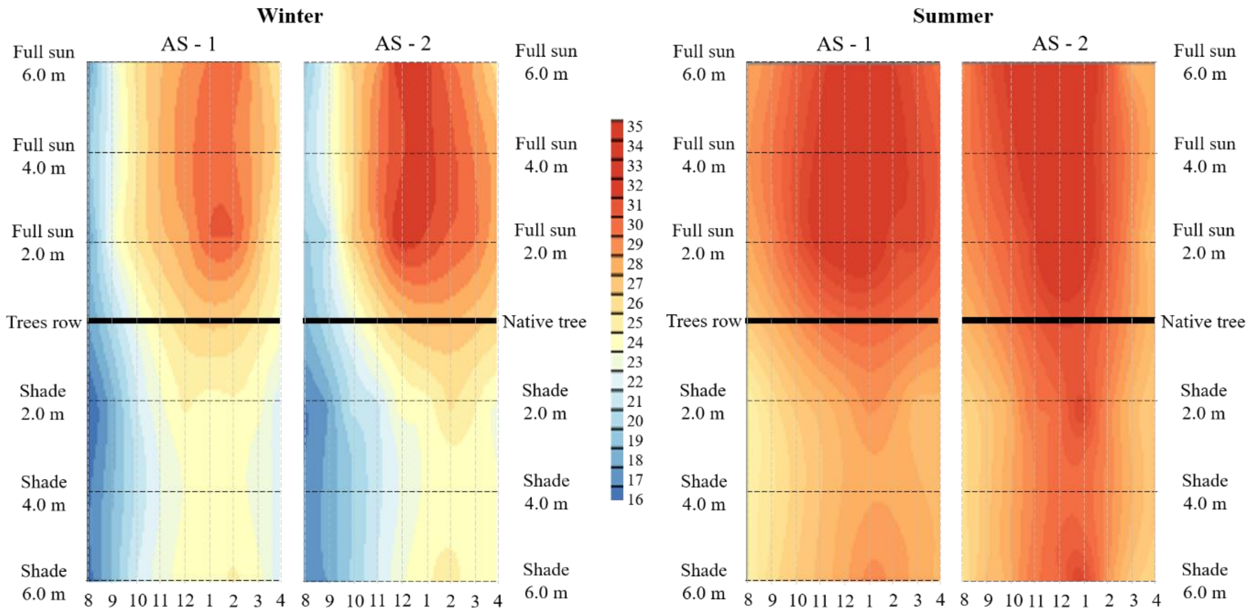

Figure 2. Spatiotemporal distribution of infrared temperature in full sun and shade in agroforestry systems with eucalyptus (AS-1) and native trees (AS-2), during the winter and summer seasons.

CONCLUSIONS

Spatiotemporal thermal distribution has shown that the environment inside agroforestry systems is not homogeneously comfortable but depends on the displacement and projection of shadow due to the spatial orientation of the tree rows.

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GYPSUM AND LIME EFFECTS ON TEAK GROWTH AND SOIL CHEMICAL ATTRIBUTES IN SILVOPASTORAL SYSTEM

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ABSTRACT

A field experiment was conducted to determine the effects of limestone and gypsum application on the soil chemical properties and growth of teak in a silvopastoral system, in the Amazon biome, Brazil. The factors studied were liming; gypsum; liming + gypsum (3000 kg ha^{-1} each) and control (no amends). Growth and soil data were evaluated at the age of eigth years. Teak height growth followed a sigmoidal pattern. Teak height and yield were increased with the combined application of lime and gypsum. The basal area and yield were the smallest with gypsum application. The leaf nutrient content was not improved with the separate application of gypsum and lime. However, the combined application of lime and gypsum increased the macronutrient contents i.e. calcium, nitrogen, phosphrus and potasium. Liming increased the values of soil pH, the sum of base (SB), base saturation (V%), Cation Exchange Capacity (CEC), and organic matter (OM). The results obtained in the present study indicate that the combined application of gypsum and lime together improves the teak productivity in the silvopastoral system.

Key words: *Tectona grandis*; Livestock-Forest Integration; calcium sulfate

INTRODUCTION

Brazil is the second largest producer of beef globally with the largest herd (about 214.7 million heads of cattle). It is the world's largest cattle exporter totalled 1.9 million tonnes in 2019 (ABIEC, 2018; IBGE, 2019). Most of Brazil's beef cattle herds are located in the central-west and northern regions of the country. Mato Grosso state plays an important role in the economic development of the country, because of the largest cattle herd, being 14.8% of the total (TEIXEIRA; HESPANHOL, 2014; IBGE, 2019), that is largely based on grass production. The increase in degraded pasture mostly due to overgrazing, low indexes of production and low soil fertility has been a great challenge for livestock farming (ABADIAS et al., 2020; PACIULLO et al., 2014).

Integrated production systems, such as silvopastoral systems are important to improve the quality of the available forage, and also to obtain higher yield and profit per hectare. The adoption of silvopastoral system - that is constituted by forest components, pasture, and animals - decrease environmental impacts inherent to conventional cattle raising systems by favoring animal well-being, soil and water conservation, mitigation of greenhouse gases and carbon sequestration. It also diversifies farm production, reduces dependence on external inputs, and enhances sustainable land use (CABRAL et al., 2017; CORRÊA et al., 2015; DENIZ et al., 2018; NAIR, 2014).

Teak as a tree component in silvopastoral systems establishment is an option that is highly appreciated by producers. It present easy cutting and lamination and its wood has high market value (CABRAL et al., 2017). One of the biggest challenges to increase teak productivity in silvopastoral systems in

Mato Grosso is related to low levels of soil nutrients, such as calcium, magnesium and mainly phosphorus, and high levels of iron and aluminium.

The use of lime can raise soil pH and reduce aluminum saturation in surface layers. Gypsum ($CaSO_42H_2O$) has been used with lime, as an alternative to reduce the toxicity of Al in depth, in addition to increase the levels of Ca and S. Surface application of lime + gypsum is an effective strategy to increase the vertical movement of exchangeable bases in the rooting zone at greater depth (FAGERIA; NASCENTE, 2014; GABRIEL et al., 2018). Thus, this research aims to assess the effect of lime and gypsum application on the growth of teak and soil chemical attributes in a silvopastoral system with marandu palisade grass pastures, in the Amazon biome, Brazil.

MATERIAL AND METHODS

The study was carried out at Bacaeri Farm, Alta Floresta, Mato Grosso (56° 52' 44" W and 09° 58' 17" S, and elevation of 230 m). The region's climate, according to Köppen, is Am, with a well-defined rainy season (October to April), and precipitation averaging 2,000 mm year^{-1} (Souza et al., 2013). The soil is red-dystrophic Argisol and Red-Yellow Latosol with medium to the clayey texture of low fertility and high acidity (SANTOS et al., 2011). The chemical soil characteristics in the experimental area, before the establishment of the system indicated that fertilization correction was required.

In February 2012 teak (*Tectona grandis* L. F.) clonal seedlings were established with a spacing of 3 m x 20 m in an area with marandu palisade grass (*Urochloa brizantha* cv. Marandu). Cattle (average of 325 kg) was introduced at 12 months after planting (2 animal units per hectare). Lime and gypsum (0 and 3000 kg ha^{-1}) were applied 30 days after teak was planted, both distributed in 4 m x 45 m plots along the planting line, with 15 trees. The treatments consisted of control; 3000 kg ha^{-1} of lime; 3000 kg ha^{-1} of gypsum and 3000 kg ha^{-1} each of lime and gypsum.

The total height (*ht*) and the diameter at 1.3 m in height (*dbh*) of the 15 teak plants per plot were measured at 5 (except for dbh), 77 and 95 months of age. Chapman and Richards model was adjusted to assess the growth trend for total height over ages in each treatment. The equations were compared by model identity tests (Regazzi; Silva, 2010). To estimate the volume with teak bark (Vcc) the volumetric equation: $vcc = (\pi * dbh^2/40000) * ht * ff$..

The mean annual increment in volume (MAIv) per tree were calculated by dividing the the individual volume at the age of 8 years by the number of years.

Soil samples were collected at 95 months after planting at five depths (0–5, 5–15, 15–30, 30–40 and 40–60 cm) from different points. Leaf samples were collected in each plot in the lower third of the crown for the first three trees, at 77 months of age.

RESULTS AND DISCUSSIONS

The growth in height followed the Chapman-Richards model ($Y=\beta_0(1-e^{-\beta_{1I}})\beta_2 + \varepsilon$). All parameters of the model were significant ($p < 0.05$). The adjusted equations, after being compared using model identity tests, were grouped when required ($p>0.05$). The tree height for the treaments with gypsum, lime + gypsum, and control has similar growth pattern ($p>0.05$) Thus, it was represented by a single equation: with a correlation coefficient of 0.9898 and a residual standard error of 1.0630. The height growth with the application of lime was represented by the equation, with a correlation coefficient of 0.9983 and a residual standard error of 0.3948 m. The sigmoidal teak growth (height, *dbh* and yield) was observed by other authors from monoculture (SILVA et al., 2014) and silvopastoral system (MARIA et al., 2019) with high increments in height up to 3 years of age. This behavior indicates adaptation of the species to the region.

Teak exhibited different growth responses to the treatments (Table 1). The combined application of lime and gypsum produced higher height growth than the control. The application of gypsum and lime alone showed very small height growth. The application of gypsum and lime presentend *dbh* 5% greater than for the control. The teak individual volume with the application of gypsum were 14% greater than for the control. However, there was lower yield and basal area.

The yield and basal area with the application fo gypsum were 10% lower than for the control. This was due to the smaller tree number in the gypsum treatment (75% survival). Basal area and yield both depends on the population density. The combined application of lime and gypsum increased in 3% the yield of teak trees. The MAIv per tree (0.047 to 0.053 m^3 year^{-1}) exhibted little variation among treatments (Table 1).

The growth values of height, diameter and volume obtained in this study were higher than for those found by Silva et al. (2014): 16.1 m, 15.7cm and 0.1454 m^3 at 8 years in a homogeneous stand in Alta Floresta, MT. The mean values of height, diameter and individual volume were higher than those reported by Maria et al. (2019) and Pachas et al. (2019) in larger spacings (167 trees ha^{-1} at 4.4 years, and 159 trees ha^{-1} at 9,3 years old, respectively). The volume was higher than that estimated by Pachas et al. (2019) at 9.3 years old (47.0 m^3 ha^{-1}) in northern Lao PDR. Probably, this difference is related to the use of clonal seedlings, edaphoclimatic conditions, and the application of gypsum (MEDEIROS et al., 2018; MARIA et al., 2019; PACHAS et al., 2019).

Table 1. Dendometric variables and productivity of teak at 8 years of age and leaves nutrient content in a silvopastoral system with application of gypsum and lime, in Alta Floresta, MT.

Treatment	***ht*** **m**	**dbh** **cm**	**vcc** **m^3**	**MAIv** **m^3 year^{-1}**	**BA** **m^2 ha^{-1}**	**Yield** **m^3 ha^{-1}**
Control	16.94±0,76	26.64±1.06	0.37±0.03	0.047	9.19	62.27
Gypsum	16.98±1.52	28.01±1.34	0.42±0.04	0.053	8.23	55.78
Lime + Gypsum	17.34±0.89	26.52±1.32	0.38±0.04	0.048	9.23	63.92
Lime	15.38±0.49	28.08±1.35	0.38±0.04	0.048	10.34	63.62
			Nutrient leaf content			
Macronutrient (dag kg-^{1})	N	P	K	Ca	Mg	S
Control	1.96	0.17	0.99	1.27	0.15	0.10
Gypsum	2.24	0.17	1.01	1.03	0.16	0.10
Lime + Gypsum	2.24	0.18	1.15	1.89	0.16	0.07
Lime	1.82	0.17	1.00	1.44	0.15	0.08
Micronutrient (mg kg-^{1})	B	Cu	Fe	Mn	Zn	-
Control	27.88	18.76	183.70	116.55	16.87	-
Gypsum	20.37	17.72	129.11	127.76	18.07	-
Lime + Gypsum	13.49	9.87	113.04	149.35	39.70	-
Lime	18.93	9.54	83.94	132.87	19.21	-

±: standard deviation; **vcc:** individual volume and **BA:** basal area.

The application of lime in the soil (Table 1) improved the leaves content of N, P, K, Ca, Mg, Mn and Zn. An increase in foliar Ca and Mg after liming – especially if containing both Ca and Mg – may be expected (BAKKER et al., 1999). However, the leaf content of Ca, Mg and K were lower (41; 50 and

10%, respectively) than the values reported by Behling (2009) in a 7.5 years old teak stand in high soil fertility with high productivity. Zhou et al. (2016) reported positively and significant correlation of MAI with foliar mineral element concentrations of N, P, K, Ca, Mg, S, Zn, Fe, B, Cu. They also reported that the relationship between foliar Ca and N and productivity of teak plantation is linear. They reported that foliar content Ca, at the age of 5–8-years was 5.63 to 13.55%, higher values than the findings values of this study (Table 1).

Soil liming increased soil pH, exchangeable Ca content, base saturation, and organic matter (OM) mainly in the upper layers (<30 cm) (Table 2). The application of gypsum alone promoted the greatest S-SO_4 availability especially in the soil layers deeper than 15 cm compared to the control.

Table 2. Soil chemical properties of teak stands in silvopastoral system with application of gypsum and lime.

Soil chemical properties	**Treatment**											
	C	**G**	**L**	**L+G**	**C**	**G**	**L**	**L+G**	**C**	**G**	**L**	**L+G**
	Depth (cm)											
	----------- *0 – 05* -----------				----------- *05 – 15* -----------				----------- *15 – 30* -----------			
P (mg dm^{-3})	2.7	1.6	2.3	1.1	1.9	1.4	2.1	1.8	1.5	0.5	0.8	1.4
K (mg dm^{-3})	60	61.6	90.4	111.3	38	51.8	95.9	75.5	46.8	34.1	70	68
Ca ($cmol_c$ dm^{-3})	2.74	2.07	2.85	2.32	2.23	2.56	2.93	2.2	2.32	1.31	3	2.13
Mg ($cmol_c$ dm^{-3})	0.71	0.54	0.73	0.6	0.58	0.64	0.61	0.51	0.51	0.32	0.53	0.52
S (mg dm^{-3})	3.6	4.7	4.5	4.4	3.2	4.1	4.1	4.1	4.3	8.1	5.6	4.4
Al ($cmol_c$ dm^{-3})	0.17	0.15	0.09	0.11	0.12	0.18	0	0.1	0.1	0	0	0
Zn (mg dm^{-3})	2.1	1.9	1.9	1.7	1.2	1.5	1.1	1.1	0.4	0.5	0.7	0.4
Fe (mg dm^{-3})	12.1	16.7	21.9	12.7	14	13.7	21.2	17.4	19.2	15.4	18.6	21.9
Mn (mg dm^{-3})	108.5	129.3	107.7	93.3	104.2	79	79.8	98.9	61.1	57.7	47.1	67.2
Cu (mg dm^{-3})	0.9	1.9	1.8	1	1.2	1.4	1.9	1.4	1.5	2.4	1.7	1.7
B (mg dm^{-3})	0.15	0.14	0.14	0.11	0.13	0.13	0.12	0.1	0.11	0.08	0.1	0.09
pH_H_2O	5.6	5.7	5.9	5.7	5.7	5.7	6	5.8	5.8	5.8	6.1	6.1
H+Al ($cmol_c$ dm^{-3})	3.7	3.9	2.8	2.8	3.2	3.7	2.5	2.5	2.6	3.1	2.2	2.5
SB (cmolc dm^{-3})	3.6	2.8	3.8	3.2	2.9	3.3	3.8	2.9	2.9	1.7	3.7	2.8
ETC ($cmol_c$ dm^{-3})	7.3	6.7	6.6	6	6.1	7	6.3	5.4	5.5	4.8	5.9	5.3
OM (dag kg^{-1})	3.37	2.92	2.92	2.63	2.59	2.53	2.79	2.15	1.86	1.63	2.08	1.68
Base saturation (%)	49.3	41.3	57.7	53.3	47.7	47.6	60.2	53.7	53.6	35.8	62.9	53.2
m (%)	4.5	5.1	2.3	3.3	4	5.1	0	3.3	3.3	0	0	0
	----------- *30 – 40* -----------				----------- *40 – 60* -----------							
P (mg dm^{-3})	0.7	0.8	1.7	1.7	0.4	1.1	0.4	1	-	-	-	-
K (mg dm^{-3})	43.2	27.1	32.5	37.6	22.4	19.5	30.6	20.5	-	-	-	-
Ca ($cmol_c$ dm^{-3})	1.96	1.44	2.59	1.92	1.86	1.51	2.2	1.33	-	-	-	-

Mg (cmol$_c$ dm-^{3})	0.49	0.24	0.51	0.54	0.55	0.28	0.45	0.38	-	-	-	-
S (mg dm-^{3})	7.1	22.2	17	8	14.6	61.6	37.4	12.9	-	-	-	-
Al (cmol$_c$ dm-^{3})	0.16	0.1	0	0.17	0	0.08	0	0	-	-	-	-
Zn (mg dm-^{3})	0.2	0.3	0.4	0.4	0.2	0.3	0.3	1	-	-	-	-
Fe (mg dm-^{3})	7.4	14.5	13.5	13.7	7.3	11	12	18	-	-	-	-
Mn (mg dm-^{3})	36.1	47.9	44.6	51.7	34.7	31.1	39.5	49.6	-	-	-	-
Cu (mg dm-^{3})	1.4	2.4	2.5	1.8	1.9	2	2.5	3.3	-	-	-	-
B (mg dm-^{3})	0.09	0.08	0.09	0.1	0.1	0.08	0.06	0.1	-	-	-	-
pH_H$_2$O	5.9	5.6	5.9	5.8	5.9	5.6	5.7	5.5	-	-	-	-
H+Al (cmol$_c$ dm-^{3})	2.8	2.3	2.3	2.2	2.9	2.2	2.5	2.5	-	-	-	-
SB (cmolc dm-^{3})	2.6	1.8	3.2	2.6	2.5	1.8	2.7	1.8	-	-	-	-
ETC (cmol$_c$ dm-^{3})	5.4	4.1	5.5	4.8	5.4	4	5.2	4.3	-	-	-	-
OM (dag kg^{-1})	1.6	1.42	1.6	1.44	1.21	1.18	1.51	1.38	-	-	-	-
Base saturation (%)	47.4	42.7	57.8	53.3	45.7	46	52.5	40.9	-	-	-	-
m (%)	5.9	5.4	0	6.2	0	4.2	0	0	-	-	-	-

C: control, **L:** lime, **G:** gypsum.

The surface application of lime alone, or associated with gypsum, increased soil Ca and Mg levels along the soil profile, and K levels up to 30 cm depth, which influenced the base saturation. As a result of the improved soil chemical properties due to lime and gypsum application, the yield of teak increased (Table 1). Zhou et al. (2016) reported significant correlation betweem MAI and base saturation at a depth of 0-20 cm. They also reported a significant correlation between the MAI and soil pH, available P, exchangeable Ca, Mg, Zn and Cu, and a negative correlation between the MAI and total exchangeable acidity, and Al and Mo concentration. According to Zech and Dreschsel (1991), teak growth decreases with increasing soil acidity. Thus, the highest tree height and individual volume were mainly due to the increased availability of Ca, Mg and K in the soil. Crusciol et al. (2019) reported that simultaneous application of lime and gypsum increased peanut, white oat, and corn crops yield and had positive economic results.

CONCLUSIONS

Surface liming reduced the exchangeable acidity and Al concentration even after 95 months. Gypsum application increased S levels through the soil profile. Lime + gypsum increased teak heigth and volume in silvopastoral system.

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SIS-ICLF: A SOFTWARE SUITE FOR THE MANAGEMENT OF FOREST PLANTATIONS IN ICLF SYSTEMS

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ABSTRACT

SisICLF is a software suite that can be used to manage and plan the forest component of integrated crop-livestock-forest (ICLF) systems with Pine, Eucalyptus, *Toona ciliata*, *Khaya ivorensis*, and *Tectona grandis*. The software supports decision making related to how, when, and how much to thin, and when to conduct the final harvest. Based on inventory data, the software allows users to: simulate all tree component management options of ICLFs; forecast present and future production; conduct economic analyses; and decide on the best alternatives to manage their plantation. The software suite was developed by Embrapa, the Brazilian Agricultural Research Corporation, and is available for download on Embrapa Forestry's website (www.embrapa.br/florestas).

Key words: Precision management; carbon; methane

INTRODUCTION

Beginning in the 1980s, the Brazilian Agricultural Research Corporation (Embrapa Forestry) has been developing software to simulate the growth and yield of forests, mainly for precision management of planted forests (OLIVEIRA, 2011). The development of such tools was driven by partnerships with companies in the commercial forestry sector, which provided forest inventory data. These data enabled the development of algorithms, which led to the creation of several software programs, initially in the programming language Pascal and later in Delphi.

Each software suite, named 'Sis' followed by the popular name of the species or genera (i.e., SisEucalyptus, SisPinus, SisTeak, etc.; SisEucalyptus-ICLF, SisPinus-ICLF, SisTeak-ICLF, etc.), describes the growth and yield of forest plantations (monoculture or integrated crop-livestock-forest-ICLF) based on management regimes defined by the user. The software Planin provides parameters for the economic analysis of forest production (OLIVEIRA, 2021). For ICLF systems, Embrapa initially built SisILPF_Eucalyptus, with the version for *E. urograndis* presented at Expoforest and the IV Brazilian Silviculture Meeting in 2018 (OLIVEIRA et al., 2018). SisICLF is a software suite that assists in the management, economic analysis, and planning of the forest component of integrated crop-livestock-forest (ICLF) systems with Pine, Eucalyptus, *Toona ciliata*, *Khaya ivorensis*, and *Tectona grandis*. In this paper, key features of SisICLF will be presented.

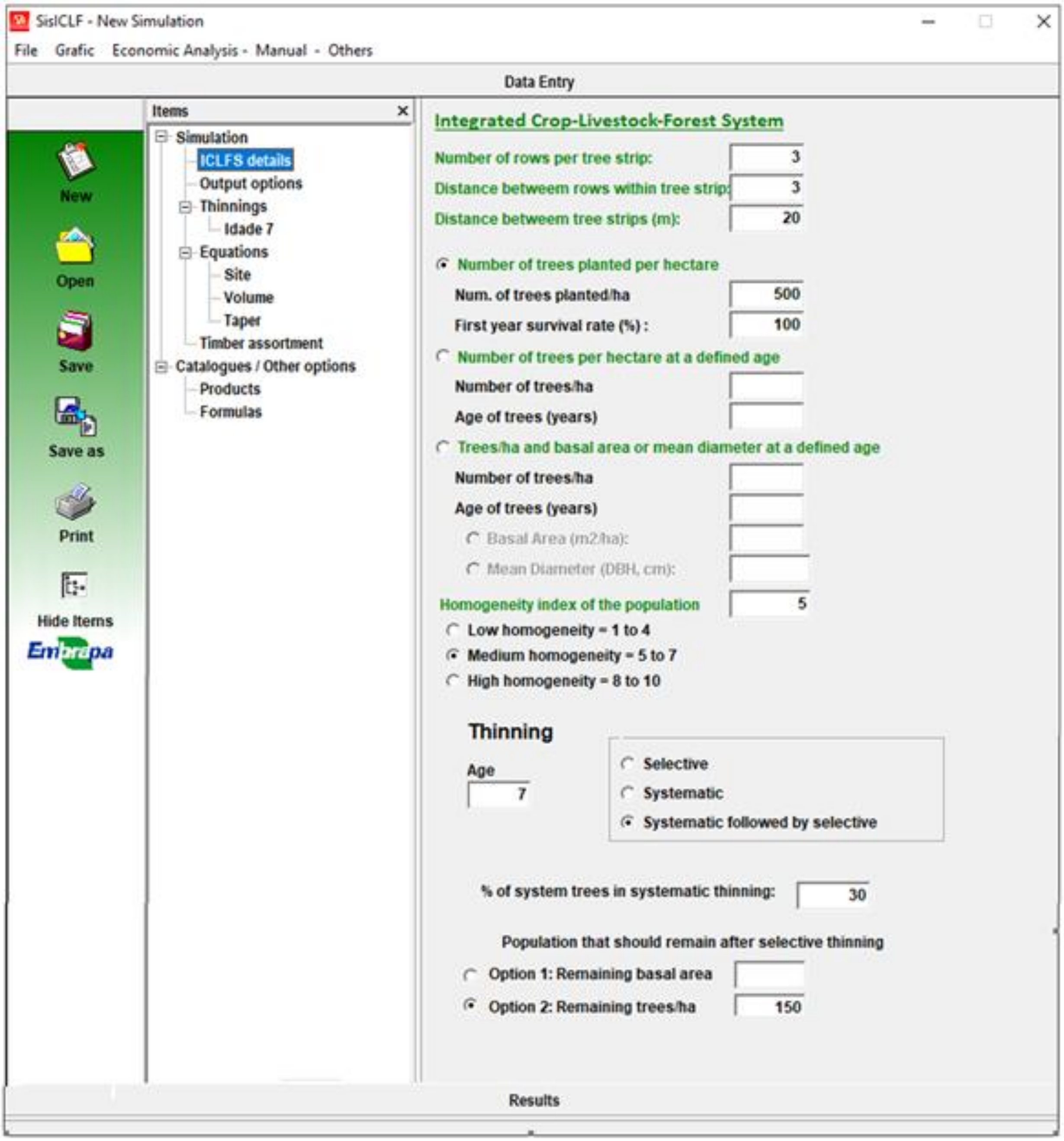
MATERIAL AND METHODS

To describe the software, an example of an ICLF system will be used. The example will consider an ICLF with 500 *Eucalyptus urograndis* (*E. urophylla* x *E. grandis*) hybrids, planted in triple rows, with 3 m between rows and 20 m between strip rows. The Site Index is 29.0 m. For this example, we will implement a mixed thinning at 7 years, with a systemic removal of 30% of trees in the system, followed by a selective removal to achieve a population of 150 trees. The final harvest will be at 12 years. To calculate the resulting production, we will use a diameter class interval of 2 cm, classifying the wood into the following two end products: sawlog (Length = 2.6m, Minimum diameter = 18.0

cm) and fuel (no restrictions). These represent the basic information that should be entered in the initial SisILCF data entry screen.

RESULTS AND DISCUSSIONS

Figure 1 shows how the data describing the ICLF system and thinning should be input. The user must choose one of the three forms of inventory available on the screen. The Site Index is always required. The option “Number of trees planted per hectare” assumes that the data provided corresponds to a recently planted forest, or one that has not yet experienced much growth. In the appropriate boxes, the user indicates the number of trees planted per hectare and the rate of survival in the first year. With the option “Number of trees per hectare at a defined age”, the previous data input option is deactivated. The option “Trees per hectare and basal area or mean diameter at a defined age” is the most complete, resulting in a more precise and accurate simulation.



Integrated Crop-Livestock-Forest System

Number of rows per tree strip: 3

Distance betweem rows within tree strip: 3

Distance betweem tree strips (m): 20

● Number of trees planted per hectare

Num. of trees planted/ha 500

First year survival rate (%) : 100

○ Number of trees per hectare at a defined age

Number of trees/ha

Age of trees (years)

○ Trees/ha and basal area or mean diameter at a defined age

Number of trees/ha

Age of trees (years)

○ Basal Area (m2/ha):

○ Mean Diameter (DBH, cm):

Homogeneity index of the population 5

○ Low homogeneity - 1 to 4

● Medium homogeneity - 5 to 7

○ High homogeneity - 8 to 10

Thinning

Age 7

○ Selective

○ Systematic

● Systematic followed by selective

% of system trees in systematic thinning: 30

Population that should remain after selective thinning

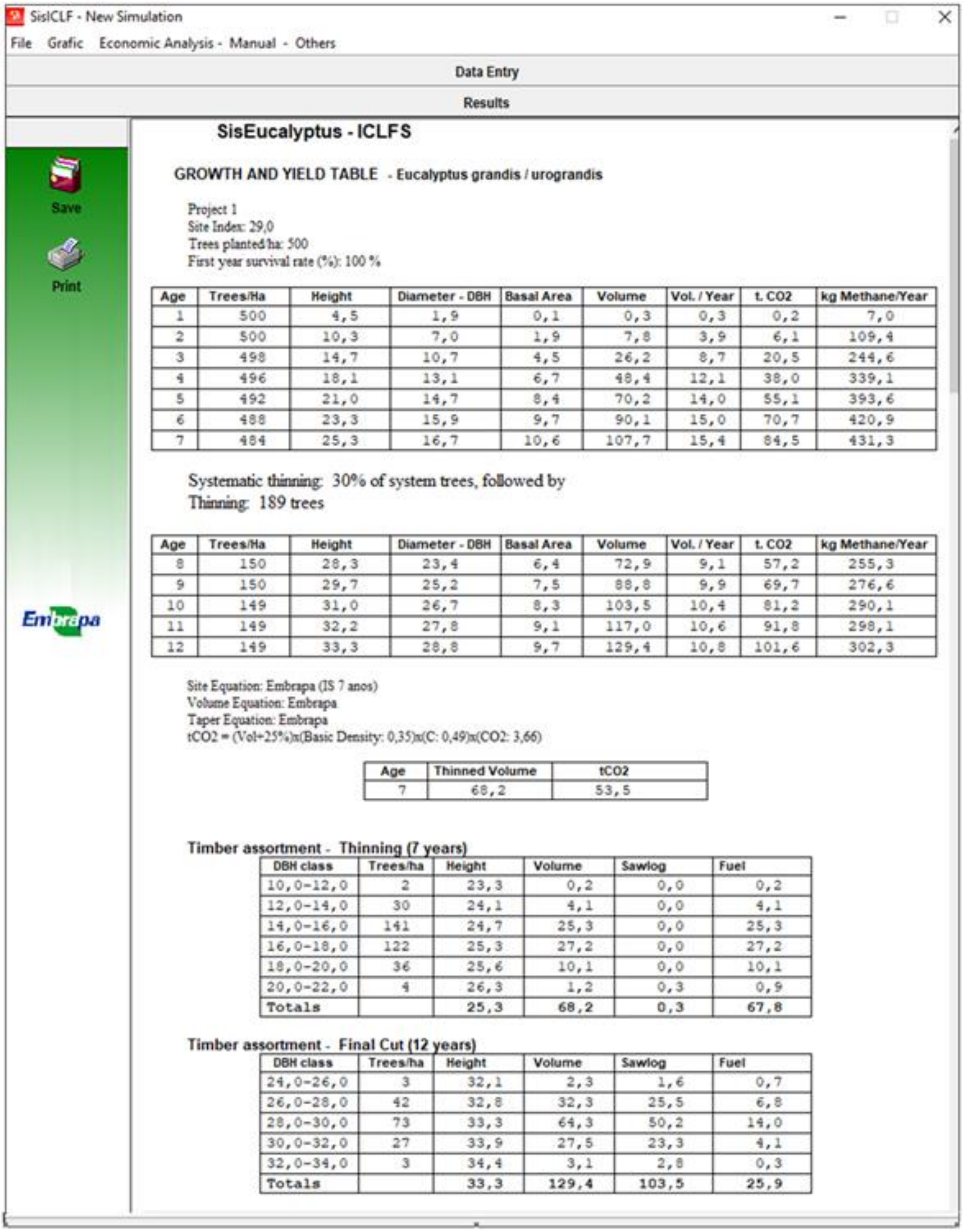
○ Option 1: Remaining basal area

● Option 2: Remaining trees/ha 150

Figure 1. Simulation screen showing a summary of the information to be processed.

The parameter “Homogeneity index of the population”, which allows an input ranging from 1 to 10, can be based on statistical analyses (such as variance and coefficient of variance) or on empirical measurements. Clone plantations do not necessarily have a value of 10 because the parameter considers both genetic and site variability.

The growth and yield table and wood assortment tables by industrial use classes are shown in Figure 2.



SisEucalyptus - ICLFS

GROWTH AND YIELD TABLE - Eucalyptus grandis / urograndis

Project 1
Site Index: 29,0
Trees planted/ha: 500
First year survival rate (%): 100 %

Age	Trees/Ha	Height	Diameter - DBH	Basal Area	Volume	Vol. / Year	t. CO2	kg Methane/Year
1	500	4,5	1,9	0,1	0,3	0,3	0,2	7,0
2	500	10,3	7,0	1,9	7,8	3,9	6,1	109,4
3	498	14,7	10,7	4,5	26,2	8,7	20,5	244,6
4	496	18,1	13,1	6,7	48,4	12,1	38,0	339,1
5	492	21,0	14,7	8,4	70,2	14,0	55,1	393,6
6	488	23,3	15,9	9,7	90,1	15,0	70,7	420,9
7	484	25,3	16,7	10,6	107,7	15,4	84,5	431,3

Systematic thinning: 30% of system trees, followed by
Thinning: 189 trees

Age	Trees/Ha	Height	Diameter - DBH	Basal Area	Volume	Vol. / Year	t. CO2	kg Methane/Year
8	150	28,3	23,4	6,4	72,9	9,1	57,2	255,3
9	150	29,7	25,2	7,5	88,8	9,9	69,7	276,6
10	149	31,0	26,7	8,3	103,5	10,4	81,2	290,1
11	149	32,2	27,8	9,1	117,0	10,6	91,8	298,1
12	149	33,3	28,8	9,7	129,4	10,8	101,6	302,3

Site Equation: Embrapa (IS 7 anos)
Volume Equation: Embrapa
Taper Equation: Embrapa
tCO2 = (Vol+25%)x(Basic Density: 0,35)x(C: 0,49)x(CO2: 3,66)

Age	Thinned Volume	tCO2
7	68,2	53,5

Timber assortment - Thinning (7 years)

DBH class	Trees/ha	Height	Volume	Sawlog	Fuel
10,0-12,0	2	23,3	0,2	0,0	0,2
12,0-14,0	30	24,1	4,1	0,0	4,1
14,0-16,0	141	24,7	25,3	0,0	25,3
16,0-18,0	122	25,3	27,2	0,0	27,2
18,0-20,0	36	25,6	10,1	0,0	10,1
20,0-22,0	4	26,3	1,2	0,3	0,9
Totals		**25,3**	**68,2**	**0,3**	**67,8**

Timber assortment - Final Cut (12 years)

DBH class	Trees/ha	Height	Volume	Sawlog	Fuel
24,0-26,0	3	32,1	2,3	1,6	0,7
26,0-28,0	42	32,8	32,3	25,5	6,8
28,0-30,0	73	33,3	64,3	50,2	14,0
30,0-32,0	27	33,9	27,5	23,3	4,1
32,0-34,0	3	34,4	3,1	2,8	0,3
Totals		**33,3**	**129,4**	**103,5**	**25,9**

Figure 2. The growth and yield table generated by the software.

The software supports decision making related to when, how, and how much to thin, and when to conduct the final harvest. Based on inventory data, the software allows the user to simulate all tree component management options in ICLFs, forecast present and future production, conduct economic analyses, and decide on the best alternatives to manage their plantation.

Thinning alows for a reduction in the number of trees per area, thus providing trees with more space to grow. One method of thinning involves the preservation of the best trees, eliminating those that are suppressed, bifurcated, or broken and those with symptoms of disease or extensive damage from pests. Well-planned and well-executed thinning increases the likelihood of obtaining a high-quality final product. It also increases the economic profitability of the population and allows the producer to receive some economic return before the final harvest. The methods that can be used for simulated thinning of a population include: **Systematic** – when trees are removed using a chosen, fixed regime, depending on the available stand. For example, the removal of an entire row of trees, with other rows of trees remaining intact; **Selective** – in this case, the smallest trees in the population are removed (low thinning). Both the diameter as well as the height can be used as a variable in choosing the trees for removal; **Mixed** – this method integrates both types described above first by conducting a systematic thinning and subsequently a selective thinning in the remaining tree rows.

CONCLUSIONS

SisILCF generates prognosis charts and graphs for growth and yield of trees, indicates how much wood will be produced at any age, tests any management regime that the user wishes to apply, and calculates the carbon (methane and CO_2 equivalent) stored by the trees. The program also generates wood assortment tables by industrial use class, such as laminate, sawlog, and fuel, according to log diameters and lengths identified by the user. SisILCF enables the simulation of different thinning regimes, generating an assortment table for each. The software is available for download on Embrapa Forestry’s website (www.embrapa.br/florestas).

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MODELLING INTEGRATED CROP-LIVESTOCK SYSTEMS: PRELIMINARY RESULTS FROM AN AGROECOSYSTEM MODEL

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ABSTRACT

Integrated Crop-Livestock Systems (ICLS) are being considered to improve food production sustainability and are of increasing interest to the modelling community worldwide. Our goal was to evaluate the ability of an agroecosystem model simulator (ECOSMOS) to predict plant growth and yield, and water dynamics in an ICLS in the Western region of São Paulo State, Brazil. Four fields of approximately 50 ha each were monitored after the implementation of the ICLS at the end of 2018. Soybean yields (two seasons), mixed-pasture aboveground dry biomass and soil water content (for the pasture only) measurements were contrasted with predictions from ECOSMOS with recently implemented soybean and pasture sub-models. Preliminary results from a generic simulation for the whole farm showed that the model was able to capture fairly well the seasonal variation in growth and water dynamics. Such results suggest that the existing knowledge and modelling approaches embedded in the model are robust. Future steps toward modelling the ICLS will involve to parameterise the model for Brazilian cultivars of the system using data from controlled/manipulative experiments, develop a framework to simulate two plants concomitantly, and then assess its capability to predict environmental variables of interest, such as carbon dynamics.

Key words: Agriculture (Soybean); Pasture; Intensification

INTRODUCTION

Integrated crop-livestock systems (ICLS) have been replacing traditional agricultural and extensive/degraded pastureland areas as an alternative for sustainable food production intensification (BALBINO et al., 2019). Estimates indicate that ICLS is adopted over 9.5 M ha across production lands in Brazil in 2015/2016, representing ~ 83% of the integrated systems (REDE ILPF, 2021). One possible way to predict the performance of such systems, both in terms of productivity and environmental aspects, is by using dynamic simulation models. Agricultural, forestry and pasture process-based models have been used to analyse and simulate the performance of food, energy and fibre production systems worldwide (BOOTE, 2020). However, little is developed in the modelling community for integrated systems that combine different species growing concomitantly.

In this context, we evaluated as a preliminary analysis, the capability of the ecosystem model simulator (ECOSMOS) with recently included soybean and pasture submodules to predict soybean yields, pasture aboveground dry biomass and soil water dynamics in a commercially managed ICLS, recently implemented, in the Western region of São Paulo (SP) State, Brazil.

MATERIAL AND METHODS

1) Study area and measurements descriptions

The study area is a commercial farm with approximately 200 ha located in Caiuá, Western SP (21º38'15" S; 51º54'57" W, 310-380 m). A detailed description of the area and management can be found in Dos Reis et al. (2020), and here we highlight only the main features. The soil texture is predominantly sandy loam with clay contents ranging from 22 to 241 g/kg. Long-term annual averages for rainfall and temperatures (1950-1990) in this region are 1246 mm/year and 22.4 ºC/year, which is characterised as a tropical Aw climate according to Köppen's climate classification (ALVARES et al., 2013).

The ICLS was implemented in 2018 after an extensively managed pasture (*Urochloa brizantha* cv. Marandu) since Aug. 2007. The area was then split into four fields of approximately 50 ha each, and soybean (*Glycine max*) was sown (cultivars BRS 7380 RR, AS 3730 IPRO, and NS 6700 IPRO) under no-till between 17th-23th November. Harvest took place between 28th March and 6th April 2019. After the first soybean harvest, the area was split into 13 paddocks, and a mixed-pasture of millet (*Pennisetum americanum*) and ruzigrass (*Urochloa ruziziensis*) was established to feed farm animals (primarily cattle), in a rotational management operation, until ~ 16th November 2019. Animals grazed on two occasions, from May to June and from August to October. The remaining pasture was then mowed and desiccated for the second soybean season. Between 7th-10th December 2019 the same three cultivars previously mentioned were sown under no-till and harvested last from 29th Mar to 5th April 2020.

Commercial soybean grain yields were measured at harvest (at 13% moisture). Point-based measurements of yields in the first soybean season were taken (100 points), while the data from a harvesting machine with a yield monitor embedded were used for the second season. Point-based measurements of aboveground (dry) biomass were taken on six occasions in the mixed pasture (100 points; roughly monthly). An automatic weather station (METOS®, Pullman, USA) was installed on 17th June 2019 in the area. Climate variables prior to this date and eventual gaps on records were filled with a nearby station (~ 21 km). On that same day, 20 locally calibrated soil water sensors (Teros 10 model; logger EM 5b; METER®) were distributed in the pasture area and installed at 20 cm depth in the soil to measured volumetric soil water content til before sowing the second soybean season. These collected data were then benchmarked with the ECOSMOS predictions after proper configuration of the system in the model, as described in the next section.

2) Modelling

ECOSMOS is a biophysical model that relies on the Agro-IBIS model (FOLEY et al., 1996; KUCHARIK; BRYE, 2003). Researchers from EMBRAPA (Brazilian Agricultural Research Company) have been improving the original model and implementing the most important cultivated plant species in Brazil. The model solves biophysical processes, such as photosynthesis, energy balance, and soil-related processes dynamics. The CROPGRO (BOOTE et al., 1998) and CROPGRO-Perennial Forage (PFM; RYMPH et al., 2004) models were brought from the DSSAT (HOOGENBOOM et al., 2019) and implemented (code rewriting) in the ECOSMOS framework. The previously mentioned biophysical processes (the core of the land surface module) were kept as in the ECOSMOS, and the soybean and pastures now develop and grow following the modelling approaches of CROPGRO and CROPGRO-PFM. Nitrogen deficiency is not allowed yet as in DSSAT, although the biogeochemical model in ECOSMOS simulates such nutrient dynamics. We lack at the moment of nitrogen-related data for a proper evaluation.

Soil properties for generic sandy loam type from Agro-IBIS database were used at this stage. The CROPGROs are well-known and have some cultivar calibrations for Brazilian soybean (BATTISTI; SENTELHAS; BOOTE, 2017) and single pasture experiments (BOSI et al., 2020; PEQUENO; PEDREIRA; BOOTE, 2014), which can be leveraged until we have a fully parameterised model for the cultivars in the ICLS we simulated. Genotype coefficients from Pequeno et al. (2014) for the pasture and from CROPGRO for soybeans representing the generic maturity group 7 were employed.

Simulations were performed for the whole area in this study. Soybean sowing dates in both seasons considered were set as the earliest among the four fields. Implementation of the mixed pasture was set on the posterior day of the latest harvest date in 2019. Simulations for the mixed pasture comprised only the single plant of CROPGRO-PFM. Grazing was mimicked by using the 'mowing' approach as used currently in the DSSAT. It is worth mentioning that the model does not take into account pests and nutrients deficiencies (apart from nitrogen, to be evaluated in future).

The evaluation at this stage was made by visually analysing the time-series graph for predicted and measured dry yields at harvest (soybeans) and aboveground biomass (mixed pasture), and soil water measurements built with the *ggplot2* (WICKHAM, 2016) package in the *R* environment (R CORE TEAM, 2018).

RESULTS AND DISCUSSIONS

Daily meteorological conditions throughout the period monitored and modelled is presented in Figure 1A. Accumulated precipitation in the soybean cycle in 2018-2019 was 642.1 mm, and averages of maximum and minimum air temperatures were 33.2 ºC and 21.6 ºC, respectively. For the pasture phase, accumulated precipitation reached 504.8 mm with temperatures averages of 31.5 ºC and 17.9 ºC for maximum and minimum values recorded. In the second soybean season, total precipitation was 438.8 mm, and the averages of maximum and minimum air temperatures were 33.5 ºC and 21.1 ºC, respectively.

The simulation for the ICLS in Western SP reproduced fairly well the crop yields and pasture growth, given that practically any parameterisation at this stage was done (Figure 1BC). It suggests that the existing knowledge and modelling approaches embedded in the ECOSMOS and plant models CROPGRO and CROPGRO-PFM are robust. Despite the reasonable performance, there are a few points of parameterisation that needs to be addressed, such as soybean phenology and grazing management (Figure 1B). Because the soybean fields were not monitored frequently, phenology may not be accurately simulated. Matching cycle length by manipulating genotype parameters for each soybean cultivar at least will be necessary. The mowing events to represent grazing perhaps will need to be replaced for another modelling approach that takes into account the grazing intensity imposed by the number, type and living weight of the animals to some extent. The slow pasture regrowth, now predominated by ruzigrass, predicted by the model (see the last measurement in Figure 1B) after the second grazing during springer also deserves attention. Such behaviour may be related to excessive grazing imposed by us, an excessive water stress penalisation in winter by the model, and/or the different ability of the ruzigrass to respond to the environment not captured by the genotype traits adopted.

Simulations accounted quite well for the variations in the soil water content at 20 cm (Figure 1C), considering the standard deviation from the mean values. It is expected that the simulations for each paddock with their respective soil properties as well as calibrated genotype parameters and specific grazing events will give more confidence to the modelling; nevertheless, there are a few steps before fully modelling the ICLS.

Future steps toward modelling of integrated systems will involve first to parameterise and evaluate the model for each species (crops and pastures) with fluxes in the agroecosystem (CO_2, energy and water), phenology and biometric data from manipulative and/or controlled experiments in diverse agricultural production systems. Another plant model is under implementation for maize, millet and sorghum in single production systems. Then we will develop and test a framework based on the existing approach of the ECOSMOS to simulate intercropping and mixed systems (two species competing for resources such as light and water). The simulations will be paddock-specific at this stage for the ICLS that was monitored for this study. We will parameterise and evaluate a grazing modelling approach and the biogeochemical submodule to predict carbon dynamics in such an integrated system.

A mixed pasture system was implemented after the soybean harvest in 2020, but monitoring was paralysed in most of 2020 when restrictions due to COVID-19 pandemic were imposed. Measurements have been resumed following the farm, local and state guidelines in 2021, and further data will be used to evaluate the modelling performance of the ECOSMOS.

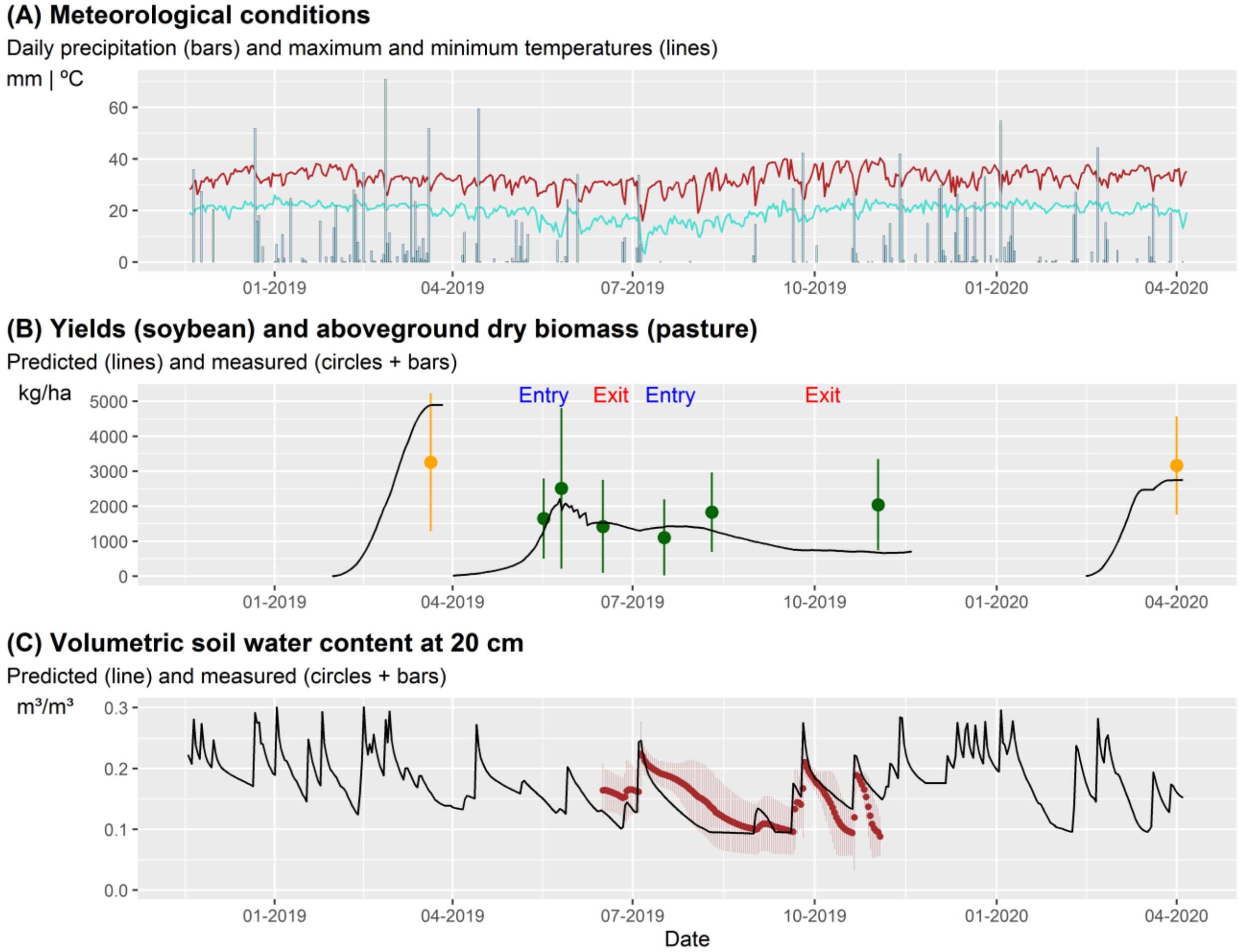

Figure 1. Meteorological conditions and the simulation by the ECOSMOS model for the ICLS in Western SP, Brazil, between November 2018 and April 2020. A) Daily precipitation and maximum and minimum air temperatures throughout the monitored period. B) Predicted (line) and measured yields at harvest for soybean seasons (orange circles plus bars; 2018/2019 and 2019/2020) and aboveground dry biomass for the mixed-pasture of millet and ruzigrass (dark green circles plus bars; 2019). Harvest soybeans at 13% moisture. Grazing intervals (earliest entries and latest exits) are also indicated. C) Soil water content at 20 cm measured (red points plus bars) and predicted (line) for the pasture phase. Bars represent the standard deviation from the mean values.

CONCLUSIONS

The preliminary simulation indicated that the ECOSMOS model reproduced reasonably well the aboveground biomass of a mixed-pasture and yields of two soybean seasons, as well as the soil water content (during the pasture phase) of an ICLS in the environmental conditions of Western SP, Brazil.

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SPATIAL AND TEMPORAL CHANGES OF THE SOIL CHEMICAL ATTRIBUTES AFTER TWO YEARS OF IMPLEMENTING AN ICLS.

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ABSTRACT

Mapping soil attributes and their variations through space is one of the major concerns in Precision Agriculture. Although many studies have successfully mapped soil chemical quality attributes such as Organic Matter (OM) and Cation Exchange Capacity (CEC) in agricultural lands, it is a challenge to acquire the variability of soil attributes through space in mixed systems like the Integrated Crop–Livestock System (ICLS). Hence, our objective with this study was to characterize the spatial and temporal variability of soil chemical attributes in two years of ICLS. We carried out spatial principal component analysis (MULTISPATI-PCA), interpolated the most important spatial principal components (sPC) through kriging, and analyzed the spatial distribution sPC before and after the implementation of ICLS. The implantation of the ICLS promotes spatial and mainly temporal changes in the soil's chemical attributes. Organic matter, base saturation, potential acidity, CEC, and Magnesium showed more significant temporal variation in known homogeneous regions. There was a change in the spatial distribution of the soil's chemical attributes after implanting the ICLS, and the change in the contents occurred variably throughout the space. In some portions of the field, there was an increase of chemical attributes content, while in other portions occurred a reduction of these contents.

Key words: soil chemical attributes; multivariate analysis; precision agriculture

INTRODUCTION

The Integrated Crop – Livestock System (ICLS) is an alternative for sustainable intensification of food production. However, this system's complexity is associated with the diversification of activities practiced in a short period since crops and livestock are practiced in succession year by year. In this sense, it is considered that the soil is the "memory" of the system, with changes in its chemical, physical, or biological quality a consequence of the adopted management. An example of management influence is the cycling of nutrients through the deposition of excrement (feces and urine) from cattle grazing, usually concentrated in resting areas or near troughs and drinking fountains (CARNEVALLI et al., 2019). Such distribution can be a source of change on soil chemical attributes and directly impact the next crop's productivity. Therefore, mapping and understanding spatial and temporal changes in soil chemical attributes after ICLS implementation can be an alternative to maximize the use of correctives and fertilizers, associating the ICLS with the techniques practiced in precision agriculture (AP). Thus, the study aimed to characterize the soil chemical attributes' spatial and temporal variability in two years of ICLS, seeking to understand the impacts of adopting the ICLS after a short period.

MATERIAL AND METHODS

The experimental field has 200 ha and is located in the Campina farm in Sao Paulo State - Southeast Brazil with coordinates of 21°38'15" S 51°54'56" W. The climate is classified as Aw – tropical with dry winter and precipitation varying from 1100 to 1300 mm, and average annual temperature ranging from 22 to 24 °C. Soil is classified as Argisol with a sandy texture (SANTOS et al., 2018). This field has been cultivated with pasture and used for livestock production before ICLS implementation in 2018 with soybean seeding. The ILP system formation took place in August 2018, with 1.5 Mg ha^{-1} application of a mixture of lime and plaster. The fertilization of soybeans was carried out at the time of seeding (no-tillage), with 150 kg ha^{-1} of KCl in both growing seasons and monoammonium phosphate (MAP) at doses 250 and 150 kg ha^{-1} in 2018/19 and 2019/20 growing seasons, respectively.

Soil sampling occurred in two periods: 2018 (before ICLS implementation) and 2020 (after two soybean growing seasons). Sampling design followed simulated annealing optimization using the minimum distance criteria (WALVOORT et al., 2010) and collected 399 samples in 0-0.2 m depth layer with four subsamples.

To assess whether there was a temporal change of soil chemical attributes, we initially explored the behavior of the data using descriptive statistics by calculating the values of mean, median, minimum, maximum, coefficient of variation, asymmetry, kurtosis, and normality of the data through the test of Shapiro-Wilk ($p < 0.05$). Most of the evaluated data did not present a normal distribution. Thus the non-parametric means test "bootstrap" (SOARES et al., 2020) was used to compare if there was a significant difference in the means of soil chemical attributes in the samples of 2018 and 2020.

Afterwards, we applied the spatial principal component analysis (MULTISPATI-PCA) (DRAY et al., 2008) to the datasets of 2018, 2020, and to the difference between attributes collected in 2018 and 2020. Similar to the traditional principal component analysis (PCA), MULTISPATI-PCA allows the summarization of the number of variables correlated with each other in a smaller number of uncorrelated variables, called spatial principal components (sPC). However, unlike conventional PCA, MULTISPATI-PCA uses a spatial weighting matrix to consider the existence of a spatial correlation between the observations and the averages of the neighboring observations and at a given point (CÓRDOBA et al., 2012). This adaptation allows the first sPC to present strong spatial structures, as their scores maximize the spatial autocorrelation between points (ARROUAYS et al., 2011). The number of sPC adopted for the interpolation was enough to explain at least 70% of the total data variance, as suggested by Ferreira (1996).

Lastly, we performed the sPC interpolation using the geoR package from software R to compute Residual Maximum Likelihood (REML) semivariogram, fitted a spherical model directly to the data, and predict unsampled locations using Ordinary Kriging. To evaluate spatial changes, we compared the visual modifications on the interpolated data and the importance of attributes on the sPC before and after ICLS implementation. We also compared how the changes happened spatially through the map of the difference between 2018 and 2020.

RESULTS AND DISCUSSIONS

There was an increase in most soil attributes' average values after two years of implementing the ICLS, especially P, with an increase of 95%. On the other hand, OM presents a reduction and the attributes Mg and BS that no change was observed after two years of ICLS (Table 1). The increase in most of the soil's chemical attributes is probably related to the interaction between soil fertility management (lime and fertilizer application) required by soybean cultivation. The reduction in OM might be related to the recent conversion from livestock to ICLS since OM accumulation is modified slightly over time (BIELUCZYK et al., 2020) and relies on the management practices (OLIVEIRA et al., 2018). Also, the implementation of agriculture in sandy soils causes an acceleration in the mineralization of OM, especially in the soybean phase. Hence, it might be too soon to detect changes in OM in the experimental field.

Table 1. Descriptive analysis of the chemical attributes of a Argisol, in the 0-0.20 m layer depth, under a livestock crop integration system.

Attributes	**Value**				**Coefficient**[a]			**Probability**[b]	
	Mean[c]	**Median**	**Minimum**	**Maximum**	**CV (%)**	**Kurt.**	**Skewn.**	**Pr<W**	**DF**
					2018 Sampling				
OM (g dm^{-3})	12.8 A	13.0	7.0	22.0	18.9	0.8	0.5	0.00	-
pH	5.0 B	5.0	4.3	5.6	3.4	1.7	-0.1	0.00	-
P (mg dm^{-3})	7.7 B	6.0	2.0	153.0	137.0	116.1	9.8	0.00	-
K ($mmol_c$ dm^{-3})	1.6 B	1.3	0.4	5.4	55.1	2.2	1.4	0.00	-
Ca ($mmol_c$ dm^{-3})	15.8 B	15.0	6.0	41.0	30.5	2.6	1.0	0.00	-
Mg ($mmol_c$ dm^{-3})	9.2 A	9.0	4.0	21.0	22.4	3.3	1.1	0.00	-
H+Al ($mmol_c$ dm^{-3})	16.2 B	16.0	10.0	26.0	15.8	0.5	0.3	0.00	-
CEC ($mmol_c$ dm^{-3})	42.9 B	42.3	25.5	77.5	16.7	2.0	0.9	0.00	-
SB ($mmol_c$ dm^{-3})	26.7 B	26.4	11.5	58.5	24.5	2.3	0.9	0.00	-
BS (%)	61.6 A	62.0	43.0	81.0	10.7	0.0	-0.1	0.06	N
					2020 Sampling				
OM (g kg^{-1})	10.7 B	10.0	4.0	25.0	26.9	2.1	1.0	0.00	-
pH	5.3 A	5.3	4.7	6.1	4.6	0.1	0.3	0.00	-
P (mg dm^{-3})	15.0 A	11.0	1.0	212.0	93.0	103.3	8.2	0.00	-
K ($mmol_c$ dm^{-3})	2.5 A	2.4	1.0	8.2	36.8	5.9	1.7	0.00	-
Ca ($mmol_c$ dm^{-3})	17.0 A	16.0	9.0	61.0	31.9	19.1	3.3	0.00	-
Mg ($mmol_c$ dm^{-3})	9.0 A	9.0	5.0	24.0	25.3	5.0	1.4	0.00	-
H+Al ($mmol_c$ dm^{-3})	17.0 A	17.0	10.0	27.0	15.5	0.9	0.7	0.00	-
CEC ($mmol_c$ dm^{-3})	45.6 A	44.8	30.6	104.9	18.5	13.0	2.5	0.00	-
SB ($mmol_c$ dm^{-3})	28.6 A	27.3	16.4	80.9	26.8	13.0	2.6	0.00	-
BS (%)	62.1 A	62.0	45.0	80.0	9.7	0.0	0.2	0.07	N

OM: Organic matter. P: phosphorus. K: potassium. CEC: cation exchange capacity at pH 7.0. SB: sum of exchangeable bases. BS%: Base saturation. (a) Kurt.: Kurtosis; Skewn.: Skewness. (b) Pr <W: Probability referring to normality by the Shapiro-Wilk test ($p < 0.05$); N: Normal distribution. (c) Different letters for the same attributes in the respective assessments differ by the "bootstrap" comparison test ($p < 0.05$).

We identified for the three datasets (2018, 2020, and difference between 2018 and 2020) that the number of two sPC was enough to explain at least 70% of the total variance of the data (cumulative variance of 70%, 81%, and 70% for 2018, 2020, and the difference between them, respectively). We also calculated Moran's index for sPC 1 and sPC2 for 2018 (0.52 and 0.34); 2020 (0.33 and 0.26); and for the difference between the years (0.19 and 0.15). Lower values of Moran's index indicate lower autocorrelation and higher randomization on the spatial structure. Hence, even with a high global explained variance (MULTISPATI-PCA), there was increased randomization of spatial autocorrelation (lowered values of Moran's index) from 2018 to 2020.

The interpolation of the sPC scores allowed clear visualization of the low and high concentration sites (blue and yellow regions in the maps, respectively) of most of the soil chemical attributes evaluated, both before (Figure 1 A and B) and after (Figure 1 C and D) the implementation of the ICLS, in addition to the sites of the difference between the years (Figure 1 E and F). The importance of the characterized attributes is given by the relationship between score and correlation within the component (Figure 1); that is, the attributes with the highest correlation give greater weight in the separation of the components, and this decreases with the increase in the number of components. When comparing the sPC 1 maps from 2018 and 2020 (Figure 1A and 1C), we identified similarities in the spatial patterns and attributes of greater relevance for the sPC 1; the only exception was H+Al, which became relevant in sPC 1 in the year 2020. The area's western region concentrated the highest values of OM, Ca, Mg, CEC, SB, and BS and the lowest values in the central and southeastern regions (Figure 1A and 1C).

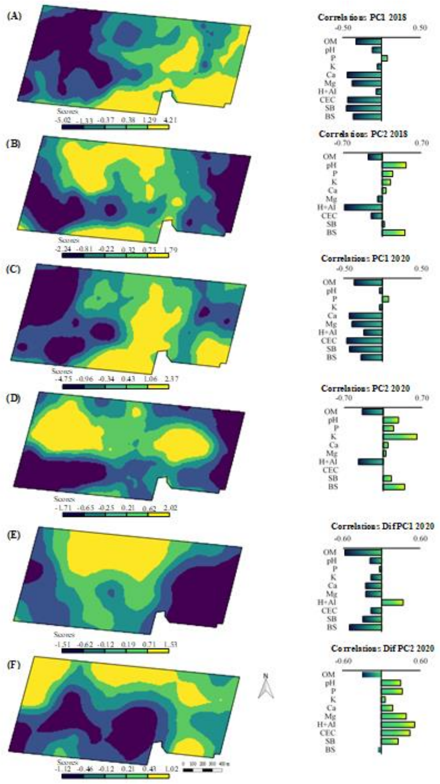

Figure 1. Spatial distribution maps of the scores of the spatial principal components (sPC 1 and 2) of the soil chemical data determined in 2018 (A and B) and 2020 (C and D), in addition to the difference between the years (E and F).

As for sPC 2, in 2018, the most relevant attributes for the component were pH and BS (directly proportional) and H+Al (inversely proportional) (Figure 1B); and in 2020 (Figure 1D), in addition to these attributes, K became directly relevant to sPC 2. These results show that the regions of the sPC 2 map with higher values of the scores (regions in yellow) are ruled by attributes related to soil acidity, thus have higher concentrations of pH and BS and lower concentration of H+Al in 2018; and this was repeated in 2020, including the highest concentrations of K. When comparing the results obtained before and after the implementation of the ICLS, we identified some changes in the spatial pattern of sPC 2 (Figure 1B and 1D). Regions with higher score values started to be concentrated in the central-east and extreme west of the area and no longer in the area's southern region (yellow region). This change occurred mainly due to the attribute K becoming more relevant in this component in the year 2020, in the same way, that the attribute H+Al became in sPC 1. Hence, H+Al and K presented more significant spatial autocorrelation after implementing ICLS. Spatial distribution was less random in the area; thus, the practice of ICLS, even after only 2 years, signs for the uniformity of the spatial distribution of some chemical attributes of the soil.

The spatial distribution maps of the sPC that represent the difference between the soil attributes determined before and after the implementation of the ICLS (Figure 1E and 1F) helped to identify regions with a low and high temporal variation. The map of sPC 1 mainly shows the temporal variation of OM and BS, because they are the attributes with the highest weight in the sPC1 component (Figure 1E), where regions in blue and yellow represent the increase and reduction within years of these attributes, respectively. The greenish-colored regions represent the temporal stability of the two attributes. The spatial distribution map of sPC 2 (Figure 1F) indicates temporal variation in the attributes H+Al, CEC, and Mg, which showed an increase of attributes in the yellow regions and a decrease in the blue darker regions. The less relevant attributes for the components (represented by the smallest bars) showed little temporal or even random variation in space.

These results can guide the farmers' decision-making for the different management of the area regarding the application of agricultural inputs to maximize their use, given that, with this approach, it is possible to recognize regions with unfavorable chemical soil conditions for the development of crops (TAVANTI et al., 2020). Besides, the results allow for guiding the position of the soil collection points in the next samplings, i.e., in regions that indicate a group of attributes with greater spatial stability, a smaller number of samples can be collected.

CONCLUSIONS

The implantation of the ICLS promotes spatial and mainly temporal changes in the soil chemical attributes. The change in the spatial distribution of soil chemical attributes occurred mainly for K and H+Al, which increased spatial autocorrelation. After two years of implementing the ICLS, there was a global improvement in the soil chemical over time due to an increase in attributes' values, mainly for P and except for OM, Mg and BS. The positive or negative temporal variation of OM, BS, H+Al, CEC, and Mg occurred differently according to the spatial location.

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THE IMPORTANCE OF FIELD MANAGEMENT INFORMATION FOR A PROPER SOIL CHEMICAL PROPERTY MAPPING ON INTEGRATED CROP-LIVESTOCK SYSTEMS

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ABSTRACT

Crop livestock integrated systems have high agricultural dynamics influenced by management with plants, soil, and animals. Such combination affects the fields spatial variability and generates complex systems that are difficult to be mapped. The characterization of spatial variability of soil attributes is necessary to enable fertilization at variable rates. Thus, this study aims to show the importance of the management covariables to improve the spatial variability mapping of two soil attributes, potassium (K) and phosphorus (P). We used the water sources' distances and the paddocks' boundaries as covariables representing the field management. We used robust multiple linear regression (RMLR) and robust universal kriging (RUK) as multivariate predictive methods. The inverse distance weighting method (IDW) and robust ordinary Kriging (ROK) were used for comparison purposes, as they are univariate interpolators. We demonstrated here that the insertion of management covariables in the predictive methods improves the accuracy of P and K spatial variability characterization. Among the covariables used, the paddocks showed a high potential to characterize the existing variability. In this way, covariables related to field management must be identified, mapped, and inserted in predictive methods to improve fertilizer variable-rate efficiency.

Key words: Precision Agriculture; Digital soil mapping; paddocks

INTRODUCTION

The high agricultural dynamics integrated of crop and livestock systems (ICLS), influenced by management with plants, soil, and animals, affect areas' spatial variability and generate complex systems to be mapped. Animals contribute to increasing variability by redistributing nutrients via excretion (VENDRAMINI et al., 2014). The characterization of spatial variability of the soil attributes used in the fertilizer recommendations is necessary to make fertilization at variable-rates efficient, which guarantees the systems' sustainability and the correct handling of agricultural inputs. Since the spatial variability is affected by the agricultural systems' dynamics, the inclusion of covariables that characterize the management adopted in the area allows for modeling such a source of variation and generating more accurate maps of soil attributes' spatial variability. The work's objective is to show the importance of the management covariables to improve the spatial variability mapping of two soil attributes, potassium (K) and phosphorus (P).

MATERIAL AND METHODS

The study area has 200 ha and is located in Caiuá, SP, Brazil (21° 38'13" S; 51° 54'55" W). The climate is tropical with a dry winter season, with precipitation and average annual temperatures between 1,100 and 1,300 mm, 22 ° C and 24 ° C, respectively (Aw - ALVARES et al., 2013). The terrain is gently undulating, and the soils are classified as Argisols, with texture ranging from medium to very sandy (SANTOS et al., 2013). The area remained under grazing (*Urochloa brizantha* cv.

Marandu) rotated for 11 years (2007-2018) with heifers from two to three years, at an occupancy rate of ~ 1.7 AU (animal unit) ha^{-1}.

The soil sampling took place in October 2018, and 399 samples were collected in the 0.0-0.20 m depth layer. Each compost sample consisted of four simple samples collected within a radius of 5m from the central grid point. The sampling configuration used was obtained by simulated spatial annealing, and as a criterion, we used the minimization of the mean of the smallest quadratic distance (MSSD) between the sample points and the prediction points (SAMUEL-ROSA, 2019). The soil properties evaluated in this study were available potassium (K) and phosphorus P.

The spatial covariates used were chosen based on the capacity of characterizing the area's management practices and according to the acquisition availability. Hence, we used the distances from the water sources (WTD) and the paddocks' contours (Paddocks). We analyzed the collinearity between the covariates and used the AKAIKE (AIC) criterion stepwise to select the covariates that best represented the data.

To predict the values in non-sampled locations, we used four methods, we used robust multiple linear regression (RMLR) and robust universal kriging (RUK) as multivariate predictive methods. The inverse distance weighting method (IDW) and robust ordinary Kriging (ROK) were used for comparison purposes, as they are univariate interpolators. RMLR was used because it allows the use of covariables and does not consider the spatial autocorrelation in the residues, whereas the RUK method performs the semivariographic modeling in the residues. For semivariographic modeling of the geostatistical models (RUK and ROK), we used a mixed linear model, and the semivariogram parameters were estimated by robust residual likelihood (REML) (KÜNSCH et al., 2011). The robust methods of prediction allow us to deal with outliers in the data set, and through a redescent function, it assigns different weights to the values considered outliers. The redescent function used was the huber function with the tuning constant c = 2 (HUBER, 1973).

The efficiency of the predictions was analyzed by leave-one-out cross-validation (LOOCV). The metrics used in the comparison of the models were: Mean error (ME), Square root of the mean error (RMSE) (LI & HEAP, 2011), and the Nash-Sutcliffe efficiency index (NSE) (KRAUSE et al., 2005). ME and RMSE the closer to zero, the better the estimates and NSE, ranges from -1 to 1, the closer to 1, the better the variability than the mean, negative values, indicating that the mean represents better the variability of the area.

RESULTS AND DISCUSSIONS

The insertion of management covariables in the predictive methods improves the accuracy of P and K spatial variability (Table 1, RMSE and NSE). Such improvement occurs because, in ICLS in addition to the variability caused by traditional factors of soil formation, such as topographic characteristics, the spatial variability of soil chemical attributes is affected by the dynamics of animals. Therefore, management covariates become essential predictors of soil variability. Animals are responsible for redistributing nutrients, mainly K through urine and P through fezes (Vendramini et al., 2014, apud MATHEWS et al., 1996). However, given that the redistribution of nutrients via excreta occurs in an inconsistent manner (DUBEUX et al., 2006), it is challenging to monitor the places where animals deposit excreta. Thus, an alternative to improve the characterization of soil attributes' spatial variability is to use covariables that indicate preferential regions with high animals' activity and insert such information in predictive methods.

Table 1. Cross-validation statistics (LOOCV) for the analyzed predictive models and covariates used in the modeling.

	K (mmol$_c$ dm^{-3})			P (mg dm^{-3})		
	ME	**RMSE**	**NSE**	**ME**	**RMSE**	**NSE**
IDW	-0.01	0.80	0.14	0.00	5.02	0.12
ROK	0.05	0.80	0.13	0.67	5.02	0.12
RMLR	0.05	0.79	0.16	0.56	4.50	0.29
RUK	0.01	0.77	0.20	NA	NA	NA
Selected covariables	Paddoks			Paddoks		

NOTE: NA - Models that did not converge to maximum probability for the semivariogram parameters.

The covariable paddocks showed a high potential to characterize the existing variability in pasture areas, given that such information remained in the data set after selection by AIC via stepwise (Table 1). The selection of covariables was carried out to reduce the data set's dimensionality to ensure a more accurate adjustment to the data's behavior. We observed high P and K values close to the animals´ preferred sites (long central areas with high values), represented by paddock 26 (Figure 1A and 1B), which caused both higher valuer and variability of soil attributes in relation to the other paddocks evaluated. This occurs due to the high permanence of animals in this area. Althought RUK method did not converged to a solution for P modeling, RMLR highlights the importance of paddocks to explain P variability (Figura 1C). In this case, RMLR explained the most part of the variability presented in the area and, thus, kriging was not demanded in the end of the prediction process. Therefore, in pasture areas where there is a high variability, the covariable paddocks' inclusion improves the mapping of soil attributes' spatial variability.

Among the factors that affect the heterogeneity of integrated systems, the animal activity becomes the most complex to be mapped and transformed into a covariate that can represent this variability. However, we believe that such kind of information is mandatory to deliver better spatial predictions of soil chemical properties. This is because the animals are responsible for the redistribution of P and K contents via grazing. Among the covariates mapped, the WTD was not efficient to explain P and K variability, since it was deleted during selection by AIC by stepwise. However, sites that record greater animal activity should be identified, mapped and tested in selection methods and also in the characterization of variability. McEntee et al. (2020) studying spatial and temporal stability in hybrid systems, suggests that animals equipped with GPS can identify grazing behavior and distribution of animals in the areas. Identifying animals' activity can contribute to the understanding of the variability of soil chemical attributes in integrated systems, and consequently, to apply precision agriculture techniques in search of more sustainable management.

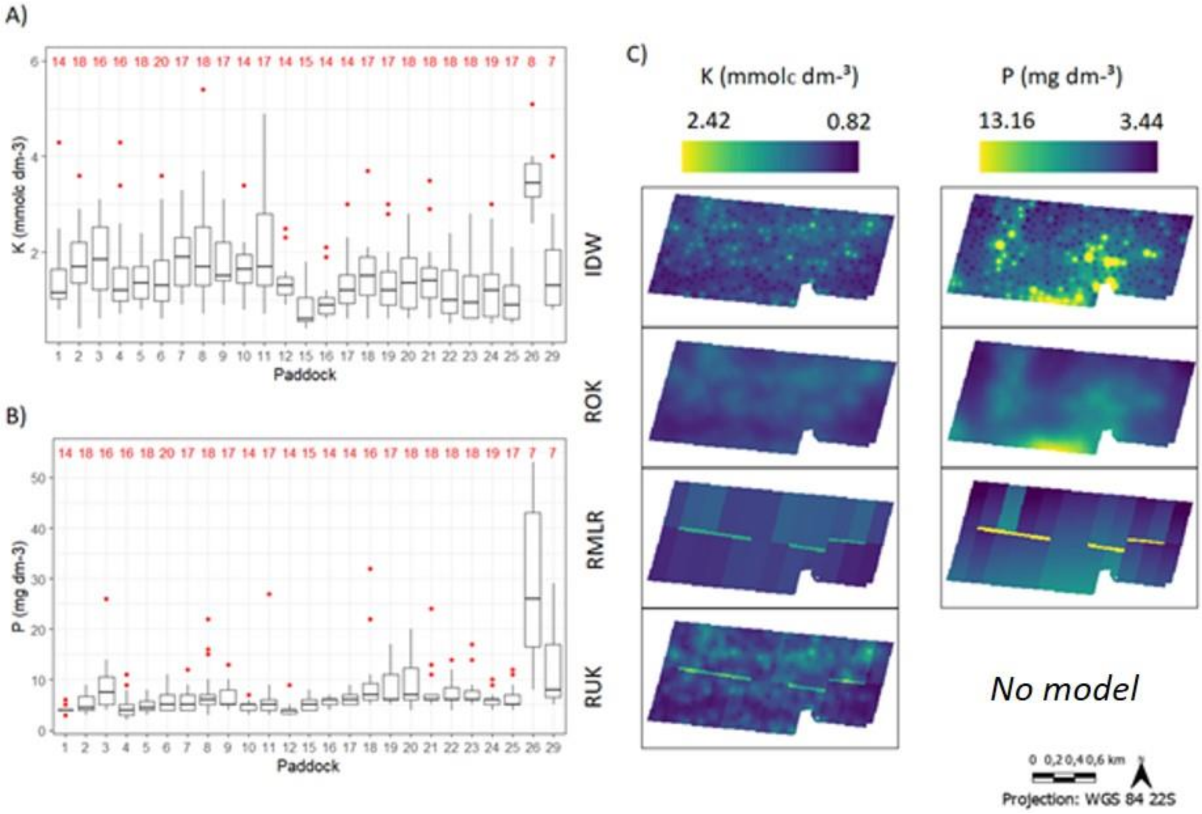

Figure 1. A) and B) - Data distribution between each paddock factor, for available potassium (K) and phosphorus (P) levels, respectively. C) Spatial distribution of P and K contents according to the IDW- Inverse distance squared methods; ROK- Robust ordinary Kriging; RMLR- Robust multiple linear regression; RUK- Robust universal Kriging. NOTE: No model Models that did not converge to maximum probability for the semivariogram parameters.

CONCLUSIONS

The use of management covariables in pasture and ICLS areas improve the mapping of soil attributes. This way, covariables that characterize the management adopted in areas must be identified, mapped, and inserted in predictive methods to map soil properties' spatial variability.

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PRECISION FARM TO IMPROVE CROP-LIVESTOCK SYSTEMS IN SOUTHERN BRAZIL

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ABSTRACT

The expansion of soybean crop in southern Brazil, driven by good prices in recent years, has raised concerns about decrease in cattle herd and gradual increase of monoculture economic dependency. In this work are analyzed, the productive and economic performances of three different systems: soybean crop monoculture; crop-livestock system with soybean crop in summer and ryegrass pasture in winter and crop-livestock system composed by soybean crop and Sudan grass in summer and ryegrass pasture in winter, the latter, obtained by simulation of soybean crop replacement by BRS Estribo Sudan grass in low productivity areas, obtained by productivity map evaluation in six years. The operating profit in all systems showing that crop-livestock systems can minimize the risks of soybean crop frustration due to water soil deficit. Just as crop-livestock systems can be improved using precision farming techniques. The weather forecasting as a decision-making to choose crop seeding, soybean or Sudan grass, in the different management zones is also discussed.

Key words: Precision Agriculture; Pampa Biome; Soybean

INTRODUCTION

The good prices of soybeans in recent years have led to the expansion of crops in southern Brazil and are pushing for the reduction of cattle and livestock activities, which have historically been adapted to local vegetation, soil and climate conditions. Despite the tendency to increase the cultivated area, soybean productivity has a high oscillation, mainly related to water deficiency in the soil. This factor has been identified as the most relevant for reducing the productivity of the main crops of spring and summer (MATZENAUER et al., 2002; BERGAMASCHI et al., 2004), affecting the production of nine out of twenty soybean crops (OLIVEIRA et al., 2020), facts that raise great concerns about the expansion of monoculture during the summer. This concern can be attested in the region of the Southern Campaign where, during the evaluation period of the present work, the soybean area grew by 600%, while the number of cattle was reduced by 13% (EMATER RS, 2021). The good prices of soybeans promote the expansion of crops in southern Brazil and press for the reduction of cattle and livestock activity, historically adapted to the conditions of vegetation, soil and local climate.

Currently, the use of precision technologies has allowed to detail the impact of climatic risks within the crop areas on the same farm. Harvest map helps to identify low productivity areas relating them to climatic variables and economic results (PEREZ et al., 2015). This procedure can help decision making in relation to the areas to be cultivated or not, reducing the risks of crop frustration due to the low soil humidity. Expanding this perspective, the concept of management zones was used to address the spatial variability of production within agricultural areas (LUCHIARI et al., 2011). With this information, it was simulated the partial replacement of the soybean crop with a crop more resistant to water deficiency. With that, it was possible to compare the economic results and the stability of the crop-livestock systems, considering the oscillations of the summer rains in the Southern Campaign of Rio Grande do Sul.

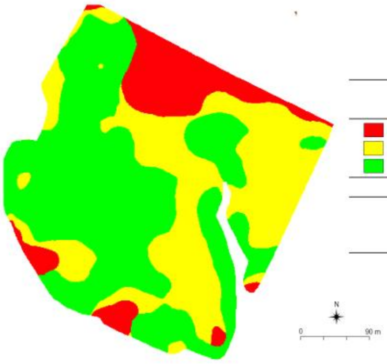
MATERIAL AND METHODS

The experiments were carried out at Embrapa Pecuária Sul, Bagé, RS, Brazil, on 13 ha, cultivated with soybean [*Glycine max* (L.) Merrill] during the summer and ryegrass (*Lolium multiflorum* L.) pasture during the winter. Grain and l beef cattle production were monitored since 2011. Soybean crop established in direct sowing after natural reseeding of ryegrass, had its productivity measured from a SLC 6300 harvester coupled to the Topper 4500 Controller from Stara Precision Agriculture, with infrared productivity sensors corrected by capacitive humidity and temperature sensors. Through interpolation, using the Krigagem method, productivity surfaces were generated for each year, which were cut out at the boundaries of the area, generating six productivity maps for the crops: 2011/12, 2012/13, 2013/14, 2015/16, 2017/18 and 2018/19. The maps were used as attributes (normalized productivity values) in a classification by Cluster Analysis, method k-averages, resulting in a map with 3 output classes, called low (red), variable (yellow) and high productivity zones (green). The interpolation was done with SURFER 9 application and the classification with QGIS 3.4.1 system.

Animal production obtained during the winter on ryegrass pasture kept under natural reseeding, between 2012 and 2019, was evaluated monthly, through the weight gain of young steers. After 12 hours fasting animals were weighed individually using an electronic scale to record weight and adjust stocking to 12% of live weight in forage dry matter. For the economic analysis, the values of a historical series of soybean production costs for Rio Grande do Sul, obtained from CONAB (2021), were used. The commercialization values of soybeans (60 kg bag) and steers (kg live weight) were provided by Emater RS (2021), internal records related to livestock (costing and weight gain) and data from the literature were used to estimate the gross margin of Capim BRS Estribo (SILVEIRA et al., 2015).Once the soybean areas and productivity zones were measured, a simulation process was carried out in order to replace the area occupied by the low-productivity soybean zone with the cultivation of BRS Estribo (*Sorgum sudanensis* L.). The results of animal productivity were converted into soybeans in the same year as the harvest, in order to mitigate the effects of price fluctuations and inflation and to allow a better comparison between the evaluated systems. Finally, a comparative analysis was made between the operating profits of soybean and fallow monocultures in winter, the real crop-livestock system and the alternative system simulating the planting of Sudan grass in the areas with the lowest productivity.

RESULTS AND DISCUSSIONS

The data set and maps of productivity of the six harvests showed the existence of variability, both spatial and temporal. The multivariate classification of soybean productivity, in 3 classes, referring to the management zones synthese and favor the understanding of the variability existing in the different zones throughout the harvests. Figure 1 shows the result of the productivity classification process in management zones: high, medium and low, with relative dimensions of 51.7%, 35.0% and 13.3%, respectively, as well as the values of productivity in bags (60 kg) in each year harvest in the different management zones and the accumulated rainfall values, in the period from November of the year of soybean planting to April of the following year.



	management zones	area (%)	Soybean productivity - bags (60 kg)/ha						mean
			2011/2012	2012/2013	2013/2014	2014/2015	2017/2018	2018/2019	
🟥	low productivity	13.3	14.0	25.5	23.4	35.3	13.1	35.8	24.5
🟨	variable productivity	35.0	20.0	33.8	41.1	31.1	14.7	48.2	31.5
🟩	high productivity	51.7	23.5	37.4	39.2	45.7	20.4	50.2	36.1
	total	100.0	21.0	34.5	37.8	39.2	17.5	47.6	
		accumulated rainfall (mm)	567.1	725.1	1079.6	623.4	436.1	865.3	

Figure 1. Management zones and soybean productivity data in different zones and harvests, and the accumulated rainfall in the six months of influence on cultivation (November to April).

The green zone with high productivity presented the best performances in five of six harvests. The exception occurred in the 2013/14 harvest when there was the greatest accumulated precipitation exceeding the crop requirements. The yellow zone of medium productivity presented the most unstable performance over time. In four of six harvests evaluated the yellow zone showed intermediate productivity values in relation to the other two zones. However, in the 2013/14 harvest, which excessive rainfall, it was the most productive area. Istead in 2014/15 harvest it was the least productive area. The red zone of low productivity presented the worst productivity in five of the six years of evaluation, except in 2014/15 harvest, when it overcame the yellow zone. It should be noted during the winter period that preceded the harvest the ryegrass grazing period was shortest, in order to enable the ryegrass harvest in the area, increasing the vegetable residue prior to the sowing of soybeans this year.

Table 1 presents the financial results of the different production systems. It is possible to verify in the first column that the operational profits obtained for the soybean crop were negative or very low in two of six monitored harvests. This fall in soybean productivity corresponds to periods with the lowest accumulated rainfall. Matzenauer et al. (2002) and Bergamaschi et al. (2004) point out that the main factor for decreases in productivity, both in frequency and intensity, is the water deficiency caused by the poor distribution of rainfall. In the present study drought imposed a reduction of more than 40% in the average productivity in one third of the harvests evaluated in the period. The analysis of operating profit for crop-livestock system where the results of the livestock phase are added to the soybean crop results, presented in the second column of Table 1, shows that over years the operating profit made it possible to obtain positive results in all years, even in the years of low soybean productivity.

Table 1. Operational profits of the different production systems in six monitored harvests.

	Operating profit – bags (60 kg)/ha		
systems	**soybean**	**soybean and ryegrass**	**soybean/sudan and reygrass**
2018/19	27.6	52.1	51.8
2017/18	-5.8	12.9	16.0
2014/15	22.4	46.7	46.0
2013/14	22.3	45.0	45.7
2012/13	16.8	27.5	28.2
2011/12	9.4	30.8	32.2

These results corroborate the importance of crop-livestock system to minimize the frequent crop soybean frustrations in the Campaign Region of RS in low rainfall. The simulation of operating profit obtained in crop-livestock system enhanced by harvest map information made it possible to exercise the substitution of soybean cultivation by Sudan grass cv. BRS Estribo. Considering the animal productivity in areas of low soybean productivity. To arrive at operating profit in simulated system, shown in the third column of Table 1, were used the gross margin value obtained for Sudan grass cv. BRS Estribo by Silveira et al. (2015). This value was transformed into soybeans (13.25 bags/ha) assuming the same performance for all harvests. Therefore, was considered even for driest period, there was no water deficiency for Sudan grass cv. BRS Estribo due to the lower requirement when compared to soybeans (20% moisture in the soil). Comparing the results of the two systems, real crop-livestock system (soy and ryegrass) with simulated crop-livestock system (soy / Sudan grass and ryegrass) it appears that the differences in yield are not very significant, 10% on average for the driest years, corresponding to an average increase of 2.3 bags / ha in annual operating profit in years of low productivity. This is partly explained by size of the management area used with Sudan grass cv. BRS Estribo 13.3% of the total area, which limits the effects. However, in the most favorable years for soybean production, there was no reduction in operating profit of the simulated system, when compared to the traditional crop-livestock system.Considering these results an interesting alternative would be to adopt a flexible strategy where decision to plant soybeans or Sudan grass cv. BRS Estribo in different proportions, in management areas, would be made according to the weather forecast for the coming months: i) dry periods, soybeans planted only in the high productivity zone and BRS Estribo Sudan grass in the others; ii) wet periods, soybeans in all management zones; and intermediate periods, soybeans in the high and medium productivity zones and Sudan grass cv. BRS Estribo in the low productivity zone. This flexible strategy would probably have more significant results. However, it is dependent on a good accuracy of the forecasts for the region based on the improvement of the meteorological models currently available.

CONCLUSIONS

Soybeans crops in the Southern Campaign Region of RS are often impacted by water deficiency and may have their economic risk reduced by crop-livestock sistem. The use of management zones, based on the yeld soybean maps allows the establishment of a strategic plan to minimize the impacts of dry years on soybean crops, replacing soybeans by Sudan grass cv. BRS Estribo. The strategy of using Sudan grass cv. BRS Estribo in areas of low soybean productivity, can still generate additional gains, either by calling for greater forage production during the summer period, which is fundamental for the maintenance of crop-livestock systems, or for the benefits of animals sale outside of high offer for sale just before sowing soybeans.

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Stara Precision Agriculture.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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ESTIMATING FORAGE MASS OF A CROP-LIVESTOCK SYSTEM (ICL) USING SATELLITE IMAGES AND CLIMATE DATA

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ABSTRACT

The Simple Algorithm for Evapotranspiration Retrieving (SAFER) was used to estimate forage mass in a beef cattle production system, in São Carlos (SP), Brazil. Harmonized Landsat-8 and Sentinel-2 (HLS) surface reflectance bands were used with daily weather data from a station adjacent to the experimental area and from a INMET station (OMM: #86845). The experimental area is a crop-livestock system (iCL) with pasture managed under rotational stocking in rotation with corn for silage during pasture renewal. Monthly field campaigns in 2018 and 2019 were conducted and aimed to estimate ground-measured forage mass. A bootstrapped linear least-squares regression was employed for evaluating the results for model validation. SAFER is a feasible tool to estimate forage mass in a crop-livestock system (iCL), as around 73% of the variability in forage mass was explained through the integration of HLS surface reflectance images, ground-measured data, and cattle management, in an agrometeorological modeling approach. The methodology will assist farmers and policymakers to estimate forage availability to improve decision-making on pasture management. Future works will discriminate estimated forage mass in intensive and extensive pasture systems

Key words: digital agriculture; remote sensing; agrometeorology

INTRODUCTION

The Brazilian Gross Domestic Product (GDP) reached R$ 7.3 trillion in 2019. The agribusiness GDP reached R$ 1.5 trillion, 21% of the total Brazilian GDP, and the beef cattle GDP reached R$ 618.5 billion, 39% of the Brazilian agribusiness GDP and 8% of the total Brazilian GDP. Brazil has 213.6 million head of cattle spread over 162.5 million hectares. In 20 years, the animal stocking went from 0.71 to 1.06 heads per hectare and the productivity from 1.6 to 4.3 @ / ha / year (ABIEC, 2019). These numbers show an important role of the beef cattle sector in the Brazilian economy.

Commodities' values, food security, and environmental sustainability can be pointed as different vectors in productivity growth. In this scenario, innovation is essential to meet the demands that exist for the next decades. Precision cattle ranching is a management method that aims to improve production processes, reduce environmental impacts, obtain greater consumer satisfaction, and, thus, better economic return for rural producers (BERNARDI et al., 2014). Is a concept based on the existence of a great diversity of information and increasingly advocates the use of new technologies, such as GPS, remote identification of animals, sensors, satellites or aerial images, management software, artificial intelligence, and geographic information system (GIS) to assess and understand field variations (PIRES et al., 2014).

Satellites and unmanned aerial vehicles (UAVs) allow producers to effortlessly survey the conditions of their land, plantations, and herds. Thus, it is possible to identify wet or dry fields, identify soil erosion and other factors, which can assist in defining the most suitable types of pastures. The data can be used by the producer who will automatically adopt more favorable practices for his business (PIRES et al., 2014). Here, we examine the suitability of a remote sensing and agrometeorological modeling perspective to estimate forage mass. We aimed to address this gap using the Simple Algorithm for Evapotranspiration Retrieving (SAFER) and Monteith’s light use efficiency (LUE) model to estimate forage mass in a crop-livestock system (iCL).

MATERIAL AND METHODS

The study area is located at São Carlos municipality, Sao Paulo State, in Cerrado biome. According to Köppen–Geiger climate classification system, the local climate is temperate or subtropical hot summer (Cwa), with average temperature and precipitation of 19.9 °C and 250 mm, in the dry season (Apr to Sept), and with 23.0 °C and 1,100 mm in the wet season (Oct to Mar), respectively. The soil is classified as Dystrophic Red-Yellow Latosol with a medium clay texture (CALDERANO FILHO et al., 1998).

The beef cattle production system is a crop-livestock system (iCL) and was established in 2010 with Piatã palisadegrass (*Urochloa* (*syn. Brachiaria*) *brizantha* (*Hochst ex A. Rich.*) *Stapf* cv. BRS Piatã. iCL system is contiguous and composed of two replicate areas of 3 ha each. Each intensively managed pasture replicate area was divided into six paddocks (0.5 ha each). In early 2018, two paddocks from each system were grown with corn for silage, while other paddocks were grazed under rotational stocking with 9 days of occupation and 27 days of rest. Later the corn has been harvested, the paddocks were grazed under rotational stocking with 6 days of occupation and 30 days of rest.

SAFER algorithm was applied together with Monteith's Light Use Efficiency (LUE) model to estimate biomass, here forage mass. As input data, SAFER requires remote sensing and weather data. SAFER algorithm is based on the modeled ratio of actual evapotranspiration (ET) and reference evapotranspiration (ET_0) and has been developed and validated in Brazil with field data from four flux stations and Landsat image data and its equations are described in detail in Teixeira et al. (2015).

Surface reflectance time-series were extracted from the Harmonized Landsat and Sentinel-2 (HLS) project (CLAVERIE et al., 2018). HLS products combine surface reflectance data from OLI/ Landsat-8/ and MSI/ Sentinel-2 in a single data set, as both sensors have similar measurements in terms of spectral, spatial, and angular characteristics. HLS is recommended for land monitoring, including monitoring agricultural management and condition (WALDNER et al., 2016). Even though the similarity, a harmonized surface reflectance data set needed efforts to mitigate these differences, for example, grid to a common pixel resolution; atmospherically correction and cloud mask to surface reflectance using a common radiative transfer algorithm and normalize to a common nadir view geometry via Bi-directional Reflectance Distribution Function (BRDF) estimation (CLAVERIE et al., 2018).

Input weather data were global solar radiation (R_G, MJ m^{-2} dia^{-1}); air temperature (T_a, °C); and reference evapotranspiration (ET_0, mm dia^{-1}) from an agrometeorological station adjacent to the experimental area and from an INMET station (OMM: #86845). HLS bands from the visible, red-edge, NIR, and SWIR regions were used to calculate surface albedo (α0), the Normalized Difference Vegetation Index (NDVI), while the surface temperature (T_0) was obtained as a residue in the radiation balance (TEIXEIRA et al., 2014).

Above ground-measured forage mass was evaluated according to the protocol described by Bayma-Silva et al. (2019). Mainly, we used the double-sampling method, a traditional agronomic sampling method (Wilm et al., 1944) to measure pasture height, which was converted into kilograms of dry mass per hectare (kg DM ha^{-1}). We estimated ground-measured dry green mass (DGM) from dry mass (DM), weighing green leaves and stems.

To calculate the accumulated SAFER forage mass, the daily values estimated by the SAFER model, on the sampling dates or in a close date, were multiplied by the days according to the stage (grazing, post-grazing, growth, and pre-grazing) of the forage paddock growth. Considering the case of the grazing paddock, the value of SAFER forage mass was multiplied by the grazing days, considered negative. Each grazing day reduced 1/6 of the number of days on which growth had occurred. Linear regression between the ground-measured dry mass and the accumulated SAFER forage mass was performed using the mean values of the management stages.

Monthly accumulated SAFER forage mass was plotted with dry and green mass production to verify the relationship between them, through linear least-square regression. To assess the linear regression (equations parameters and associated error), a bootstrap procedure was performed with 1001 random repetitions (EFRON; GONG, 1983). Upper and bottom limits were estimated using a 95% confidence interval.

RESULTS AND DISCUSSIONS

Linear regression analysis for all paddocks in iCL system showed that DGM fitted better with SAFER forage mass estimation than DM, $R^2 = 0.73$ and $R^2 = 0.42$, with a root-mean-square error (RMSE) ~445 and ~637 kg of DGM and DM, respectively (Table 1 and Figure 1). We can explain this result as SAFER is an agrometeorological model based on NDVI. NDVI is calculated from the visible and near-infrared (NIR) bands from OLI/ Landsat-8 and MSI/ Sentinel-2. Nutritious vegetation reflects a large portion of the NIR and absorbs most of the visible light. Thus, a major innovation of this study lies in DGM estimation.

Table 1. Bootstrap estimated parameters of dry green mass (DGM) and dry mass (DM)

	intercept DM	intercept DGM	slope DM	slope DGM	*pvalue* dm	*pvalue* DGM
Upper	3381.361	668.750	1.181	1.303	1.033e-01	5.030e-04
Median	2778.072	409.861	0.841	1.076	1.077e-03	1.035e-06
Bottom	2224.146	93.206	0.448	0.851	5.470e-07	1.328e-10
	correlation DM	correlation DGM	R^2 DM	R^2 DGM	RMSE DM	RMSE DGM
Upper	0.872	0.951	0.747	0.899	814.573	585.760
Median	0.676	0.862	0.426	0.729	636.799	444.991
Bottom	0.375	0.706	0.093	0.471	434.624	276.220

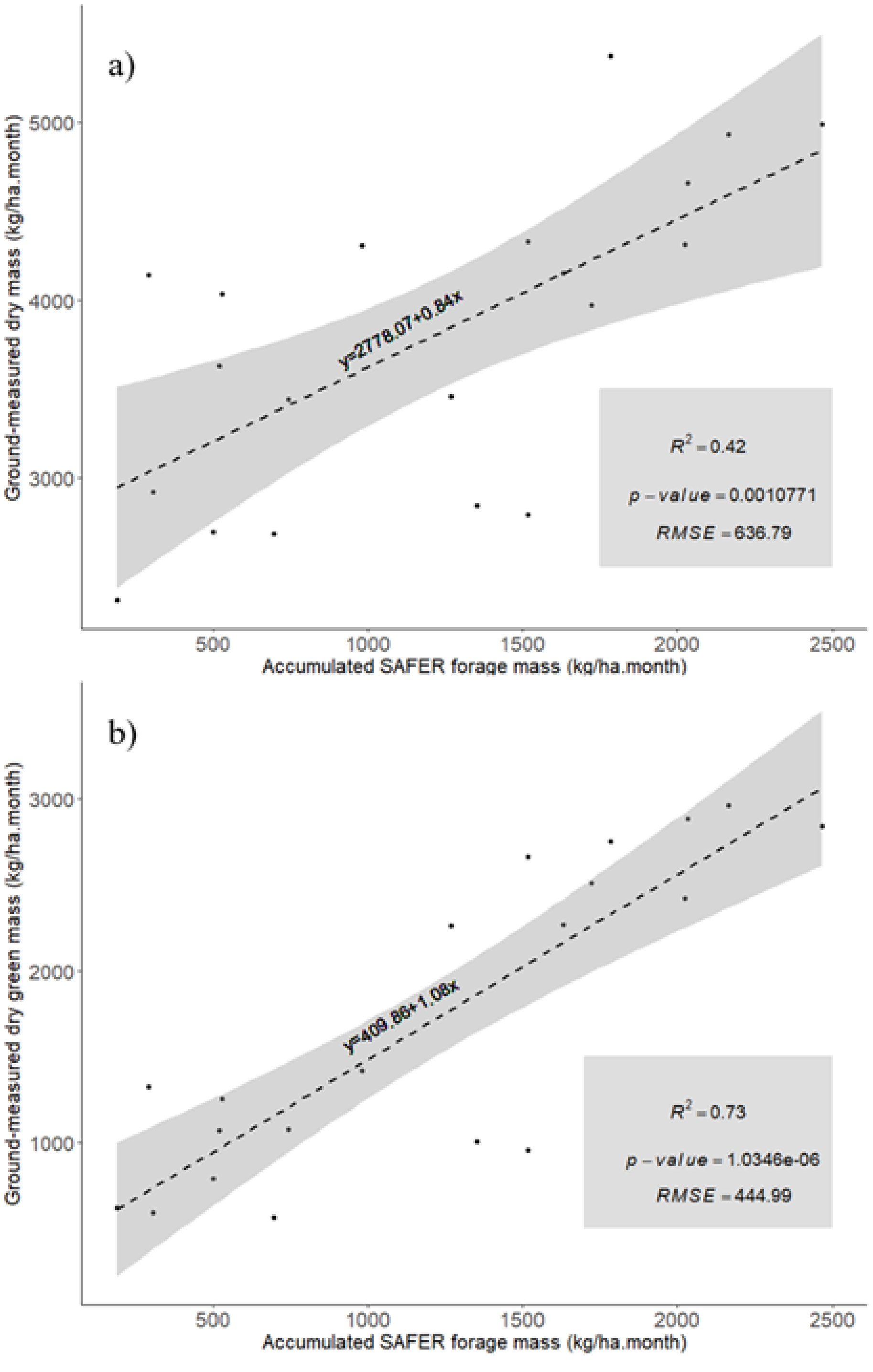

Figure 1. Relationship between the ground-measured (a) dry and (b) green mass (kg/ha.month) and accumulated SAFER forage mass (kg /ha.month). Each point represents the mean SAFER estimative for all pixels in the paddock and monthly measured forage mass.

Sibanda et al. (2015) resampled hyperspectral data to spectral resolutions of MSI/ Sentinel-2 and the OLI/Landsat-8 for comparison purposes. Using sparse partial least squares regression, the resampled data was applied in estimating above ground biomass of grasses treated with different fertilizer combinations of ammonium sulfate, ammonium nitrate, phosphorus, and lime as well as unfertilized experimental paddocks. MSI/ Sentinel-2 derived models satisfactorily performed better ($R^2 = 0.81$) than OLI/Landsat-8 ($R^2 = 0.76$). Reis et al. (2020) assessed the feasibility of using spectral and textural information derived from high spatiotemporal resolution PlanetScope imagery for estimating and monitoring aboveground biomass (AGB) and canopy height (CH) of intensively managed mixed pastures in an iCL system in the western region of São Paulo State, Brazil. The methodology was able to predict the spatiotemporal changes in pasture AGB and CH with moderate ($R^2 = 0.65$) to high ($R^2 = 0.89$) prediction accuracies, respectively, with a root mean square error (RMSE) of 26.52%.

Chen et al. (2021) explored the suitability of high spatio-temporal resolution MSI/ Sentinel-2 imagery and the applicability of advanced machine learning techniques for estimating aboveground biomass at the paddock level in five dairy farms across northern Tasmania, Australia. The optimal model was, therefore, able to explain about 60% of the variability existing in the pasture biomass data, with a root-mean-square error (RMSE) of ~356 kg dry mass (DM).

CONCLUSIONS

SAFER is a feasible tool to estimate forage mass in a crop-livestock system (iCL), as around 73% of the variability in forage mass (leaf +stem mass) was explained through the integration of HLS surface reflectance images, ground-measured data, and cattle management, in an agrometeorological modeling approach. The results of this study can lead farmers and farm managers to improve their productivity through better pasture management. Future work will discriminate the estimation of forage mass in intensive and extensive pasture systems.

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USE OF BIOESTIMULANTS IN THE TREATMENT OF SOYBEAN SEEDS

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ABSTRACT

The soybean culture is widely cultivated in Brazil and is extremely important for the Brazilian economic trade balance. Thus, it is common to use biostimulants towards improvement of productivity in various physiological and / or morphological processes. In this context, the objective of this work was to evaluate the effect of the use of biostimulants on the development of soybean seeds. The trial was conducted with four treatments: T1 - control without biostimulant, T2 - with biostimulant Stimulate 4.7 mL / 0.2 g of seeds, T3 - with the biostimulant Raiz 0.6 mL / 0.2 g of seeds, T4 - 4.7 mL of Stimulate plus 0.6 mL of Raiz / 0.2 g of seeds with five replications. The germination index was checked after five and eight days. In the second verification, the length of roots and hypocotyls was analyzed. Through the laboratory results, it was found that the Stimulate 4.7mL / 0.2g biostimulant of seeds was the most efficient in relation to germination after 5 days, and on the 8th day the Raiz biostimulant 0.6 mL / 0.2 g of seeds was more efficient when compared to the other treatments. In general, it can be said that the biostimulant provided an increase in the number of pods per plant and grain yield in application via seeds.

Key words: seed performance; germination; Glycine max

INTRODUCTION

According to Popov (2021), soy is a crop of great economic importance for Brazil, being the main source of income for the country and for rural producers, leading the ranking of most exported products for over 22 years. The soybean cultivated area in Brazil, in 22 years, went from 11.3 million hectares to an area of just over 35.7 million hectares, which represents an increase of 216%. In addition to this factor, there is the average productivity, which has grown around 43% since 1997 until today, going from 39.7 bags to 56.6 bags. These two factors led Brazil to achieve a current total production of almost 120 million tons, competing with the United States for the position of the world's largest producer of oilseeds.

Agriculture is a practice that constantly demands the search for alternative tools that increase the productivity of crops. The management has been improving according to the requirements of the culture and adding this to the available technologies, maximize the final productivity (SILVA, 2019).

In this context, Fetter (2018) states that one of the alternatives available on the market is the use of plant regulators, which have the ability to optimize the metabolism of the plant, accelerate its growth, improve their defenses or stimulate the germinative power of seeds in a way that makes it more resistant to adverse environmental conditions, allowing the crop to express an increase in the capacity of production.

The application of biostimulants can be done directly on the leaves, seeds, fruits, stems and roots, interfering in multiple processes, such as germination, rooting, flowering, fruiting and senescence. The good results of the application depend on a series of factors, from the region and species of the plant to situations such as the process of absorption of the product, associated with the condition of the plant, as well as equipment and the application methods, which may be influenced by environmental conditions (MANOEL et al., 2015).

The benefits promoted by these substances have been researched in order to solve problems of the production system and to improve productivity, such in quality as in quantity. However, the effect of some hormones together is unknown, so this study aimed to evaluate the effect of using biostimulants on soybean production.

MATERIAL AND METHODS

The experiment was carried out in the seed laboratory of Catholic University Center of Tocantins, Campus of Agricultural and Environmental Sciences in Palmas - TO, located at Highway TO 050, Allotment Coqueirinho, lot address 7, corresponding to the geographical coordinates “48º16'34” W and 10º32'45” S at an altitude of 230 meters. According to the international classification of Köppen, the climate of the region is of the type C2wA'a'- Sub-humid humid climate with small water deficiency, in winter, average annual evapotranspiration potential of 1,500 mm, spreading in summer around 420 mm along of the three consecutive months with the highest temperature, with average annual temperature and precipitation of 27.5º C and 1,600 mm, respectively (INMET, 2019).

0.200 g of soybean seeds (*Glycine max*) were used for each treatment. These seeds, previously weighed, were stored in a plastic container so that the biostimulant product could be added and mixed. There were a total of 04 treatments and five repetitions, being: T1 - control, without biostimulant; T2 - with Stimulate biostimulant 4.7 mL / 0.2 g of seeds; T3 - with the biostimulant Raiz 0.6 mL / 0.2 g of seeds; T4 - 4.7 mL of Stimulate plus 0.6 mL of Raiz/ 0.2 g of seeds with five replications. After this process, the seeds were placed on a wooden tray, in order to facilitate the counting of 50 units. Subsequently, they were placed on a layer of filter paper with a spacing of 1 cm, moistened with distilled water and covered with another layer of filter paper. These seeds were carefully rolled and tied with strings; this procedure was repeated five times. Finally, the five repetitions corresponding to each treatment were placed in Becker’s recipients. 450 ml of water was added to each Becker, and the water was replenished every two days. The first count to verify the germination index was carried out after five days. The second count was made after eight days. In the second count, in addition to checking the germination index, the root and hypocotyl length were also measured.

The results of the analysis were submitted to studies of variance and the means were compared using the Tukey test with a 5% probability of significance with the aid of the ASSISTAT statistical software.

RESULTS AND DISCUSSIONS

Table 1 shows the results of treatments applied to soybeans to assess the effect of using biostimulants.

According to the results presented in Table 1, it can be seen that the control sample and the sample containing Raiz obtained an average of 43.8 germinated seeds. The average of the sample with the use of Stimulate was 47.2 germinated seeds. Stimulate also maintained the highest average germination rate at the second count, reaching 47.8. And the worst average of germination was the combination of Stimulate 4.7 mL + Raiz 0.6mL / 0.200g. However, as a general result, the worst average count of all samples was the control sample, which was the group without the use of any biostimulant.

In possession of these results, the Tukey test was applied at the level of 5% probability.

Table 1. treatment of soybean seeds under the influence of biostimulants.

SAMPLES	GERMINATED ON APRIL 24th, 2017	GERMINATED ON APRIL 27th, 2017
Control group	T1 R1 44 Germinated T1 R2 46 Germinated T1 R3 44 Germinated T1 R4 45 Germinated T1 R5 40 Germinated	44 Germinated 49 Germinated 49 Germinated 49 Germinated 45 Germinated
Stimulate 4.7 mL/0.200 g of seeds	T2 R1 46 Germinated T2 R2 48 Germinated T2 R3 50 Germinated T2 R4 49 Germinated T2 R5 43 Germinated	48 Germinated 48 Germinated 50 Germinated 50 Germinated 46 Germinated
Root 0.6mL/0.200g of seeds	T3 R1 42 Germinated T3 R2 47 Germinated T3 R3 45 Germinated T3 R4 43 Germinated T3 R5 42 Germinated	48 Germinated 47 Germinated 48 Germinated 47 Germinated 48 Germinated
Stimulate 4.7 mL+ Root 0.6mL/0.200g of seeds	T4 R1 47 Germinated T4 R2 47 Germinated T4 R3 46 Germinated T4 R4 41 Germinated T4 R5 43 Germinated	47 Germinated 47 Germinated 46 Germinated 47 Germinated 46 Germinated

Table 2. Average use and effect of biostimulants in the treatment of soybeans (*Glycine max*), with 4 treatments and 5 repetitions for the 5th day of germination evaluation.

TREATMENTS (BIOSTIMULANTS)

5th DAY

VF	LG	QS	MQ	F	SAMPLES	MEANS
5th day	3	154.40000	51.46667	2.0753 ns	Control group	87.60000 a
Residue	16	396.80000	24.80000		Stimulate	94.40000 a
Total	19	552.20000			Raiz	87.60000 a
		VC% = 5.55			Stimulate + Root	89.60000 a

TREATMENTS (BIOSTIMULANTS)

8th DAY

VF	LG	QS	MQ	F	SAMPLES	MEANS
5° dia	3	6.55000	2.18333	0.2679 ns	Control Group	94.40000 a
Residue	16	130.40000	8.15000		Stimulate	93.60000 a
Total	19	136.95000			Raiz	94.80000 a
		VC% = 3.04			Stimulate + Raiz	93.40000 a

Variation sources; Degrees of freedom; * Significant, respectively, by the F test ($p < 0.05$). ns not significant by the F test ($p < 0.05$).

It is observed that the Tukey test presented average percentages followed by the same letter, which means that they are statistically similar. In the samples referring to the fifth day, there was the formation of only one group, where the best treatment was Stimulate (94.40000), followed by Stimulate + Raiz (89.60000) and Control group and Root (87.60000; 87.60000), which were statistically equal. In the samples referring to the eighth day, the best treatment was the Raiz

(94.80000) followed by Control Group (94.40000); Stimulate (93.60000) and Stimulate and Raiz (93.40000) (Table 2).

Manoel et al. (2015) also obtained a satisfactory result with the use of biostimulants in coffee, concluding that the biostimulant Stimullus® in the concentration of 300 mL ha-1 provides a greater number of nodes of the plagiotropic branches in the lower third of the plant. Godinho et al. (2011) concluded that the use of growth regulators Mover®, Stimulate® and Sett®, isolated or combined in soybean culture, results in seeds of better physiological quality, regardless of the stage of application of the products.

CONCLUSIONS

According to the experiment conducted and results obtained in the laboratory, it was found that the biostimulant Stimulate 4.7ML / 0.200g per seed was the most efficient in relation to germination referring to the first verification after 5 days. On the 8th day of verification, it was found that the biostimulant Raiz 0.6Ml / 0.200g of seeds was more efficient when compared to the other treatments. In general, it can be said that the biostimulant provided an increase in the number of pods per plant and grain yield in application via seeds.

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PERFORMANCE EVALUATION FOR INTERSEASON MAIZE CROP IN MARACAJU-MS, BRAZIL

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ABSTRACT

Timing for sowing and cycle of soybeans strongly impacts the following interseason maize performance, especially by influencing its sowing time. In this context, planning is an indispensable tool to achieve success, since it is crucial for decision making on adopting integrated crop-livestock systems. Therefore, knowledge of the performance of these two crops, considering also their cycles, becomes mandatory. Analyzing performance of different hybrids, taking into account financial investments necessary for different levels of technology adopted, we found that in the region of Maracaju/MS, medium-investment hybrids presented the best overall performance.

Key words: Productivity; Crop succession; Cost-benefit ratios

INTRODUCTION

Combination of soybean and interseason maize in Central Brazil stands out in the national scenario in terms of grain production, with participation in total production expected for the 2020/2021 and interseasonal maize 2021 harvests to be 49.62% and 30.41% respectively. Regarding area cultivated, these crops have a prominent participation, being 56.33% of the area of cultivation with soybean and 21.50% of the area cultivated with interseason maize (CONAB, 2021).

The increasingly economic importance of soybeans led to a shrink in area planted with the concurrent summer maize. Since there are few and poorer alternatives for soybeans interseason cultivation, farmers are led to squeeze in maize sowing despite of higher risks associated with late sowing (MIRANDA et al., 2011; MIRANDA et al, 2014; CONTINI et al., 2019; CONAB, 2021).

Interseason maize in some regions of Mato Grosso do Sul are subjected to greater climatic risk, such as poor rainfall and sporadic occurrences of frost in crucial periods of crop development.

In the Maracaju region, located in the State of Mato Grosso do Sul, the predominant production system includes soybeans in the summer succeeded by interseason maize in the interseason. A consensus grew over the years that soybeans have good productive levels, resulting in satisfactory economic return. The same view as not shared by all in regard to interseason maize, where economic viability can be substantially reduced if right timing is achieved and the proper technological package is not carefully chosen (RICHETTI et al., 2017).

Local interseason maize show best yields when sowing happens between January 20th and February 20th, using of hybrids of high and medium investment. After this seeding window, yields tend to decrease. In this case, one alternative can be hybrids of lower investment. The other option is to integrate crop-livestock, sowing grass forage for cattle short grazing periods in the interseason. Although research results evidence these scenarios, farmers tend to use maize hybrids of high investment in a period of high risk, thus compromising viability of the whole soybeans-maize system. (LOURENÇÃO, 2019).

Goal of this work was to evaluate performance of maize hybrids grouped according to investment level.

MATERIAL AND METHODS

Performance data were collected from the database from field experiments conducted by the MS Foundation, in the municipality of Maracaju-MS, in the years 2018, 2019 and 2020.

To describe the production environment, information on soil physical and chemical characteristics is presented in Table 1.

With the data collected at the MS Foundation, we used the statistical software GENES, version 1990.2020.12 to run the group comparison analyses by the Student's T Test or Significant Minimum Difference (DMS), represented by the following equation:

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{s_x^2}{nx} + \frac{s_y^2}{ny}}}$$

This significance test was developed by W.S. Gosset, where it seeks to approximate the distribution of a sample mean, used for comparison of two samples with numerical data, taking into account a null hypothesis (H_0) and an alternative hypothesis (H_1) (BRUCE, 2019).

Therefore, the average yield of groups of maize hybrids, resulting in the groups that best respond to different sowing times, were created based on the classification in relation to the level of investment used for cultivating these hybrids, not only their seed, being: high investment, medium investment and low investment, for this reason only the level of investment was considered in the groupings.

At first, tables were structured in MS Excel(R) spreadsheets, grouping hybrids according to investment level, obtaining the groups of high investment (simple hybrids), medium investment (simple modified and triple hybrids) and low investment (double hybrids and varieties).

With the structured data set, the statistical analysis was performed using the Student's T-Test method.

The analyses were run in the Software Genes, version 1990.2020.12, this program is used for analysis and processing of data based on models of genetics and experimental statistics, so that to be statistically significant differences the probability value (%), should be less than or equal to 5%, considering confidence level of 95%.

Table 1. Soil analysis from the interseason maize experimental areas from 2018, 2019 and 2020 at the MS Foundation in Maracaju/MS, 2021.

Parameters	**Unit**	**Interseason 2018**		**Interseason 2019**		**Interseason 2020**	
		Depth (cm)		**Depth (cm)**		**Depth (cm)**	
		0-20	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**
Particle size analysis							
Silt	%	-	-	-	-	-	-
Sand	%	-	-	-	-	-	-
Clay	%	53.9	55.7	59.02	69.02		
Chemical analysis							
pH $CaCl_2$	-	4.9	5.7	4.86	4.88	5.2	5.2
pH H_2O	-	5.0	5.7	5.59	5.61	5.9	5.8
pH KCl	-	-	-	4.53	4.5	27.2	17.9
Organic Matter	g dm^{-3}	33.2	23.4	31.92	18.9	13.9	1.6
P (Mehlich)	mg dm^{-3}	8.2	1.7	15.89	1.21	-	-
P (Res)	mg dm^{-3}	-	-	-	-	-	-
K	cmolc dm^{-3}	0.29	0.12	0.29	0.13	0.38	0.11
Ca	cmolc dm^{-3}	5.8	4	4.58	3.53	4.9	3.4
Mg	cmolc dm^{-3}	1.1	0.8	1.43	0.99	1.5	1.1
Al	cmolc dm^{-3}	0.0	0.0	0.0	0.11	0.0	0.0
H+Al	cmolc dm^{-3}	5.7	5.2	6.71	5.54	6.4	6.6
CEC	cmolc dm^{-3}	12.8	10.1	13.01	10.18	13.1	11.2
Base Saturation	%	55.4	48.5	48.41	45.54	51.0	41.2
S	mg dm^{-3}	19.9	83.6	22.13	69.75	6.2	6.5
B	mg dm^{-3}	0.69	0.31	0.52	0.3	155.9	96.9
Cu	mg dm^{-3}	6.0	4.8	6.47	7.38	22.5	34.9
Fe	mg dm^{-3}	25.1	28	30.54	34.19	3.3	3.1
Mn	mg dm^{-3}	97.2	55.3	76.62	32.93	2.9	1.0
Zn	mg dm^{-3}	3.0	0.5	3.45	16.18	36.9	30.4

Source: Adapted from MS Foundation (2021).

RESULTS AND DISCUSSIONS

The results of the maize hybrids presented in Table 2 show that all groupings showed significant differences at the level of 5% probability.

Table 2. Test T in interseason maize crop, Maracaju/MS. MS Foundation, 2021.

Group	Observation	Average (60 kg bag)	Degrees of freedom	Variance	t	p (%)	Confidence interval (95%) lower Iimit	Confidence interval (95%) upper limit
High	491	126.229	587.000	423.360	2.274	2.21157	124.279	128.086
Medium	98	131.271	158.723	291.646	2.574	1.06642	127.614	134.721
High	491	126.229	503.000	423.360	2.376	1.70464	124.279	128.086
Low	14	113.036	14.137	281.870	2.879	1.16567	102.536	122.189
Medium	98	131.271	110.000	291.605	3.745	0.03793	127.614	134.721
Low	14	113.036	17.077	281.870	3.793	0.15045	102.536	122.189

The hybrids of high investment presented an average of 7,578 kg per hectare, demonstrating variation in the confidence interval at 95% probability of 7,458 kg per hectare as lower limit and 7,680 kg bags per hectare of upper limit.

Analyzing the performance of medium investment hybrids, an average of 7,878 kg per hectare was observed, with variation in the confidence interval at 95% probability of 7,656 kg per hectare as lower limit and 8,082 kg per hectare as upper limit.

On the other hand, low investment hybrids presented an average of 6,780 kg per hectare, demonstrating variation in the confidence interval at 95% probability of 6,150 kg per hectare as lower limit and 7,332 kg per hectare of upper limit.

Under the conditions analyzed, there is a slight superiority of medium-investment hybrids with a better performance response when compared to high-investment hybrids.

Results suggest further detailing maize hybrids cycle, in order to verify the hypothesis of hybrids considered high investment to present lower yields than medium-investment hybrids.

CONCLUSIONS

Considering the performance of maize hybrids in the area of study, it can be concluded that medium-investment hybrids presented superior performance compared to high investment hybrids. This information can support decision-making towards readjusted planning for maize cultivation or shifting to integrated crop-livestock systems.

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PERFORMANCE EVALUATION FOR SOYBEANS IN MARACAJU-MS, BRAZIL TO SUPPORT DECISION MAKING ON INTEGRATED SYSTEMS

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ABSTRACT

The productive performance of soybean is correlated to its cycle and sowing time. Results obtained show that, for the Maracaju/MS region, at the beginning of the sowing season, short cycle cultivars have lower performance in relation to longer cycle cultivars. This scenario is reversed at the end of the sowing season, where long-cycle cultivars present poorer results when compared to shorter cycle cultivars. Considering local production systems, including integrated crop-livestock ones, which are based on the succession of crops and pastures, knowledge about the performance of these crops are key to achieve best results.

Key words: Crop performance; Crop succession; Economic viability

INTRODUCTION

In the Maracaju region, located in the State of Mato Grosso do Sul, the predominant production system includes soybeans in the summer succeeded by interseason maize A consensus grew over the years that soybeans have good productive levels, resulting in satisfactory economic return. The same view as not shared by all in regards to interseason maize, where economic viability can be substantially reduced if right timing is achieved and the proper technological package is not carefully chosen (RICHETTI et al., 2017).

However, in order to obtain high yields, production systems must be well structured, i.e., they must follow certain parameters, such as agricultural zoning, sowing time suitable for the selected cultivars, use of recommended plant densities, to perform integrated pest and disease management, crop rotation and the use of soil cover, seeking continuous improvement of soil quality and sustainability of the system (CONTINI et al., 2018; RICHETTI & LAMAS, 2019).

Among many factors directly related to productive potential, the selection of cultivars stands out, which is of high complexity. Thus, it is necessary to base the choice on research results, choosing cultivars that present better productive stability over time, since external factors, such as climate, directly impact crop productivity (BEZERRA, 2017).

MATERIAL AND METHODS

Performance data were collected from the database from field experiments conducted by the MS Foundation, in the municipality of Maracaju-MS, in the seasons 2017/2018, 2018/2019 and 2019/2020.

The production environment where this study was made these periods as well is considered favorable for soybean high yields. Table 1 presents the physical and chemical characteristics of the soil that attests its suitability as a favorable production environment.

Table 1. Physical and chemical characteristics of the soil where soybean experiments of the MS Foundation were conducted in the 2017/2018, 2018/2019 and 2019/2020 seasons. Maracaju/MS, 2021.

Parameters	**Unit**	**Season 2017/2018**		**Season 2018/2019**		**Season 2019/2020**	
		Depth (cm)		**Depth (cm)**		**Depth (cm)**	
		0-20	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**
Particle size analysis							
Silt	%	-		9.79	7.84	14.26	16.34
Sand	%	-		33.08	31.7	35.28	33.2
Clay	%	48.9	54.9	57.13	60.46	50.46	50.46
Chemical analysis							
pH CaCl2	-	5.4	5.4	5.14	4.98	5.28	5.03
pH H2O	-	6.1	6.1	5.83	5.69	5.95	5.74
pH KCl	-	-	-	4.85	4.68	-	-
Organic Matter	g dm-^{3}	32.5	19.1	27.91	20.65	32.42	21.4
P (Mehlich)	mg dm-3	9.8	0.4	7.86	1.01	20.36	3.06
P (Res)	mg dm-3	-	-	16.73	4.36	-	-
K	cmolc dm-3	0.35	0.11	0.46	0.27	0.54	0.28
Ca	cmolc dm-3	7.6	5.5	5.01	4.23	5.8	4.2
Mg	cmolc dm-3	1.7	1.2	1.72	1.39	1.72	1.2
Al	cmolc dm-3	0.0	3.7	0.0	0.0	0.0	0.0
H+Al	cmolc dm-3	3.7	3.1	4.12	4.73	5.54	5.79
CEC	cmolc dm-3	13.4	10	11.31	10.61	13.59	11.46
Base Saturation	%	72.2	68.8	63.6	55.44	59.21	49.52
S	mg dm-3	8.9	14.7	10.25	32.17	18.38	63.25
B	mg dm-3	0.62	0.21	0.47	0.21	0.41	0.29
Cu	mg dm-3	5.8	5.4	8.21	7.82	6.14	6.8
Fe	mg dm-3	20.7	21.2	40.86	39.68	15.81	25.52
Mn	mg dm-3	127.4	65.4	68.57	54.93	152.6	100.4
Zn	mg dm-3	1.7	0.5	1.68	0.71	2.64	1.53

Source: Adapted from MS Foundation (2021).

The cultivars were grouped according to their respective maturation groups, being classified as: i) early (Maturation group <6.4); ii) semi-early (Maturation group 6.4 to 6.8); and, iii) medium-late (Maturation group >6.8).

The data were submitted to a comparison test between groups by the Student's T Test, represented by the following equation:

This significance test was developed by W.S.Gosset, where it seeks to approximate the distribution of a sample mean, used for comparations of two samples with numerical data, taking into account a null hypothesis (H0) and an alternative hypothesis (H1) (BRUCE, 2019).

With this statistical analysis, it became possible to visualize the average yields of groups of soybean cultivars at different sowing times, being 1st part sowing season (October,01 to October,15), 2nd part sowing season (October,16 to October 31), 3rd part of sowing season (November,01 to November,15) and the 4th part of sowing season (November, 16 to November, 30).

The analyses were run in the Software Genes, version 1990.2020.12, this program is used for analysis and processing of data based on models of genetics and experimental statistics, so that to be statistically significant differences the probability value (%), should be less than or equal to 5%, considering confidence level of 95%.

RESULTS AND DISCUSSIONS

In the evaluation of the 1st part of the sowing season (October, 01 to October,15), there was a statistical difference in the comparisons between early x semi-early and early x medium/late cultivars. Semi-early and medium/late cultivars showed better performance when compared to cultivars of the early group at this sowing time,

For the 2nd part of the sowing season (October, 16 to October, 31) there was no statistical difference among the groups, since the probabilities found exceed the limit of 5%, thus H0 is accepted as a real result, that is, the means of the groups do not differ statistically by the T-Test at the level of 5% probability.

Results for the 3rd part of the sowing season (November, 01 to November, 15), there was a statistical difference between the groups. Results show that early and semi-early cultivars present better performance when compared to the medium/late cultivars, but when compared to each other, there was no significant minimum difference, considering T-test at the level of 5% probability.

For the 4th part of the sowing season (November, 16 to November, 30) there was no statistical difference among the groups, since the probabilities found exceed the limit of 5%, thus H0 is accepted as a real result, that is, the means of the groups do not differ statistically by the T-Test at the level of 5% probability.

Table 2. Comparison of different maturation groups for soybeans yield in the four parts of the sowing season, Maracaju/MS. MS Foundation, 2021.

Sowing Season	Group	Observation	Average (60 kg bag)	Degrees of freedom	Variance	t	p (%)	Confidence interval (95%) lower Iimit	Confidence interval (95%) upper limit
1st part	Early	123	71.813	310	60.342	4.773	0.00084	70.335	73.536
	Semi-early	189	76.128	262.137	31.224	4.781	0.00086	74.927	77.516
	Early	123	71.813	187	60.342	4.708	0.00126	70.335	73.214
	Mediu-late	66	77.586	122.899	72.581	4.578	0.00241	75.353	79.684
	Semi-early	189	76.128	253	61.224	1.274	20.08452	74.927	77.66
	Mediu-late	66	77.586	105.76	72.581	1.223	22.18886	75.353	79.684
2nd part	Early	230	74.255	431	63.21	0.016	98.41588	73.154	75.304
	Semi-early	203	74.242	405.321	81.718	0.016	98.42483	72.909	75.511
	Early	230	74.255	309	63.21	1.658	9.41438	73.154	75.304
	Mediu-late	81	72.437	118.65	97.236	1.497	13.2896	70.103	74.628
	Semi-early	203	74.242	282	81.718	1.48	13.57996	72.909	75.511
	Mediu-late	81	72.437	136.568	97.236	1.426	15.23013	70.103	74.628
3rd part	Early	224	70.65	360	39.411	1.112	26.61883	69.769	71.489
	Semi-early	138	69.896	291.493	38.938	1.113	26.56594	68.776	70.959
	Early	224	70.65	273	39.411	5.302	0.00012	69.769	71.489
	Mediu-late	51	65.214	65.043	62.672	4.587	0.00374	62.83	67.431
	Semi-early	138	69.896	187	38.938	4.246	0.00625	68.776	70.959
	Mediu-late	51	65.214	74.17	62.672	3.809	0.03678	62.83	67.431
4th part	Early	152	53.09	240	100.174	1.319	18.4991	51.377	54.714
	Semi-early	90	54.891	177.277	114.193	1.297	19.3111	52.503	57.144
	Early	152	53.09	170	100.174	1.327	18.2939	51.377	54.714
	Mediu-late	20	49.955	25.13	86.882	1.402	17.0019	45.266	54.124
	Semi-early	90	54.891	108	114.193	1.909	5.58456	52.503	57.144
	Mediu-late	20	49.955	31.153	86.882	2.083	4.32507	45.266	54.124

CONCLUSIONS

For seeding at the very beginning of the sowing season (October, 01 to October, 15), it is recommended to use cultivars of semi-early and medium/late cycles.

In the second sowing window (October, 16 to October, 31), all groups appear as a good alternatives. On the other hand, in the first half of November, early and semi-early cycle cultivars appear as the best alternative.

Cultivars of the three groups are a good alternative for sowing in the second half of November.

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8. Economic and social aspects and family farming

WCCLF 2021
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COSTS OF INTRODUCTION OF THE FOREST COMPONENT FOR THE IMPLEMENTATION OF LIVESTOCK-FOREST INTEGRATION SYSTEMS IN PORTO VELHO, RONDÔNIA

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ABSTRACT

The Crop-Livestock-Forest Integration system is a technology that combines the use of agricultural, livestock, and forestry activities in the same area. The system is being applied to improve land use by diversifying production outputs, restoring the quality of the soil and pastures, and contributing to cattle management by offering thermal comfort to the animals. Although farmers recognize the importance of trees on pastures, especially to provide shade for livestock, in general, they are concerned about the negative effects of trees on pasture growth and pasture carrying capacity. Furthermore, it is likely that ranch farmers are still not convinced regarding the costs of planting trees on pastures, because they are unsure about the economic benefits that can result from this practice. The costs of implementing a livestock-forest integration system should be used as a basis for technicians and ranchers in their decision to adopt this technology for the management of dairy herds. For the calculation of the total cost, expenses with inputs, labor, in addition to fixed costs, and opportunity costs for the period of planting and maintenance of the tree component were considered, as well as the prices practiced in the local market. The total cost for Integrated Livestock-Forest system implementation was similar regardless of the tree species, *Eucalyptus pellita* and *Samanea tubulosa* (US$ 70.31 and US$ 67.40, respectively). In conclusion, decision making should be based on the main objective of the introduction of the forest component in the system; producing wood products, or supplying multiple services.

Key words: Pasture; Natural Shading; Integrated Livestock

INTRODUCTION

The possibility of integrating the animal and forest components in the same area is an alternative for shading pastures, especially in local areas with high environmental temperatures, solar *radiation*, and relative humidity. These climatic conditions are common in the municipality of Porto Velho (RO) during almost the entire year, which leaves animals to be subject to heat stress conditions, especially during the hottest hours of the day (SOUZA et al., 2019).

The Integrated Crop-Livestock-Forest system (ICLF) is a technology that combines the use of agricultural, livestock, and forestry activities in the same area and is being applied to better take advantage of the soil, diversify agricultural production, recover the quality of soil and pastures, and contribute to cattle management by offering thermal comfort to animals. Integrated Livestock-Forest (ILF) or silvopastoral system is a modality of ICLF that can be implemented with a focus on pasture shading to mitigate heat stress in animals (OLIVEIRA et al., 2012).

Despite acknowledging the importance of trees in pastures, especially in providing shade for livestock, cattle ranchers are still not convinced that tree shade may not negatively affect pasture growth and animal support capacity. In addition, they are not willing to bear the costs of planting trees in pastures, probably because they are not convinced of the economic benefits that can arise from this practice (ANDRADE et al., 2012).

With the objective of supporting technicians and ranchers, this study provides information on the implementation costs of silvopastoral systems in the first two years using two tree species, *Eucalyptus pellita* and *Samanea tubulosa*, for afforestation of pastures for dairy herds in the municipality of Porto Velho, Rondônia.

MATERIAL AND METHODS

A technological reference unit (TRU) in Integrated Livestock-Forest (ILF) located at the Experimental Field of Embrapa Rondônia (8°48’26.61” S 63º51’01.68” O) was established using two tree species to shade pasture for Girolando dairy herd. An area of approximately 14 ha of pasture cultivated with marandu grass (*Urochloa brizantha* ‘Marandu’ *syn. Brachiaria brizantha* ‘Marandu’) was divided into two areas. The trees were planted in January 2018 in double lines with 6 m distance within rows of 300 m × 10 m aligned in the NE-SW direction (azimuth of 140º). The space between plants was 3.5 m. At the planting stage, 156 seedlings of *S. tubulosa* and 172 seedlings of *E. pellita* were used.

The area for planting the forest essences was prepared by desiccation of the grass on the planting line with the herbicide glyphosate (5.0 L/ha) followed by a subsoil at 60 cm depth. One day after planting, 4.0 L/ha of pre-emergent oxifluorfen-based herbicide was applied. Soil correction was undertaken using limestone filler in the pit (200 g/plant). Based on the results of the analysis of the chemical attributes of the soil, the area received planting fertilization with 200 g/plant of natural phosphate in the pit and 300 g/plant of NPK 04-30-16 + 6% Ca + 2% S + 0.05% B + 0.05% Cu + 0.2% Mn + 0.3% Zn, in lateral small pits. Two topdressing fertilizers were applied with 350 g/plant of NPK 20-05-20 + 0.5%B, 0.5% Zn, 0.5% Cu, at 6 and 12 months after planting. Weed control on the planting line was undertaken by mechanical removal every six months. Ant infestation was systematically monitored during the implantation period, and the necessity for control was observed at 6 and 12 months after planting in both areas. It was undertaken with an ant bait.

At the tree planting stage, the marandu grass pasture was in a moderate stage of degradation according to the evaluation criteria proposed by Dias-Filho (2017), i.e., the presence of invasive plants and the support capacity of the pasture was reduced by 30%–50% in relation to the non-degraded pasture. Therefore, it was necessary to remove animals from the pasture area for six months to restore the productivity of marandu grass. After this period, electrical fences were installed to protect the tree planting line.

For the calculation of the total cost, we considered the expenses with inputs and labor, in addition to the fixed costs and the opportunity cost for the period of planting and maintenance of the tree component considering the prices practiced in the local market. In the case of *S. tubulosa*, there were no commercial nurseries for seedling acquisition. Thus, the seedlings were produced in the nursery of the Experimental Field of Embrapa Rondônia, and the total cost for the production of 10 seedlings was US$ 3.02.

To calculate the expenses with electric fence and production costs per liter of milk, it was considered that in both systems, the pastures were managed with an average stocking rate of 2 AU (animal unit, 450 kg of live weight) per ha with a rotation cycle in six paddocks with five days of occupation and 30 days of rest periods. Further, it was considered that the Girolando dairy herd was composed of 80% of cows, with 60% in lactation with an average daily production of 10 L, and lactation period of 280 days.

The costs of implantation of *E. pellita* and *S. tubulosa* trees in the pasture areas are shown in Table 1. The period from January 2018 to December 2019 was considered for the composition of the costs for system implementation.

Table 1. Components of the total cost for implementation of integrated livestock forest (ILF) system with *E. pellita* and *S. tubulosa*.

		Unit	Unit Value (R$)	Total Amount	Total Value (R$)	R$/ha	US$/ha	% TC
E. pellita	**A – Variable Cost**							
	Operation with Machine + Implement	HMi	180.00	2.0	360.00	51.43	9.35	13.30
	Labor	day	80.00	10.5	840.00	120.00	21.82	31.03
	Seedlings	unit	2.50	212.0	530.00	75.71	13.77	19.58
	Soil correctives	kg	0.64	34.4	22.02	3.15	0.57	0.81
	Natural Rock Phosphate	kg	1.98	34.4	68.11	9.73	1.77	2.52
	Macronutrients 04-30-16 NPK	kg	3.00	60.2	180.60	25.80	4.69	6.67
	Macronutrients 20-05-20 NPK	kg	3.40	51.6	175.44	25.06	4.56	6.48
	Herbicide (Pre-planting)	L	28.20	1.0	28.20	4.03	0.73	1.04
	Herbicide (Post-planting)	L	28.20	1.0	28.20	4.03	0.73	1.04
	Ant trap	kg	15.00	1.0	15.00	2.14	0.39	0.55
	B – FIXED COST/ Depreciation Improvements	year	25,60	1.0	25.60	3.66	0.66	0.95
	C – OPERACIONAL COST							
	Expected Remuneration on Capital	year	133,72	1.0	133.72	19.10	3.47	4.94
	Land	year	300,00	1.0	300.00	42.86	7.79	11.08
	D – TOTAL COST (TC)					**386.70**	**70.31**	**100.00**
S. tubulosa	**A – Variable Cost**							
	Operation with Machine + Implement	HMi	180.00	2.0	360.00	51.43	9.35	13.87
	Labor	day	80.00	12.5	1000.00	142.86	25.97	38.54
	Seedlings	unit	1.66	159.0	263.30	37.61	6.84	10.15
	Soil correctives	kg	0.64	34.4	22.02	3.15	0.57	0.85
	Natural Rock Phosphate	kg	1.98	34.4	68.11	9.73	1.77	2.62
	Macronutrients 04-30-16 NPK	kg	3.00	60.2	180.60	25.80	4.69	6.96
	Macronutrients 20-05-20 NPK	kg	3.40	51.6	175.44	25.06	4.56	6.76
	Herbicide (Pre-planting)	L	28.20	1.0	28.20	4.03	0.73	1.09
	Herbicide (Post-planting)	L	28.20	1.0	28.20	4.03	0.73	1.09
	Ant bait	kg	15.00	1.0	15.00	2.14	0.39	0.58
	B – FIXED COST Depreciação Benfeitorias	year	25.60	1.0	25.60	3.66	0.66	0.99
	C – OPERATIONAL COST							
	Expected Remuneration on Capital	year	128.45	1.0	128.45	18.35	3.34	4.95
	Land	year	300.00	1.0	300.00	42.86	7.79	11.56
	D – TOTAL COST (TC)					**370.70**	**67.40**	**100.00**

RESULTS AND DISCUSSIONS

The total cost for the implementation of one ha of the ILF system with *E. pellita* or with *S. tubulosa* were estimated as US$ 70.31 and US$ 67.40, respectively (Table 1). These costs represent 83% and 82.5% of the income of the factors considered for *E. pellita* and *S. tubulosa*, respectively, and the combined fixed costs represent 16% and 16.5%, respectively, for a period of two years.

Decomposing the total cost for the implementation of both systems (Figure 1A and Figure 1C), it was verified that current expenditure required more financial resources, and within these, labor had a significant impact on the variable costs (37.4% and 46.7% in the ILF with *E. pellita* and *S. tubulosa*, respectively). In the implementation of the system with *S. tubulosa*, the labor costs were higher because of the lack of availability of seedlings from commercial nurseries. Thus, it was necessary to purchase the seeds and supplies necessary to produce seedlings in the nursery of the Experimental Field of Embrapa Rondônia, and it is necessary to consider the expenses associated with labor.

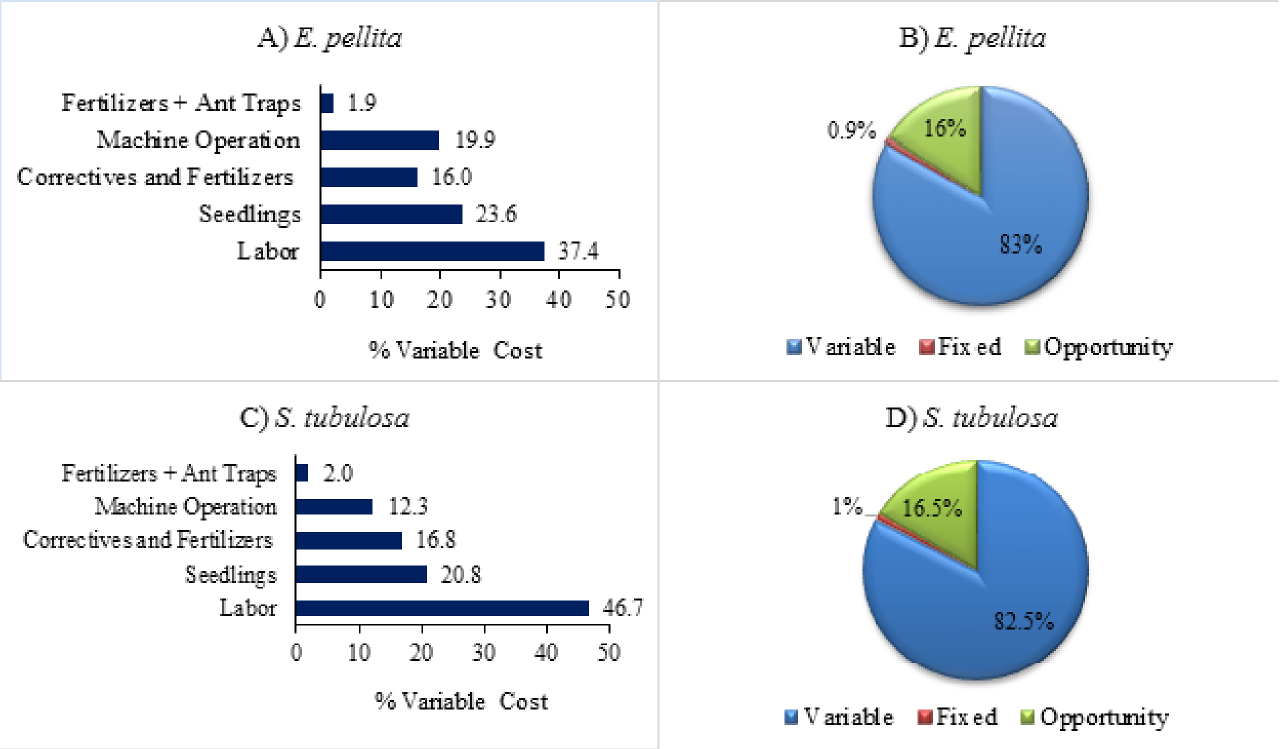

Figure 1. Proportion of costs (variable = A and C; and total = B and D) for implementation of Integrated Livestock-Forest (ILF) system with E. pellita and S. tubulosa in the municipality of Porto Velho, Rondônia, Brazil.

The total cost for ILF implementation was similar between the tree species, *E. pellita* and *S. tubulosa*. Thus, the choice of a tree species should be based on the main objective of the forest component, i.e., to produce wood products, or to supply multiple services. The main features of each tree species should be considered.

The advantages of eucalyptus as the forest component in the ICLF system are related to the availability of technical information for management (VALE et al., 2014) and to the advanced genetic improvement, which is responsible for the easy access to seedlings with excellent quality and affordable price, and a range of species for the various desired purposes. These factors place eucalyptus in a prominent position as a forestry essence and as an important component of silvopastoral systems (MELOTTO et al., 2012). In general, eucalyptus species have good growth and coppicing properties, resistance to *leaf disease*, adaptability to a variety of environmental conditions, and are useful as multipurpose timber. In the specific case of *E. pellita*, this species is recommended to the Amazon region because of its relative tolerance to leaf diseases related to tropical climate (FERREIRA and SILVA, 2004) and its adequate timber productivity in acidic soils with low fertility levels (AMEZQUITA et al., 2018). Other advantages of eucalyptus as a tree component in ICLF systems are: considerable wood productivity, cultivation at a high technological stage in some Brazilian regions and the potential to capitalize on agroforestry systems, as it works as "green savings". Despite the wide possibility of using eucalyptus wood in ICLF, farmers must focus on more noble forms of use, such as poles, sawn wood, and laminates for the production of furniture, thus obtaining greater profitability in the system (MELOTTO et al., 2012).

The use of native trees in the composition of integrated systems has been a trend of scientific research, as an alternative for increasing the biodiversity of the systems and for the conservation of natural resources. According to Andrade et al. (2012), there are 51 Amazon native tree species with the potential to be integrated with pastures, including the *S. tubulosa* tree. The main feature of this species is that it is a tree legume with the capacity to fix nitrogen from air, one of the most desirable multiple services in the afforestation of pastures. The other traits of *S. tubulosa* are: 1) the adequate canopy architecture characterized by a flabeliform form with low density that allows the radiation passage through it and does not negatively affect forage productivity, 2) the production of fruits with adequate nutritional value for animal feeding, 3) the absence of negative interference on the soil covering, the adequate natural regeneration in pastures, 4) a relative high growth rate (mean of 1.64 m per year), and 5) the facility for seedling production. In addition, *S. tubulosa* produces honey flowers.

CONCLUSIONS

The total cost for ILF implementation was similar regardless of the tree species, *Eucalyptus pellita* or *Samanea tubulosa* (US$ 70.31 and US$ 67.40, respectively). Thus, the choice of the tree species to be introduced in the system should be based on the main objective of the forest component, for producing wood products, or for supplying multiple services.

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HOW FARMERS UNDERSTAND AND USE DIVERSIFICATION AS A RISK MANAGEMENT TOOL

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ABSTRACT

The theme farm diversification and how it has been used and understood by farmers around the world is complex, since diversification can be and it is treated in different aspects by farmers. This broad spectrum of analysis is influenced by the most diverse variables, from practical business issues up to factors such as the production culture of a given region, the history of that country, its origins and even the relationship of its population with agriculture.Thus, trough structured case studies carried out through field visits in different parts of the globe, we sought to understand how farmers understand and apply diversification of production, especially from the aspect of risk management. The study showed that only 10% of the producers brought diversification as one of the main tools for risk management. At the other hand, 30% of these producers did not even mention diversification or some similar term. It was also observed that 90% of the producers who answered the research had some kind of diversification in their farm, even though they did not formally pointed it as a risk management tool. Thus, it was concluded that the complexity of the theme creates different layers of analysis, not always considered by the producer in his conscious decision-making process, even though it is an integral part of his production strategy.

Key words: farming; diversification; survey

INTRODUCTION

By definition, corporately, diversification is closely related to scope economy and risk management. When a company, regardless of its motivation, adopts more than one product in its portfolio, it is diversifying its production and, consequently, its revenue. As a result of this diversification, the economic theory predicts the reduction of the average cost of the product(s), thus generating savings in scale (PINDYCK and RUBINFELD, 2015). This spraying of revenue, through portfolio diversification, is also fundamental in the organization's risk management.

This reasoning, however objective, clear and logical, is far from being the main motivation of rural producers in the diversification of their production, according to the information gathered and compiled in the interviews presented below in this paper. Usually, these elements appear in the business discourse, after the diversification of production, as a justification given to a decision that originally has another motivator.

Therefore, it is clear that there is a relationship between definition and motivation. This relationship can be paradoxical, when the motivation for the adoption of diversification is not related to its definition, or complementary, when diversification is adopted so that the company takes advantage of the benefits of scope savings and risk management.

MATERIAL AND METHODS

By the investigative and qualitative nature of the work, seeking to understand, map and show how the relationships mentioned above impact the result of the sector, the methodologies of exploratory, descriptive and explanatory research will be applied.

Exploratory research seeks to increase knowledge about the research problem in order to construct hypotheses. Commonly, this type of research seeks to conduct a bibliographic survey, analyze examples that stimulate understanding and interview agents who have practical experience with the theme (GIL, 2007).

In this sense, descriptive research integrates the methodology, providing, according to Vergara (2000) the exposure of characteristics of a certain phenomenon, establishing a relationship between its numerous variables, thus helping in the definition of its nature.

In complementarity to the two methodologies and even as continuity of descriptive research, the application of explanatory research is applied, since it is concerned with identifying factors that can contribute or determine phenomena (GIL, 2007).

The study also sought to investigate the theme directly with producers through the application of questionnaires, following the Survey methodology. According to Figueiredo (2014), survey research is one of the 14 existing types of research and consists of systematic data collection to establish some type of pattern. The structuring of the research took place as follows:

- An on-line questionnaire (following the survey methodology), applied to rural producers;
- Face-to-face interviews with producers and professionals in the agro sector, with a pre-defined script, seeking to capture the information necessary to understand the theme;
- These same interviews with predefined script were applied online;
- Finally, informais interviews, conducted throughout the trips, with rural producers and people involved in the rural sector in some way.

The studies and discussions were conducted in Brazil, more specifically in the states of Mato Grosso do Sul, Mato Grosso, Goiás, São Paulo, Minas Gerais and Paraná. Outside Brazil, the countries visited for the study of the theme were: Argentina, Bolivia, Paraguay, United States, United Kingdom, Netherlands, Germany, France, Italy, Belgium, Czech Republic, Romania, Bulgaria, Hungary, Qatar and Kenya. In addition to the countries visited, non-face-to-face interviews were conducted with producers and members of producer representative organizations from Chile, Canada, Sweden, Australia, New Zealand, Zimbabwe and South Africa.

Specifically with regard to trying to understand how these people understand diversification, the questions were asked so that the term diversification only appeared as the interviewees brought the conversation, in order not to induce answers. In addition, other topics were investigated, with the objective of understanding the relationship that rural producers would make of these themes with diversification.

Grouping the answers together so that some kind of correlation is obtained, in order to form clusters of analysis, there are three large groups. In the first group, Brazil, USA, Argentina, Canada, Australia and New Zealand. In the second, European and African countries. In the third, the only representative of the Middle East in the analysis, Qatar. It is noteworthy that the agglomeration of these countries in these 3 clusters is due to the answers and evidence collected in these countries, having no relation to their economic, social, or productive structure.

RESULTS AND DISCUSSIONS

Group 1 - Brazil, USA, Argentina, Canada, Australia and New Zealand

This group was characterized by greater theoretical knowledge regarding diversification in production and its impacts, both in productive terms and in risk management. Nevertheless, it was the group characterized by the largest number of producers that does not practice diversification in production, especially in some regions and specific belts, a fact that is not repeated in groups 2 and 3. If we look at the productive structure of the countries that are part of group 1, we will see that they have their very diversified production agenda, however, when we look inside the farms individually, we see that diversification still struggles for space, especially in medium and large properties.

It is noteworthy that the work does not intend to criticize the existence or lack of diversification in certain regions. It is known that, in many situations, diversification does not happen by technical impediments of that region.

Group 2 - European and African countries

This group was characterized by the greater adoption of diversification in production, a fact that will be better discussed and analyzed later on. With regard to the knowledge of the formal definition of diversification and its benefits, the fact that most producers have more than one product in their production portfolio makes there a more uniform and natural discourse regarding its benefits. This fact, however, does not allow us to infer the existence of greater theoretical knowledge in relation to the subject, since the productive bases of these countries, as already mentioned, are extremely diverse.

It is important to note that the countries in this group have a larger number of small properties in percentage terms compared to the total existing agricultural properties than the previous group, for example. Therefore, as diversification is always more present in small properties, this scenario is characterized as a rule in this region.

Group 3 - Qatar

The existing production structure in Qatar is very particular and its basic structure cannot even be compared with the rest of the Middle East in many respects, although many countries in the region have the same modus operandi in agricultural production, that of investing heavily in production and subsidizing prices to ensure food security.

The agricultural activity in the country is divided into two moments, the pre-blockade period of neighboring countries, and the period after the blockade (this important historical fact for the formation of the production structure of the country in question will be addressed later). Data presented by the government in the visits, show that most of the current agricultural enterprises are less than 3 years old and have emerged to meet the country's specific needs and meet clear food security objectives. Thus, diversification clearly stands aside in the discussions of formulating business models, since the volumes demanded of these companies make them seek scale above all.

Returning to the initial questions of study, within the groups presented earlier, more than one hundred producers answered questions that sought to understand some aspects related to the subject. One of the main ones was how risk management was understood and what was part of it. When asked what they considered risk management and what main points/tools within risk management would be named, the following scenario was obtained:

- Only 10% brought diversification as one of the main tools for risk management.
- 30% of these producers did not even mention diversification or some similar term;
- 60% mentioned diversification, but it only appeared in the final third of their list.

On the other hand, terms such as futures market, future sale and head dominated the lists and were almost always at the top. One of the most interesting points of the analysis is the fact that, within the sample used, almost 90% of the producers practiced diversification, having more than one product within their agro portfolio, but still, either did not point the theme, or gave it low priority.

This analysis shows that there is a tendency, even among those who practice diversification, to disregard it or give it less importance as a risk management tool.

This inference is interesting and disturbing at the same time, since if we create an imaginary line, which has the producer at the beginning and the risk management tools spread along it, with the simplest and that depend less on external factors at the beginning of the line, closer to the producer, and the more complex ones, with greater dependence on specific knowledge and influence of external factors , further away from it, at the end of the line, one has the feeling that the producer is looking at the farthest, distant and complex, than at the closest and simple issues.

As much as the whole decision-making process is complex and formed by an almost endless series of factors, some of them little objective, it is difficult to imagine that some tools of operation in the futuremarket, with daily adjustments, sometimes influenced by exchange rate, need for intermediaries, among other factors, may be more present in the producer's thinking than mere analysis than to produce.

All risk management tools have their importance, and, in fact, it is difficult to say which one is more or less important, which, however, does not disallow us to affirm that the discussion about what to produce is, or should be, number one on the priority scale.

Although the characterization of the groups presented above can give the false feeling that it is possible to find some pattern in the treatment with the theme diversification between producers, whether they are from different countries or not.

However, as discussions on the subject deepen, it becomes increasingly difficult to create any form of typification, since invariably the discussion is moving towards the theme of decision-making, which, in turn, because it is a process with great complexity, makes the discussion even more challenging.

Some points observed that limit both the vision of diversification and risk tool, as well as the beginning of the process of switching to diversified systems are:

- The excessive characterization of market mechanisms as the only risk management tools;
- Lack of mastery of project analysis tools and their feasibility;
- Emotional attachment to the activity that is practiced, making it impossible to make it impossible to consider another activity for the rural company;
- Difficulties in managing/conducting current activities, making it impossible to consider new activities;
- Lack of practical and close examples of diverse systems that have worked;
- In the case of some countries, such as Brazil, Argentina, Mexico and other countries that have undergone colonization process, the monoculturist production that accompanies the country since its production cycles of the past (coffee, sugar cane, etc.), usually linked to scale;
- Historical and/or colonization processes that imposed over time the cultivation of certain products, creating an environment in the sector with low capacity for change in the production structure;
- Entrepreneurial capacity limited by several institutional factors,

CONCLUSIONS

It would be very pretentious to try to understand and translate the decision-making process of an entire, global, extremely diverse and complex sector such as Agro. But the above points showed almost that the totality of the producers interviewed during the work. Obviously, each of these points has the potential to unfold in many others, with even more complex aspects, since psychological and totally subjective components are also part of the whole decision-making process.

However, there is a point of common agreement between respondents and visited when it comes to diversification or even scale increase. Despite the possible gains generated, and the possibility of mitigating risks, the increase in the complexity of business management is certain.

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ECONOMIC VIABILITY OF A CROP-LIVESTOCK-FORESTRY INTEGRATION SYSTEM IN SÃO CARLOS, SP

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ABSTRACT

This paper aims to analyze the economic viability of a crop-livestock-forestry integration system carried out in São Carlos, SP, Brazil and estimated for a 100-ha area. The total area was divided into three plots, and the integration system was implemented in three years. The first year after eucalyptus planting, there was a soybean (first season) and a corn (second season) production in consortium with pasture. Beef cattle were raised in the pasture between the rows of eucalyptus in the remaining years. A 14-year cash flow was estimated for the project, taking the prices observed in 2020. The Internal Rate of Return (IRR) was 10.54 per year, and the Net Present Value (NPV) was R$ 570,555.77.

Key words: economic viability; crop-livestock-forestry integration system; agrosilvopastoral

INTRODUCTION

There is a need to accommodate the growing demand for food and reduce the environmental impact caused by agriculture (CORDEIRO et al., 2015). Crop-livestock-forestry integration systems (CLF), which include the crop-livestock (CL) and forestry-livestock (FL) arrangements, have proved to be reliable alternatives. They are a more sustainable production strategy in which crops, livestock, and/or forests are jointly produced (BALBINO et al., 2011). The adoption of CLF integration systems brings environmental benefits, such as the improvement of physical, biological, and chemical quality of the soil and economic and social gains (MACEDO 2009; BALBINO et al., 2011).

The CLF integration systems are among sustainable technologies supported by Brazilian policies to reach the national goal to reduce GHG emissions (VINHOLIS et al., 2021). Information on the economic viability of CLF integration systems is essential for farmers to decide whether to adopt them. This study analyzes the economic viability of a crop-livestock-forestry (CLF) integration system carried out in São Carlos, SP, Brazil.

MATERIAL AND METHODS

A 14-year cash flow was estimated for a production area of 100 ha. Technical coefficients were obtained from a CLF integration system carried out since 2011 on the farm of Embrapa Southeast Livestock. The year zero of the cash flow comprises expenses with infrastructures, such as perimeter fence and corral, and the purchase of machinery and implements. Information on technical lifetime, residual values, and maintenance cost of machinery and infrastructure followed the CONAB methodology. Prices were collected for the year 2020 on the websites of the Instituto de Economia Agricola (IEA), Center for Advanced Studies in Applied Economics (CEPEA), Scot Consultoria and input suppliers. The income tax was calculated according to the method “Livro Caixa Digital do Produtor Rural (LCDPR)” as determined by the Brazilian Federal Revenue Office. The Net Present Value (NPV) was calculated by the equation:

$$NPV(i) = \sum_{j=0}^{n} \frac{CF_j}{(1+i)^j}$$

Where:

i= discount rate (3.48% per year);

j= cash flow period;

CFj= net cash flow for t=0, …, n;

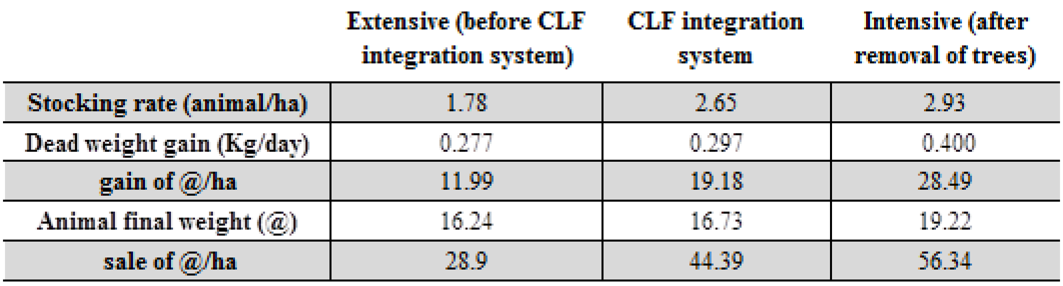
n= number of flow periods.

The Internal Rate of Return (IRR) refers to the rate in which the NPV is zero.

The area of 100 ha was divided into three plots of 33 ha each. One hectare was destined for the grazing of the horse used in cattle working. The system was implemented in the first 3 years of the cash flow, 1/3 per year. Single rows of eucalyptus were planted in an east-west orientation and a 15 × 2m spacing (15m between rows and 2m between trees in the rows), which resulted in a population density of 333 trees ha^{-1}. One year after planting, the eucalyptus, soybean (first season), and corn (second season) were planted in consortium with pasture. Local partners under contract farmed these two crops. At the end of this cycle, the pasture was recovered, allowing beef cattle to graze in the fattening phase. This strategy avoided investments in fences to protect the trees. Thus, in the first year, 2/3 of the area was occupied with pasture in which beef cattle were raised, and 1/3 was occupied with trees in consortium with crops. In the second year, 1/3 of the area was occupied with pasture in which beef cattle was raised, 1/3 was occupied with trees in consortium with the crop, and 1/3 was occupied with the CLF integration system, which replaced the pasture area of the first year. In the third year, 1/3 was occupied with trees in consortium with the crop, and 2/3 with the CLF integration system. In the fourth and following years, the total area was fully occupied with the CLF integration system. Tree thinning was performed when the trees were 4 and 8 years old. The remaining trees were cut down in the final three years of the cash flow (trees were 12 years old).

The restored pasture was divided into 7 plots, where beef cattle were raised in rotation. Steers were annually bought in April and then fattened until March of the following year when the cattle were sold. Those animals were fed with protein mineral salt as a nutritional complement during 150 days in the dry season, and with mineral salt for 210 days during the wet season. Fertilization with NPK (20-05-20) was applied (500 kilograms per hectare per year). Additional fertilization with superphosphate (500 kilograms per hectare) and limestone (1.8 tons per hectare) was carried out every 3 years. The official protocol of vaccination and preventive deworming were performed. Technical coefficients used to estimate the cash flow values are presented in Table 1.

Table 1. Technical coefficients for animal production.



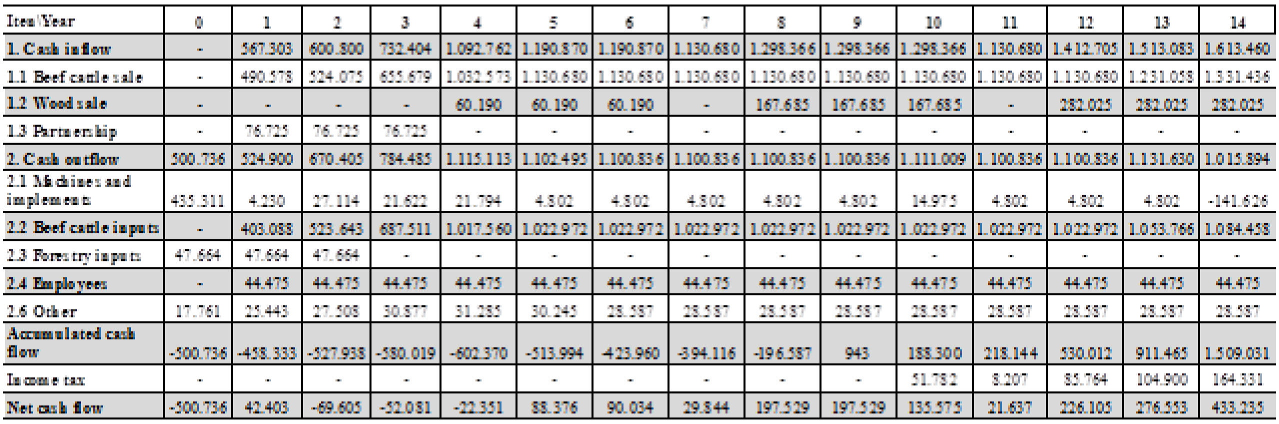
	Extensive (before CLF integration system)	CLF integration system	Intensive (after removal of trees)
Stocking rate (animal/ha)	1.78	2.65	2.93
Dead weight gain (Kg/day)	0.277	0.297	0.400
gain of @/ha	11.99	19.18	28.49
Animal final weight (@)	16.24	16.73	19.22
sale of @/ha	28.9	44.39	56.34

Trees were harvested three times to be sold every four years. The first and second harvests' estimated productions were obtained in field experiments at Embrapa: 64.45 m^3 / ha and 75.35 m^3 / ha, respectively. Production of the last harvest was estimated at 126.73 m^3 / ha.

RESULTS AND DISCUSSIONS

Table 2 shows the estimated cash flow.

Table 2. Cash flow of CLF integration system (R$).



Item/Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Cash inflow	-	567.303	600.800	732.404	1.092.762	1.190.870	1.190.870	1.130.680	1.298.366	1.298.366	1.298.366	1.130.680	1.412.705	1.513.083	1.613.460
1.1 Beef cattle sale	-	490.578	524.075	655.679	1.032.573	1.130.680	1.130.680	1.130.680	1.130.680	1.130.680	1.130.680	1.130.680	1.130.680	1.231.058	1.331.436
1.2 Wood sale	-	-	-	-	60.190	60.190	60.190	-	167.685	167.685	167.685	-	282.025	282.025	282.025
1.3 Partnership	-	76.725	76.725	76.725	-	-	-	-	-	-	-	-	-	-	-
2. Cash outflow	500.736	524.900	670.405	784.485	1.115.113	1.102.495	1.100.836	1.100.836	1.100.836	1.100.836	1.111.009	1.100.836	1.100.836	1.131.630	1.015.894
2.1 Machines and implements	435.311	4.230	27.114	21.622	21.794	4.502	4.502	4.502	4.502	4.502	14.975	4.502	4.502	4.502	-141.626
2.2 Beef cattle inputs	-	403.088	523.643	687.511	1.017.560	1.022.972	1.022.972	1.022.972	1.022.972	1.022.972	1.022.972	1.022.972	1.022.972	1.053.766	1.084.458
2.3 Forestry inputs	47.664	47.664	47.664	-	-	-	-	-	-	-	-	-	-	-	-
2.4 Employees	-	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475	44.475
2.6 Other	17.761	25.443	27.508	30.877	31.285	30.245	28.587	28.587	28.587	28.587	28.587	28.587	28.587	28.587	28.587
Accumulated cash flow	-500.736	-458.333	-527.938	-580.019	-602.370	-513.994	-423.960	-394.116	-196.587	943	188.300	218.144	530.012	911.465	1.509.031
Income tax	-	-	-	-	-	-	-	-	-	-	51.782	8.207	85.764	104.900	164.331
Net cash flow	-500.736	42.403	-69.605	-52.081	-22.351	88.376	90.034	29.844	197.529	197.529	135.575	21.637	226.105	276.553	433.235

The CLF integration system presented an IRR of 10.54% per year and a NPV of R$ 570,555.77. The integration system proved to be economically viable. These results confirm other authors' findings. Müller et al. (2011) evaluated the economic viability of an agrosilvopastoral system in Minas Gerais. The authors found an IRR of 10%, assuming the sale of standing timber. Tupy et al. (2019) evaluated a FL integration system with eucalyptus in an extensive beef cattle system, and found a positive NPV.

CONCLUSIONS

The results suggested that the crop-livestock-forestry integration system is viable. We recommend caution in generalizing the results because the analysis was performed in a single farming area, and the prices refer to a single year. It should be pointed out that some prices were high in the 2020 scenario when steer and fattened cattle prices reached high values. We suggested risk analysis as an additional evaluation in future studies.

Important environmental aspects of the CLF integration system were not measured and valued in this analysis. For example, carbon credits could have been included in the cash flow. Future studies should also consider the environmental aspects when evaluating these systems.

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ECONOMIC ANALYSIS OF THE INTEGRATION OF LIVESTOCK AND EUCALYPTUS PLANTATION UNDER UNCERTAINTIES

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ABSTRACT

The benefits of the implementation of silvopastoral systems (SPS) can be verified by means of the mitigation of environmental impacts and the economic profit. So, to measure the efficiency and the economic risks, the Monte Carlo method was used, the objective of this work was to avaliate if a investment project in the integration of livestock and forests under conditions of uncertainties is economically viable. The technical and monetary factors of the production in a 4 ha area of integration with forest and cattle were pondered, the site is in the Northwest of Mato Grosso, Brazil. The discounted cash flow was projected with a horizon of planning of 15 years. For the inputs of the mathematical model, under uncertainties conditions, were attributed the distribution of probabilities, allowing the execution of the Monte Carlo method to incorporate stochastic solutions. The results of the quantitative methods applied to the investment analysis may conclude that under the analysed conditions, the investment project in the integration of livestock and forest is economically viable.

Key words: Silvopastoral systems; rearing of beef cattle; *Eucalyptus*

INTRODUCTION

The agroforestry systems utilize the integration of two or more productive elements, whose constituents elements are forestry and crop components utilizing or not animals, distributed over the same space and time producing services and goods on a sustainable basis (PALUDO and BEBBER, 2012). Those elements can be divided into three major groups, classified by their structure and functionality. Amongst those systems, the Silvopastoral Systems (SPS) have the integration of pasture and animal breeding with trees (CRESPO, 2014).

It should be pointed out that the SPS has been more and more utilized in Brazil and all over the world because this technique can recuperate degraded lands, offer animal welfare, environmental and economic sustainability, besides the diverse environmental services like reestablishing the trophic levels, the attraction of pollinators, bigger seed dispersal. They can also be a carbon stock for the mitigation of the effects of the pollution caused by the emission of pollutant gases (BROOM, 2017; JOSE and DOLLINGER, 2019).

In this perspective, the SPS can be characterized as a financial investment project, therefore, the economic and financial analysis is justified seeking the demonstration of its economic viability (CLELAND and IRELAND, 1998). The investment project analysis commonly involves techniques that try to establish parameters of its viability (BRUNI et al., 1998).

According to Bruck et al. (2019), the analysis of investment projects in SPS must be realized in different contexts due to the diverse combinations and conditions of the market that characterizes this kind of production.

The economic and financial analysis of SPS can be made feasible inside the perspective that considers methods that weigh the value of money along the time (SANTOS and GRZEBIELUCKAS, 2014; CHIZMAR et al., 2020). That way, the analysis involves the creation of goals and indicators of success for the investment project, assessing the efficiency, relevance, impact, and sustainability of the project (TENGAN and AIGBAVBOA, 2017).

Traditionally, these analyses are realized in a deterministic way, which does not allow obtaining values with probabilities of occurrence. Nonetheless, this can be measured by the application of probabilistic techniques (SIMÕES et al., 2018a).

Within this perspective, the Monte Carlo method is a possibility to quantify the risk of the investment project (MIYAJIMA et al., 2020). In the understanding of Platon and Constantinescu (2014) and Pereira et al. (2020), this method enables the approach of the diverse uncertainties associated with the activities of the investment project. In addition, allows for the calculations of probabilities of occurrence of the economic parameters related to the project.

Thus, to measure the efficiency and economic risks by the Monte Carlo method, the objective was to evaluate if an investment project in integrating livestock and forest under conditions of uncertainties is economically viable.

MATERIAL AND METHODS

Object of study

The technical and monetary factors of production were weighted in the SPS in a four-hectare site in the northwestern region of Mato Grosso, Brazil. The breeding of Nelore animals was considered in a system of recreation and the planting of *Eucalyptus* sp. trees.

Cow-calf farming is the most common beef production system in the region, with prevailing natural breeding, using Nellore bulls. The medium stock rate of the pasture was 1.12 AU/ha. In this system, the income comes from live animals, the male calves, and the disposal of matrices and females for slaughter, the productivity was 4.18 @/ha (@ = 15 kg of animal carcass).

The arrangement of the trees was realized in a spacing of four meters between trees, two meters between simple lines, and 28 meters between tiers, with a density of 446 trees per hectare. At the final of the fifth year after the forest implantation, the selective thinning was realized, with 89 trees remaining per hectare. For the formation of pasture was adopted the growth of grasses of the *Panicum* sp. between the tiers after two years of the establishment of the trees.

Economic analysis

The monetary values were expressed in US dollars (USD), then, it was adopted the Exchange rate expressed in Brazilian Real (BRL) that was BRL 5.4854 on 11/13/2020 according to the Central Bank of Brazil (2020).

The cash flow, which was characterized as non-conventional because of its diverse outputs along the projected horizont (Damodaran, 2012), a time horizon of 15 years was projected for this project, considering the shallow thinning of the forest. Therefore, all the inputs demanded for the handling and maintenance of the animals, for the implantation of the forest, silvicultural practices, labor costs, incomes with the marketing of cattle and the timber, taxes related to the livestock and forest, taxes under the rural property, depreciation of the productive factors inherent to the livestock production and the forest exhaustion were considered.

The opportunity cost by the use of capital was estimated employing the weighted average cost of capital (WACC) according to Cunha et al. (2013). The systematic risk coefficient of the Market was estimated with a basis of the forestry enterprises that had open capital, and trading stocks negotiated on B3 S.A. – Brasil, Bolsa, Balcão (2020).

The quantitative methods for the investment analysis were grounded in the value of the money along the time. Therefore, the net present value (NPV) was estimated as proposed by Shaffie and Jaaman (2016). In addition, to determine the profitability of the applied capital was applied the modified internal rate of return (MIRR) as proposed by Mieil (2017) because this is the preconized method for non-conventional cash flows and, the profitability index (PI) in consonance to Potashnik et al. (2018), which allows measuring the return of each monetary unit applied to the investment project.

Incorporation of stochastic approach

As uncertain inputs of the mathematical model were considered the costs related to the animal breeding, the costs of forest implantation, costs with silvicultural practices, and the incomes from the ox and timber marketing, which were attributed triangular distribution of probabilities as recommended by Simões et al. (2016). The deterministic values were delimited to a variation of ± 15.0%, determined by the specialist's opinion.

The Monte Carlo method was executed for the incorporation of stochastic solutions, with 100.000 repetitions, assuring the convergency of the data to a normal distribution, realized by the software @Risk Copyright © 2020 (PALISADE CORPORATION, 2020). The generator of pseudorandom numbers used was the *Mersenne Twister* (MATSUMOTO and NISHIMURA, 1998). Moreover, was adopted the same initial parameters for the executed model as preconized by Simões et al. (2018b). In the end, the assessment of the project risk pondered the Spearman correlation (ρs) to verify the monotonic relation between the inputs and the outputs in a significance level of 5%, medium values, minimal values, maximum values, and variation coefficients as shown in Bassoli et al. (2020).

RESULTS AND DISCUSSIONS

For the construction of the cash flows of the investment project for the present date, was measured the return tax that the investor can wait to receive in an investment with equivalent risks, discussed under the perspective of opportunity cost, which was 6.37%. Hereupon, the net present value was comprehended in the interval of – USD 474.70 and USD 3,994.39, with a medium value of USD 1,763.45.

Therefore, when evaluated the associations between the variables that composed the probabilistic model (Figure 1), was verified a direct correlation of the incomes, standing out the livestock (ρs = 0.83). In opposition, was obtained inverse correlations, resultant of the outcomes, standing out the one that comes from the implantation of the forest (ρs = - 0.47). Therefore, in consonance with Gutiérrez Castro and Baydia (2008), the determination of the correlation coefficient allowed us to infer how the variable, that means, the NPV, answers the oscillation of the components of incomes and outcomes of the cash flow.

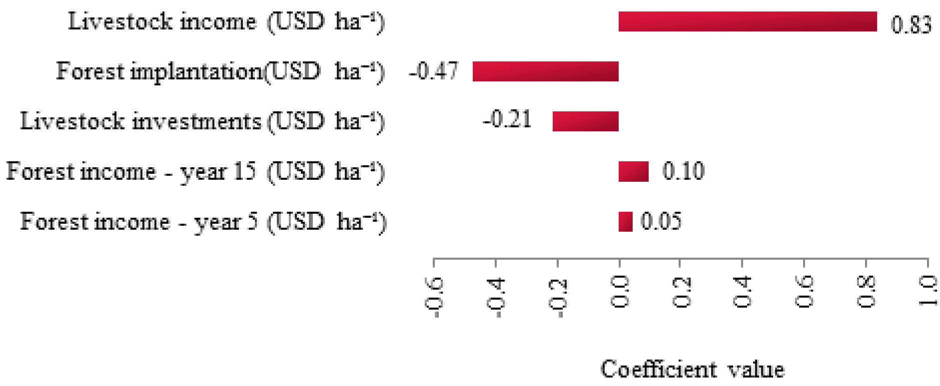

Figure 1. *Spearman* correlation of the constituents of the cash flow in the function of the net present value.

Furthermore, was observed that, with the cumulative frequency curve, the probability of the NPV be inferior to zero occurred in less than 5% of the scenarios (Figure 2). This perspective leads to the acceptability of the investment project for the manager, as the probability of the response of the economic income is positive under the stochastic perspective, as pointed out by Farias et al. (2018).

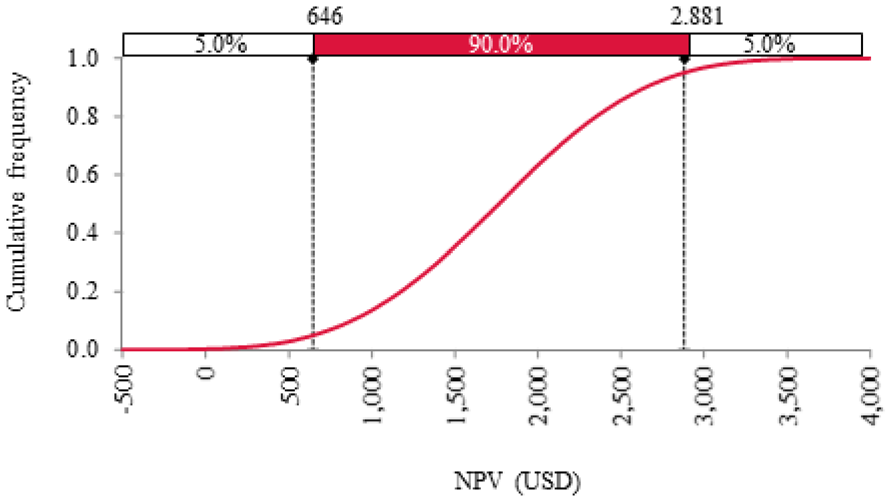

Figure 2. Frequency accumulated curve of the net present value.

Stands out, however, that the performance of an investment does not depend only on its cash flows projection, but also on its reinvestment taxes. Therefore, to make the decision based on complementary economic indicators allows its economic viability and also infer about its profitability and attractiveness.

Thus, through estimation of the MIRR, which weighs in its calculus the taxes for possible reapplication of the intermediary cash flows, was observed that it was in the interval of 3.95% to 8.65%, with a medium value of 6.34%.

Moreover, establishing the relation between the present value of the incomes and outcomes of the cash flow, reflected an interval of 0.92 to 1.87 that comprehended a profitability index of 1.33, which means that the present value was 33% superior to the outcomes, resulting in a positive NPV.

CONCLUSIONS

The investment project in the integration of livestock and planted forest of *Eucalyptus* under uncertain conditions have shown to be economically viable when analyzed in probabilistic scenarios.

Corroborated by Baggio and Schreiner (1988) who reported on the economic viability of investment projects in cattle ranching and forest integration systems, the economic indicators implemented to reinforce this assumption. Therefore, the association between ranching and the planted forest was beneficial to the producer, especially under conditions of uncertainty.

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ANALYSIS OF THE ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPACTS OF URT/ILPF - CORN AND SORGHUN IN THE CENTRAL REGION OF MINAS GERAIS.

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ABSTRACT

The objective of this work is to make an analysis of the environmental, social and economic impacts of the ILPF Strategy for agriculture in the central region of Minas Gerais and neighboring areas. The method of analysis of information was based on secondary data. The data were provided by Santos (2020) and by Noce (2017), from two different research for doctoral theses. All the analysis of this work was based on the experience of the project of installation of a URT of the ILPF System in the farm of Embrapa in Sete Lagoas - Brazil. The results analyzed showed that the economic, social and environmental impacts of the Systems implemented in the Central Region of Minas Gerais were positive resulting in farmers seeking to increase their areas with the ILPF system and adding new producers, in a spillover effect of the technology.

Key words: Impacts; economics; small farmer

INTRODUCTION

Embrapa Maize and Sorghum, located in the Municipality of Sete Lagoas, implanted a Technical Reference Unit in Integration of Crop and Livestock (ILPF), seeking to represent a rural property in the region. According to Alvarenga et al. (2015) and Balbino et al. (2011) a technological reference unit (URT) is a physical model of a production system, implanted in areas of farms to serve as a reference, aiming at the validation, demonstration and transfer of the technologies strategies generated, adapted and / or recommended for implantation and development of ILPF system.

Cattle farming predominates in the region, with grain production mostly directed to animal feed, with the surplus sold on the market (by-product of livestock). Each year, in the spring / summer, crops are grown on three 5.5-hectare plots, and a fourth plot of the same size is used for grazing, following the order: soy => corn + Urochloa => forage sorghum + Megathyrsus = > pasture, using the cultivars of grass: Piatã (*Urochloa*) and Mombaça (*Megathyrsus*). This spatial design aims at sustainable production by integrating grains and silage with the rearing and finishing of cattle (GONTIJO NETO et al., 2018).

In addition to the ILPF URT area implemented by Embrapa, the work of presenting the ILPF system to producers in the region was carried out by 3 institutions and had a very positive return in terms of using the system. Two doctoral theses analyzed the technology transfer process that was carried out over the years using the URT ILPF installed at Embrapa as a base. Santos (2020) analyzes the process as a whole and provides information on economic, social and environmental impacts of the use of the ILPF system on properties, while Noce (2018) evaluates the SEAPA-MG Program to strengthen the expansion of the use of the ILPF system also in the central region of Minas Gerais, also presenting some impacts of the use of the ILPF system.

The objective of this work is to make an analysis of the environmental, social and economic impacts of the ILPF Strategy for agriculture in the central region of Minas Gerais and neighboring areas. For this purpose, we intend to present some concepts to be able to bring to light some results, related to efficiency and sustainability, arising from the use of ILPF strategies in the Region, which were made possible by Embrapa's performance in partnership with EPAMIG and EMATER -MG.

MATERIAL AND METHODS

The concept of efficiency in production used in the economic evaluation takes into account the two aspects of efficiency, Technical Efficiency and Economic Efficiency. Many of the research results made available to be disseminated to users do not go through one of these sieves or even both.

Technical Efficiency is the result of engineering that shows that the new one works and gives technical results. We can understand technical efficiency as the maximum possible production, given levels of labor, capital and technology, resulting from the use of a technical relationship between the physical quantity of factors of production and the physical quantity of the product in a given period. time (MANKIW, 1999).

But this analysis must not be based only on pure economic concepts, established by economic theory, but also taking into account the social and environmental aspects that are affected by the new productive system. Attention is drawn to the analysis of the sustainability of the process, which should be assessed without ideological bias, but in a practical way, if possible, with tools that have some metrics.

Thus, sustainability involves in its analysis the three aspects of the desired sustainable development, where it is presented that the productive actions must be economically viable and profitable, socially fair and environmentally friendly. This productive process must take into account how its current externalities will impact our legacy for future generations.

Based on the concepts explained above, the method of analysis of information based on secondary data was used. The data were provided by Santos (2020) and by Noce (2017). It is data from two researches for doctoral theses at two different Universities that dealt with the process of technology transfer and Public Policy for the adoption of technology.

The data were compiled, organized, and analyzed using concepts focused on the impact of ILPF strategies for the sustainable development of agroforestry production in the region. The farmers' responses were considered as indicators of each of the proposed concepts. The responses of 8 rural producers were considered in the data from Santos (2020) and 35 rural producers in the data from Noce (2017).

RESULTS AND DISCUSSIONS

ILPF has already proven to be technically efficient. Although it is almost unanimous in terms of technical recognition, much has been said in its sustainability with agricultural, livestock and forestry production strategy. Questions are raised about the applicability of this system in family farming, about what is actually delivered in terms of environmental benefit, among other questions (CORTNER et al., 2019).

Santos (2020), in her research conducted with producers to evaluate the process of transferring ILPF technology in the Central Region of the State of Minas Gerais, addressed the issue of applicability of the ILPF system to small producers, showing that there was positive involvement of family agriculture in the use of technology. In the sample of producers who had the influence of Embrapa, Epamig (Minas Gerais Agricultural Research Company) and Emater-MG (Minas Gerais Technical Assistance and Rural Extension Company) in the dissemination of the ILPF System in the Central

Region of Minas Gerais, assisted by Emater-MG in all their needs, one can observe that they are small properties with small areas used with the ILPF System also. Half of these areas have 3 ha or less applying the technologies recommended by the system. These small areas have been in the areas for more than 8 years with results that show the sustainability of the system in different sizes of properties, including economic viability.

Environmental Impact

Tables 1 and 2 show information collected in Santos' research (2020) and reported in his Doctoral Thesis. Information collected by the author is reported with the properties participating in her research. It is observed in table 1 that the perception of the agents who acted in the implementation and conduction of ILPF Systems in properties (Producers, extensionists of EMATER-MG, researchers from EPAMIG and Embrapa) is positive for environmental and social improvement.

According to the producers' reports, the indicators that were positive, without the use of any metrics, but only as an observation of the evolution of the results experienced by them, were:

- Improvement of soil quality.
- Abandonment of harmful practices to the soil and the environment (e.g. burning, clearing of riparian forests, etc.)
- Recovery of degraded pasture
- Improvement of the rural landscape.
- Reduction of animal stresses by offering shades;
- Rotation of crops.

In the evaluation carried out by the producers, the environmental quality in their properties was increased. According to their reports, they were able to control erosion by keeping the soil always covered, also contributing to a sense of well-being, because the rural landscape became more beautiful. They were able to ensure more moisture for the soil, with the use of no-tillage, adding to the previously reported effect. The planting of trees brought the possibility of improving the ambience for the animals that grazed under their canopy, which resulted in an increase in the quantity and quality of the milk produced by them.

Social Impacts

Some social benefits were also identified in relation to the use of ILPF systems. In this sense, these producers were able to enjoy social benefits more because they were the ones who were at the forefront of the use of innovation in the region.

One of the great benefits of ILPF is related to the training of farmers and all who are part of the production process for questions about technical, administrative, environmental and social relationship (cooperation) development. These trainings underwent a spillover process where those who were trained passed their knowledge to their community and all benefited.

In addition to the training, Table 1 presents the social benefits of the Implementation of the ILPF System in the analysis by Santos (2020). This information was reported by the producers themselves who came to have ILPF as a promoter of welfare on their property. They considered that the activity improved the quality of the work they developed and reduced the amount of time spent with the tasks, which provided them with extra time for social interaction. They also came to be able to have improvements in the quality of their homes.

In table 1, it can still be noted that the producers increased their sense of observation because they began to perceive the importance of their activities for regional sustainability, perceived the need to offer quality products, thus had greater market opportunity, and realized that they had to produce in the right way, which placed them as an example for regional producers, increasing their self-esteem.

Economic Impacts

Although the environmental and social benefits that ILPF brought to properties and nearby region were important, producers are always entrepreneurs and always seek to maximize profit with the restrictions imposed by and on activity. Table 1 presents some of the economic and financial results reported by Santos (2020).

In Table 1, it is observed that the forest activity of ILPF was considered as a form of capitalization of the producers who adhered to the developed program of use of this system in the properties. After 7 years of planting, the producers achieved an extra income that helped them in investing in improvements in production and housing infrastructure.

In terms of production, one can observe in Table 1 that all farmers reported an increase in the volumes produced, in the best use of pastures, increase in Animal Units per hectare, and increase in the quality of the products offered by the property. With this, they realized that there was greater efficiency in production resulting in the reduction of production costs. Both the increase in productivity per hectare and the reduction of production costs contributed to the increase in the income of the properties in the activities of farming and livestock, meaning more income for the rural producer.

Table 1. Environmental and Social Benefits of Implementing the ILPF System in small properties in the Central Region of Minas Gerais.

Benefits	**Maravilha Region**	**Papagaio Region**	**Sete Lagoas Region - Otter**
Environment	Abandonment of harmful practices to the soil and the environment (e.g. burned). Control of soil erosion (soils covered all year round).	Recovery of areas with eroded soils	Improvement of soil quality.
	Recovery of degraded pasture.	Recovery of degraded pasture	Recovery of degraded pasture.
		Reduction of animal stresses by offering shades.	
	Rotation of crops		Rotation of crops
	Reinsertion of degraded areas	Improvement of the rural landscape.	Improvement of the rural landscape.
Social	Training	Training	Training
	Improving the quality of work.	Improvement of work planning.	Work reduction (improved work planning)
	Interaction with other producers.	Interaction with other producers.	Interaction with other producers.
	Perception of production quality	Perception of production quality	Perception of production quality
	Search for economic and environmental sustainability	Search for Economic and Environmental Sustainability	Search for Economic and Environmental Sustainability
	Improving self-esteem	Improving self-esteem	Improving self-esteem
Economic/ Financial	Eucalyptus = Green savings Income of up to R$ 2,136.40 ha/year from the 7th year.	Eucalyptus = Extra income Income of up to R$ 11,000.00 in 23 ha, in the first cut (R$ 473.00 /ha).	Eucalyptus = Extra income Income of up to R$ 400.40 ha/year in the 1st cut in the 7th year.
	Increased income Cost of corn production plus pasture: R$ 3,132.40/ha/year; Total Milk Revenue plus corn: R$ 5,249.83/ha/year	Increased income	Increased income
	Increased production Milk: went from 150lt/day to 450 liters per day; Corn Yield: 6873 kg/there is in the useful area.	Increased production: Milk: Increased production by 10% / increased quality per animal; Went from 0.5 AU/ha/year to 2.0 AU/ha/year	Increased production Increased the amount of dairy cow head in the same space.
	Cost reduction per unit produced.	Cost reduction per unit produced.	Cost reduction per unit produced.

Source: Santos (2020). Content compiled by the authors.

Noce (2017) is another author who analyzes the implementation of ILPF in the Central Region of Minas Gerais. In his work, he sought “to analyze the process of the transfer of agricultural technologies (TT), usually practiced in Brazil. For the analysis of the process, we opted for a case study related to the program initiated in 2008, at the initiative of the government of the state of Minas Gerais, through the Department of Agriculture, Livestock and Supply (SEAPA-MG). This program aimed to disseminate the Crop-Livestock-Forest (ILPF) integration system among family farmers in the central region of Minas Gerais." To present his analysis of this process, he interviewed 54 producers, as well as extension workers from EMATER-MG and researchers from EPAMIG and Embrapa.

Of the 54 producers surveyed by Noce (2017), 35 became users of the ILPF System, after the implementation of the SEAPA-MG program. Table 2 depicts the items that were important to convince to use ILPF system technologies. It can be seen that at least 71% of the adhering producers had economic reasons to implement ILPF. Although this research was done in 2016 and they still did not have the results of the returns of the forest part of ILPF, they had perception that they were in a better situation than those who did not adopt the system.

To infer about the benefits of the ILPF System, we can turn to Noce´s (2017) research again. In the research he reports that: "As for the levels of satisfaction of producers with the technology implemented, it is observed that only a small minority, less than 6%, declared themselves dissatisfied with the results, while almost 90% say they are satisfied or very satisfied. The interviewed adoptive producers praise the improvement of pasture under eucalyptus, the shading of trees that benefits cattle, the condition of a better and greener pasture in the drought, the preservation of moisture, the production of wood and, in some cases, the production maize in the system”. It can be used as a positive indicator of the environmental and economic benefits of using the ILPF System on properties in the Central region of Minas Gerais.

In the sustainability assessment the benefits are generally comprehensive for the region, not becoming specific to the property, but when it comes to the evaluation of economic returns, the indicators bring results that "site specific", because they represent the values of exclusive analysis of the case (property) and system being evaluated. Thus, in the previous paragraphs we show results that represent an approximation of the analysis of the sustainability of the use of the ILPF System in some properties of the Central Region of Minas Gerais.

Table 2. Reasons pointed out by rural producers as instruments to convince them to use ILPF technology.

Itens	**Levels of importance (%)**
Importance of technology for the environment	5.71
Technology presentation at events	37.15
Donation of inputs and seeds	62.86
It could increase your profits from your production system	71.43
Action by rural extension workers	82.86

Source: Noce (2017). Content compiled by the authors.

CONCLUSIONS

All the analysis of this work was based on the experience of the project of installation of a URT of the ILPF System in the area of Embrapa. In addition, it was thought to present evaluation both to see the sustainable aspects and the economic returns of the use of the ILPF System. In the case of sustainability analysis, results of two studies were presented that indicate information collected from producers who participated in a technology transfer program that was based on the implementation of URT at Embrapa. The results analyzed showed that the economic, social and environmental impacts of the Systems implemented in the Central Region of Minas Gerais were positive resulting in farmers seeking to increase their areas with the ILPF system and adding new producers, in a spillover effect of the technology.

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MARKET AND COMMERCIALIZATION STRATEGIES OF THE CERRADO'S SOCIOBIODIVERSITY

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ABSTRACT

This research aims to evaluate the market and commercialization strategies that can be used by extractive production, as a sustainable social, economic, ecological and cultural productive alternative for family-based producers in the region of Chapada dos Veadeiros, which belongs to the northeastern region of the State of Goiás. Through exploratory and ethnographic means, our goal is to map the producers and commercial practices of these family farming organizations. We believe that this study will provide local communities with access to information from market segments with economic potential that can be exploited by them.

Key words: Chapada dos Veadeiros; Local Productive Arrangements (APLs); smallholding farming

INTRODUCTION

Consumers are increasingly choosing to adopt new values and consumption habits that reduce the degradation of the environment, in alternatives that promote productive development in all stages of the production chain. This new consumer demand has been stimulating the creation of new markets. Many companies in various sectors have been reinventing themselves, to meet productive demands with sustainable concerns that meet this new consumer market. Given this scenario of environmental concern, the models of sustainable agricultural production have been gaining prominence and guided by this marketing proposal, it is necessary that these productive arrangements are organized and access these markets.

The region of study in this research is the Chapada dos Veadeiros Territory, which belongs to the northeastern region of the State of Goiás. An area of greater conservation of the Cerrado Biome. The Chapada dos Veadeiros Territory - GO covers an area of 21,475.60 km² and consists of 8 municipalities: São João d`Aliança, Alto Paraíso de Goiás, Campos Belos, Cavalcante, Colinas do Sul, Monte Alegre de Goiás, Nova Roma and Teresina de Goiás (Figure 1).

The total population of the territory is 62,656 inhabitants, of which 20,546 live in the rural area, which corresponds to 32.79% of the total. It has 3,347 family farmers, 1,412 settled families, 6 quilombola communities and 1 indigenous land. Its average HDI is 0.68.

Agriculture in this region has always been alongside extraction and livestock, but it has never been an expressive economic activity. In the remote past, the inhabitants produced rice, beans, corn, sugar cane, cassava and everything needed to feed their families in their fields. At that time, they prepared the soil, planted and harvested in a traditional way, using rudimentary instruments and techniques: scythe, ax, hoe and fire (SILVA and XAVIER, 2004)

The discussion on food sovereignty has been gaining strength in recent decades, with a focus on valuing a diversified diet, respecting the tradition and food culture of the populations and valuing the production of food produced in a healthy way, free from physical, chemical contaminants, biological and organic. Contrary to this, there is a weakening of the production of food for human consumption in many Brazilian regions.

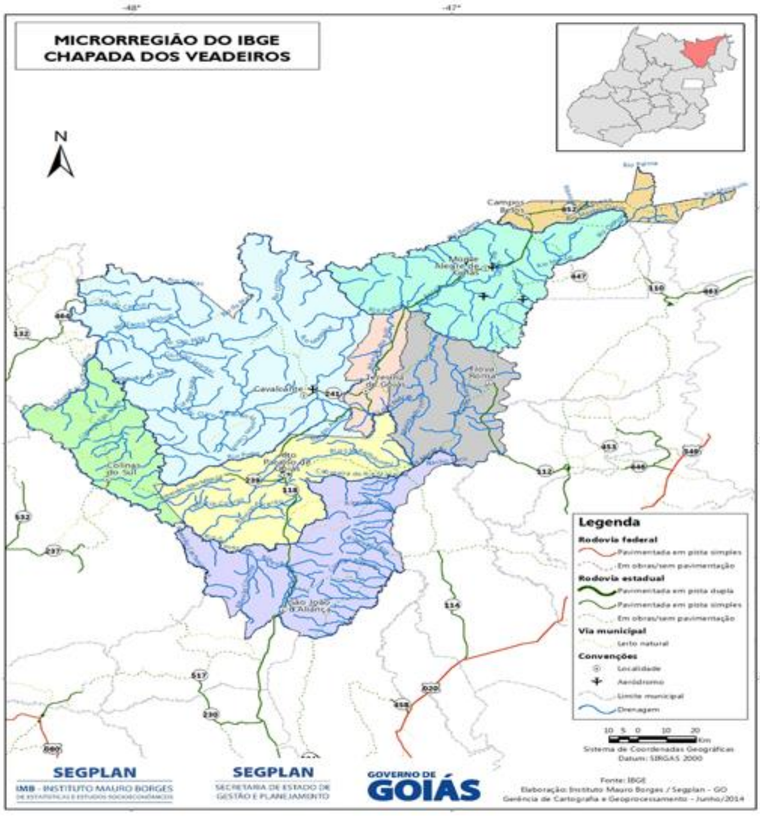

Figure 1. Map of the Chapada dos Veadeiros Territory. Fonte: IBGE/2010.

The participation of family farming in Brazil in food production and, increasingly, growing in importance with regard to its social dimension and market share. However, this participation can take on different expressions, which can be geared towards serving agro-industries. However, the strengthening of these local productive arrangements, developed by family farming, has been challenged by the market that requires processes based on well-developed management and marketing strategy.

This knowledge to be inserted in family farming has the support of technical assistance, educational training projects, among other actions. In the context of the Cerrado of Chapada dos Veadeiros in the northeastern region of the state of Goiás, which is often afflicted, for a long period of drought, productive diversification through the resources of local biodiversity must be seen as strategic in maintaining food security for family farmers, as well as guaranteeing an alternative income. Based on this assumption, the objective of this project is to evaluate the market and marketing strategies that can be used by extractive production, as a sustainable social, economic, ecological and cultural productive alternative for family-based producers in this region.

MATERIAL AND METHODS

The so-called “Green Revolution” disseminated in the State of Goiás between the 1960s and 1970s, is configured mainly by the incentive to great production, but it brought in its baggage a discourse of occupation and preservation of the cerrado. However, this large production, which predominantly reaches the central-southern part of the state, has advanced quickly and efficiently in the degradation of important ecosystems, and the cerrado, vegetation that predominates in the state, is today, about 50 years later, with about 60% devastated.

Of the approximately 40% of preserved vegetation in the cerrado biome, most are in the Chapada dos Veadeiros region which houses the Chapada dos Veadeiros National Park, considered a world natural heritage, protected by Decree No. 5,419, of May 7, 2001, from Government of the State of Goiás, which created the Environmental Protection Area - APA in Pouso Alto.

Chapada dos Veadeiros, currently has the advancement of an employer model of agriculture, being a risk for the traditional production model and for preserving the environment. Traditional agriculture becomes important in the context of sustainability as it establishes agricultural practices that go hand in hand with the environmental and cultural preservation of the communities in which it operates.

Thus, environmental sustainability, especially for traditional communities, has developed through ethical behaviors, in their cultural aspects, maintaining a concern for the conservation and preservation of life and the environment. Sustainability is a process that implies a social and economic adjustment with methods and techniques, so that nature meets the basic needs of the community.

Traditional communities are characterized by the diversity of their productive activities, an attribute that ensures their survival, as long as this productive diversity is related to the pattern of needs and resources available in the place.

In these communities, the substitution of the traditional model for the culture of cattle is growing, or even the abandonment of cultivation for a significant dependence on agro-industrial products, which can lead to an increasing degradation of the environment and cultural of these communities.

In view of the demand from consumers concerned with consuming healthy food, which is constantly growing, it is necessary that the marketing of these items be effective and reach the latent market share. On the other hand, competition and the choice of distribution channels represent a challenge for family producers.

Family agricultural organizations, especially those that are extractivists, suffer from the low volume of labor, which ends up overloading the family nucleus when carrying out production-oriented tasks, leaving little time and even little willingness to plan and control the products. marketing processes.

In this way, this research aims to elaborate a survey of these communities by means of exploratory and ethnographic research, with the objective of mapping the producers and commercial practices of these family agricultural organizations. That said, the research intends to answer the following question: How does the strategic planning, focused on commercialization, of family farmers and traditional communities in the Chapada dos Veadeiros Microregion in the Northeast of the State of Goiás, for the insertion and maintenance of their products of the land and local biodiversity in the consumer market?

RESULTS AND DISCUSSIONS

The articulation of small capital companies around arrangements and local productive systems (APLs) has been an important factor supporting the development of this segment of companies. The productive arrangements developed are a tool for industrial growth in the region. Strategies that are based on the development of Local Productive Arrangements or Systems have been the basis of many public policies for regional and local development in Brazil. One of these programs supported by the federal government is the Local Productive Arrangement (APLs), linked to the Ministry of Science and Technology (AMARAL FILHO et al., 2002).

According to SEBRAE (2017), the definition and dimensions of local productive arrangements (APL) are as follows:

The Local Productive Arrangement is an agglomeration of companies, located in the same territory, which have productive specialization and maintain links of articulation, interaction, cooperation and learning among themselves and with other local actors, such as: government, business associations, institutions of credit, teaching and research. The main dimensions of an APL are: the territorial dimension (the actors of the APL are located in a certain area where interaction occurs); the diversity of activities and actors (entrepreneurs, unions, government, educational institutions, research and development institutions, NGOs, financial and support institutions); tacit knowledge (knowledge acquired and passed on through interaction, uncoded knowledge); the innovations and interactive learning (innovations and learning that arise based on the interaction of the actors); and governance (leadership of the APL, usually exercised by entrepreneurs or by their representative group - unions, associations) (SEBRAE, 2017).

The arrangement has its own original, economic and socio-cultural characteristics that will guide the process of analyzing market strategy. In this sense, the strategy of market analysis of the productive arrangement of the biodiversity of the cerrado enables an analysis of the internal and external environments aimed at this market, providing important definitions in decision making aimed at this segment. That will guide sustainable, social and economic development aimed at this production.

CONCLUSIONS

The research, still in the development stage, whose objective is to identify the economic potentialities in the value chain of products and services, based on extraction, in the Chapada dos Veadeiros Microregion in the northeast of the state of Goiás, as well as the insertion of family farmers in a productive structure that provides them with competitive advantages. We believe that this study, based on the identification of niche markets already related to them, through exploratory and ethnographic research, by identifying the practices and strategies of commercialization already existing in the Chapada dos Veadeiros Microregion will provide local communities with access to information on segments of markets with economic potential that can be exploited by them.

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ECONOMIC RESULTS OF CROP-LIVESTOCK INTEGRATION SYSTEM DURING THREE YEARS IN A RURAL PROPERTY OF GOIAS, BRAZIL

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ABSTRACT

This research aimed to evaluate the economic results of the Crop-Livestock integration system (CLI) implemented during three years in a rural property in the state of Goiás, Brazil. Real economic and financial data of the property were collected, obtaining data from the operational activity, costs and revenues of the productive activities involved. This information was organized in cash flow, which allowed to perform economic analysis (MARR, NPV, BCR, IRR, Profitability), since the implantation of the project, until the commercialization of the products. The result of the 3 years of CLI demonstrated economic viability, with IRR greater than MARR and a positive NPV. The BCR indicator of the 3 years resulted in R$1.93 (nominal balance corrected at 6% p.a.), that is, the 3 years of CLI resulted in an average benefit of R$1.93 for each R$1.00 invested. The economic viability is not an attribute of the CLI, but a situation of the conjuncture to which it is associated, the characteristics of the property, the technical coefficients associated with the management of the components and the region in which it is inserted.

Key words: crop-livestock integration system; economic evaluation; beef cattle

INTRODUCTION

Agricultural production models based on monocultures are being rethought worldwide, either by selection of pests, diseases, weeds that increasingly adapt to the main crop cycle and still present the minimum profit margin to the producer due to the high use of inputs that impact the cost of production. Several technologies have been proposed and developed to increase the sustainability of production systems in the various Brazilian biomes. Among the most prominent researches is the CLI, for being a technological model of integrated production system and that presents as an alternative the optimization of agricultural resources (PRADO, 2011). Crop-livestock integration (CLI) is an agricultural production system that consists of integrating grain production and livestock in order to intensify land use obtaining reciprocal benefits for both productive segments. In this sense, integrated production systems have been seen as an environmentally sustainable and economically viable intensified production alternative (DOMINSCHEK et al., 2018).

To be considered productive, profitable and sustainable, it is essential to plan the management of the different components of the system according to the characteristics of each rural property. The economic viability of integrated systems is linked to some basic fundamentals: optimization of production resources immobilized in the farm, synergy between crop and animal production activities, revenue diversification through the production and sale of grains, meat, milk, biofuel, fibers, and wood; reduction of total costs due to better use of production infrastructure and lower demand for agricultural inputs (BALBINO et al., 2011), occupy a prominent position when the objective is to make viable the agricultural and livestock activity, in the economic aspect, mainly by reducing risks with the diversification of activities and better cash flow balance, besides allowing a more rational use of inputs, machinery and labor of the property (DEBORTOLI, 2017).

The measurement and management of production costs are essential factors for the implementation, maintenance and continuity of CLI on farms. For a technology to be accepted by the market it must be technically feasible, this technology has to be able to provide a sufficiently attractive financial return for those who are going to make it part of the productive system of the farm. In other words, being economically viable is a necessary condition for a technology to be widely adopted (Possamai, 2017). Even though integration systems are shown as a promising strategy for increasing productivity and optimizing land use, the lack of economic results is often an obstacle to the adoption of these systems (REIS et al., 2019).

The economic feasibility can be evaluated by building a Cash Flow and, from it, building feasibility and profitability indicators (PRADO, 2011): Minimum Attractive Rate of Return (MARR) also called opportunity cost or discount rate, is a rate of return that represents the minimum that an investor proposes to earn when making an investment; Net Present Value (NPV) according to Gitman (2004), is the result of the difference between the value of cash flows brought to the initial period and the value of the investment; The Internal Rate of Return (IRR) is the rate required to match the value of an investment (present value) with their respective future returns or cash balances; Return is the relationship of the value of profit with the amount of sales; Profitability is a measure of the return on an investment by dividing the profit obtained by the value of the initial investment. Profitability can be said to be the amount of money the investor earns for each amount invested (PRADO, 2011); The Benefit Cost Ratio (BCR) is the comparison between the benefit (revenues) and the cost of any given investment (BARROS, 2008). The BCR ratio tells whether the net revenues at present value are greater than, equal to, or less than the initial investment.

This research aimed to evaluate the economic results of the Crop-Livestock integration system (CLI) implemented during three years in a rural property in the state of Goiás. Thus, an economic vision of the CLI system was sought, enabling reflection on its advantages and disadvantages for the rural producer, providing him with more information for decision making about the adoption of this system.

MATERIAL AND METHODS

The research was conducted by collecting information regarding the administrative and financial activities of a property located in the municipality of Palmeiras de Goiás, Goiás, Brazil, which implemented the CLI system, in an area of 45 hectares. The soil texture is clay-sandy, the average annual rainfall is 1457 mm, and the months with the heaviest rainfall are from November to February. Therefore, the research was conducted in real conditions, under administrative and edaphoclimatic conditions, effectively occurred.

Implementation of the CLI system

To implement the system, the property evaluated its natural, human, and financial resources and opted for the planting of summer corn intercropped with the grass *Urochloa brizantha*, and after the corn harvest the animals already present in other areas of the property start grazing. The property is 16 km away from the city, which would facilitate the logistics to commercialize the grains in the local warehouses. At the tactical and operational level of the property it was decided to outsource the machinery and labor, this decision was made by calculating the depreciation (CANZIANI; DOSSA, 2000 cited by BARROS, 2008). After budgeting the inputs and other resources demanded for the system (Table 1) the administration of the property concluded that it was possible to use the own capital, not being necessary for the investment to seek another source, avoiding the payment of interest. With the outsourcing of labor and those responsible for mechanization, a schedule of planting, covering, spraying and harvesting activities was assembled according to the stage of the culture and monitoring. In the budget and planning, the expected revenue from the grain harvest is on average a production of 105 bags/ha of 60kg, considering the fertility of the soil, the productive potential of the chosen material, and the level of technology employed. Another expected revenue is the weight gain of the animals that will graze the area after the harvest. For livestock, in arrobas of meat (@) considering the commercial @ (15 kg). For cattle ranching, the acquisition value of the animal in @ is discounted, considering only productivity. With the expected gross margin, the implementation of the system on the property for the 2017/18 agricultural year was conffirmed.

Tabela 1. Budget* to evaluate CLI implementation and projected revenues.

SPECIFICATIONS / COSTS			
Outsourced Services			
A- Services	**Value Alqueire (4.84ha**) 45ha = 9.29 Alq.**	**Quantity**	**Total**
Liming / harrowing	R$ 80.00	3	R$ 2,229.60
Planting	R$ 600.00	1	R$ 5,574.00
Post-emergence spraying / fungicide and insecticide	R$ 100.00	2	R$ 1,858.00
Covering fertilization	R$ 120.00	1	R$ 1,114.80
Harvest	R$ 750.00	1	R$ 6,967.50
Diesel	R$ 3.44 /L	860 L	R$ 2,960.00
		Total	**R$ 20,703.90**
B- Inputs			
Product	**Quantity**	**Total R$**	
Herbicides			
Post-emergent herbicide specific for corn	180 L	R$ 800.00	
pH Reducer / Vegetable Oil	30 L	R$ 100.00	
Fungicide			
Thiophanate-methyl	35 kg	R$ 1,754.00	
Seed treatment			
Systemic insecticide from the chemical group of neonicotinoids and oxime methylcarbamate specific for seed treatment.	16 kg	R$ 1,500.00	
Graphite	5 kg	R$ 50.00	
Insecticide			
Teflubenzurom	40 L	R$ 600.00	
Seeds			
Corn (Powercore™ Ultra)	50 bags	R$ 25,250.00	
Forage (*Urochloa brizantha*)	360 kg	R$ 600.00	
Fertilizers			
04-30-10 + ZN	17.6 t	R$ 24,640.00	
30-00-20 + ZN	7.5 t	R$ 12,950.00	
Ammonium Sulfate	6.6 t	R$ 7,656.00	
Cattle ranching operational cost			
75@	R$ 91,00/@	R$ 6,825.00	
Extras			
Soil analysis	2	R$ 120.00	
Meals	15	R$ 150.00	
	B- Total	R$ 82.995.00	
	C- TOTAL (A + B)	**R$ 103,698.90**	
	Total Expenses/ha	**R$ 2,304.42**	
SPECIFICATION / EXPECTED REVENUES			
Crop	**R$/un. Saca 60 kg**	**Value (R$)**	
Expected production 105 bags/ha	R$ 40.00****	R$ 189,000.00	
Cattle Raising ***	**R$/@**	**Value (R$)**	
75 @	R$ 131.00	R$ 9,825.00	
	D- Total Revenues	R$ 198,825.00	
	Total revenue/ha	R$ 4,418.33	
	Gross profit (D – C)	**R$ 95,126.10**	

*Quotation made in the year 2017. **Value Alqueire (4.84 ha), measure of land commonly used in the State of Goiás and by service providers to establish the value of the service. ***Total weight gain of the lot of rearing animals in the period of use of the area. ****Value of future contracts in 2018. Source: The authors.

Economic indicators

The absorption costing system was used, because it treats the accumulation of costs in a simplified way, determining all direct, indirect, fixed and variable production costs of the operational structure so that they are absorbed by the CLI. The System was implemented in the property in the agricultural year between the month of October 2017 until September 2018, which is when one year of integration ended, the animals were removed and preparations for planting the next crop began, Year 2 (2018/19) and the same way Year 3 (2019/20), the data of production costs and revenues were tabulated in spreadsheets (MS-Excel®), called 'Costs x Revenues', specifying the agricultural year of the facts. These data were worked out of the whole system occurred by agricultural year in order to facilitate the visualization of the totals of the implemented CLI.

To calculate input costs, we considered the disbursement for seeds, chemicals and correctives. For the Costs of Operations, we considered the disbursements with machinery rental (outsourcing of services, including equipment, labor, fuel, maintenance, depreciation and others) to perform liming, harrowing, fertilizing, spraying, planting, harvesting, transport services (freight) and technical assistance.

In relation to taxation, the Fund for the Protection of the Rural Worker (Funrural) rate of 2.1% on gross revenue and the National Rural Learning Service (Senar) rate of 0.2% on gross revenue were considered.

The MARR used was 6% per year, average of the Selic Rate in agricultural years (CENTRAL BANK OF BRAZIL, 2021). MARR, BCR, NPV and IRR were calculated according to (BARROS, 2008), and these calculations were made with the help of MS-Excel®. Gross Margin, Net Margin, Profitability and Profitability according to (PRADO, 2011).

RESULTS AND DISCUSSIONS

The execution of the previous budget with the schedule of each activity was crucial for the financial planning of outputs throughout the agricultural year. The results presented are positive for the property and this is due to the planning prior to the implementation of CLI each agricultural year and technical assistance. From the choice of the appropriate corn material for the integration with grass, fertilization of crops associated with pasture, purchase of inputs and sale of grains, moment of animal entry, stocking, and several other factors that should be planned for both crops and animal component together, seeking the integrated and cyclical productive efficiency. Corroborates with Possamai (2017), although the economic feasibility analysis of a project is a fundamental step for its implementation and continuity, the calculation of feasibility indicators is not a trivial process. The characteristics of a property and the associated technical coefficients and the region in which it is inserted for example the market, supply of the inputs and demand for the product. Economic viability is not an attribute of a technology, but a situation of the conjuncture it is associated with.

The result of the 3 years of CLI demonstrated economic viability, with IRR greater than MARR and positive NPV; the idea behind the NPV, is that if the total revenues exceed the total costs of implementing the project, then it can be said that it is economically viable. The CLI system of the property generated a NPV of R$ 298,410.91 at the end of 3 years (Table 2), in other words, this value represents a difference between revenues and payments at the end of the CLI corrected at 6% per annum. The BCR indicator of the 3 years resulted in R$1.93 (nominal balance corrected at 6% p.a.), that is, the 3 years of CLI resulted in an average benefit of R$1.93 for each R$1.00 invested.

In the third year the indicators BCR, Profitability and Profitability were lower, due to higher expenses with inputs and operational expenses to control the attack of Spodoptera complex caterpillars in corn, in this agricultural year the hydric volume was low, influencing the formation of pasture, consequently it was necessary to increase the supplementation for the animals, factors that directly influenced the production costs affecting profitability. Observed that inputs and operational costs were shared between forage and corn. Crop-livestock integration shows economic gains compared to conventional systems, which can be explained by the dilution of fixed costs and the presence of sharable inputs, which result in savings (MENDONÇA et al., 2020).

Table 2. Costs x revenues, economic and financial result.

Recipes	**Year 1**	**Year 2**	**Year 3**
Grains	R$ 218,700.00	R$ 207,900.00	R$ 208,800.00
Gain R$/@	R$ 9,825.00	R$ 10,650.00	R$ 11,250.00
(a) Total Revenues	R$ 228,525.00	R$ 218,550.00	R$ 220,050.00
Costs			
Inputs Corn/Forage	R$ 70,559.96	R$ 78,721.52	R$ 78,960.00
Livestock (Animals)	R$ 6,825.00	R$ 7,630.50	R$ 9,980.25
(b) Total input costs	R$ 77,384.96	R$ 86,352.02	R$ 88,940.25
Operations Costs	R$ 26,130.48	R$ 25,200.00	R$ 25,782.40
Tributes	R$ 5,256.08	R$ 5,026.65	R$ 5,061.15
(c) Total Costs	R$ 103,515.44	R$ 111,552.02	R$ 114,722.65
(d) Total Costs + Taxes	R$ 108,771.52	R$ 116,578.67	R$ 119,783.80
(e) Gross Margin (a-c)	R$ 125,009.56	R$ 106,997.98	R$ 105,327.35
(f) Net Margin (a-d)	R$ 119,753.49	R$ 101,971.33	R$ 100,266.20
BCR (a÷c)	R$ 2.10	R$ 1.87	R$ 1.84
Profitability (f ÷ d)	110%	87%	84%
Return (f ÷ a)	52%	47%	46%
NPV			R$ 298,410.91
IRR			49.01%

Source: The authors.

CONCLUSIONS

The study of the system provided an economic view of CLI and allowed reflection on its advantages and disadvantages for the rural producer, providing him with more information for analysis and decision making about its adoption. The economic viability is not an attribute of the system, but a situation of the conjuncture to which it is associated, the characteristics of the property, the technical coefficients associated with the management of the components and the region where it is inserted, for example the market, supply of inputs and demand for the product.

The positive results were greatly affected by the use of equity capital, avoiding the cost of interest on capital, which exposes the need for rural properties to be managed as rural enterprises so that they can have this power of choice and freedom with the investments, financial and technical planning are crucial for the rural activity of CLI.

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CAN CROP-LIVESTOCK INTEGRATED SYSTEMS REDUCE SALE PRICE RISK OF AGRICULTURAL PRODUCTS?

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ABSTRACT

The crop-livestock integrated system (CLIS) comprehends the cash/cover crops rotation and/or succession with grazing periods. Thus, the system has different income sources and one of the challenges is to find the best mix of products for each region. Sometimes, it is claimed that CLIS decrease the economic risk due the higher number of products commercialized. However, if an increase or decrease in the market price of one product reflects directly in the price of other product, the reduction in economic risk may not be so relevant. Therefore, the aim of this work was to evaluate the correlation between the market prices of beef, corn, soybean and milk. We used a historical database from the Center for Advanced Studies in Applied Economics (CEPEA). The statistical analyses of correlation and principal components were performed in R software. The price of the products had high and positive correlations (>.70). There is small reduction in price risk in simultaneous production of these four products, because, when the price of a product decrease, the others decrease at the same pace. If it is necessary to choose two between the four products, the best choice is corn with one of the others.

Key words: Soybean; Milk; Beef

INTRODUCTION

Crop-livestock integrated system (CLIS) represents the cultivation of cash crops, beef and milk cattle grazing in the same land, in rotation and/or succession (MENDONÇA et al., 2018). The design of CLIS depends on particularities of the region and the farm, adjusting to soil and climatic conditions and farmer experience. The diversification of agricultural activities and products is highlighted as one of the CLIS benefits, due a better equilibrium of income throughout the year. CLIS promotes the association of livestock, which has a more stable income, with cash crops, which normally has a higher profitability. Moreover, these systems are related with high nutrient efficiency and lower diseases and weeds (ALVARENGA et al., 2016).

The combination of different cash crops can reduce the economic risk, as if one crop has a good yield and market price can compensate some frustration in other crops (AMBROSI, 2001). Moreover, CLIS with different crops promotes income in different times of the year (MARQUES & SÃO JOÃO, 2015). However, economic risks are only really reduced if the farm products did not have high correlation, i.e. when a price drop of one product affects directly in the price of other product. Thus, the objective of this study was to evaluate the historic correlation between commodities prices (beef cattle, corn, soybean and milk), which are the main products in CLIS nowadays in Brazil.

MATERIAL AND METHODS

Quotation of the products (milk, beef, corn and soybeans) were collected from the database of Center of Advanced Studies in Applied Economics (Centro de Estudos Avançados em Economia Aplicada - CEPEA). The CEPEA website (https://www.cepea.esalq.usp.br/br) was accessed in November 25th 2019, accessing the free available data. Beef had quotation based on Brazilian real (BRL) per 15 kg of carcass. The quotation is a daily average of the prices in São Paulo State. Corn quotations (BRL per bags of 60 kg) were obtained based on prices index of ESALQ/BM&FBOVESPA, which considers average price of yellow corn, type 2, in standard good conditions. Soybean quotations (BRL per bags of 60 kg) were based on ESALQ/BM&F BOVESPA index, which is an average of soybeans commercialized in Paranaguá port. The soybean index is based on soybean in bulk of exportation type. Corn, soybean and beef had daily records, for further analyses, the month price averages were calculated.

Milk quotations were available at a monthly basis, recording: minimal crude price, mean crude price, minimal net price, mean net price and maximum net price. The mean net price represents the mean value received by the farm, without tax and transportation costs. Thus, it was used in the statistical analyses. Market prices of these four products from January of 2006 until November of 2019 were used in statistical analyses, therefore we used data of the last 13 years.

Pearson correlations were calculated using the “rcorr” function of the “Hmisc” package (FRANK, 2020) in software R. Principal components analyses were carried out using "FactoMineR" (Sebastien, 2008) and "factoextra"(ALBOUKADEL and FABIAN, 2020) packages in software R (R CORE TEAM, 2019). The graphs were plotted using "ggplot2" (WICKHAM, 2016) package in software R.

RESULTS AND DISCUSSIONS

The price time series are shown in Figure 1. Nominal prices increase through the last 13 years. In 2012, there was a drought in United States of America, Argentine and Brazil, promoting significant losses in production and consequently prices increased, especially for soybeans (BLUNDEN; ARNDT, 2013). Another important event during this period happened in 2016 with an extreme climatic event (*El niño*) impairing soybean and corn production in South America. The time series shows the consequences in milk prices in 2016.

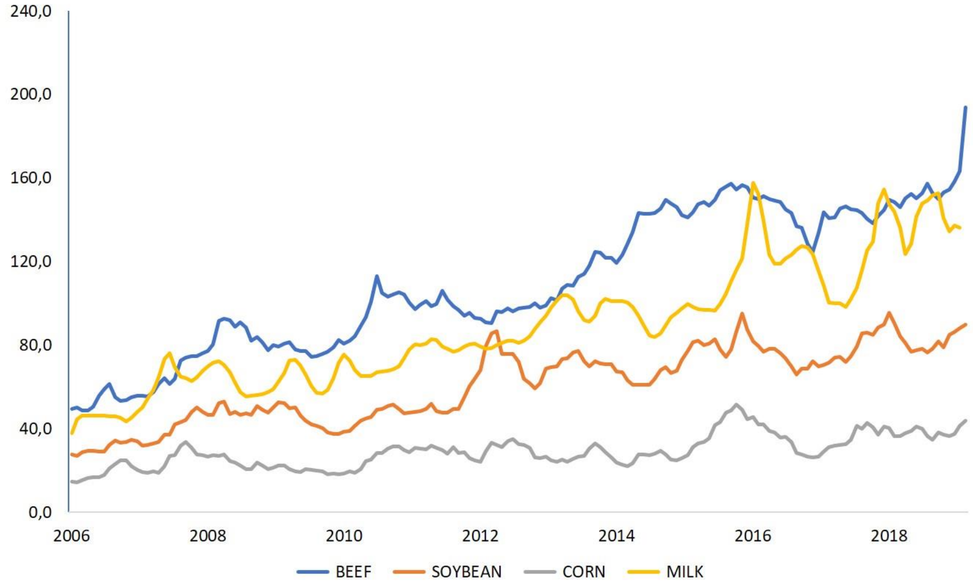

Figure 1. Beef, soybean, corn and milk (x100) quotations from 2006 to 2019 according to CEPEA database.

Pearson correlation, also known as product-moment correlation, measure the relationship between two variables at one -1 to 1 scale. A correlation close to one means strong positive correlation, which means that one increase or decrease in one variable corresponds to a proportional increase or decrease in the other variable. Negative correlation means strong negative correlation, which means that the variables are inversely related. If the coefficient equals zero means that variables did not correlate (GUIDINI et al., 2012). The prices of the four products had a high positive correlation, higher than 0.7 for all products.

Principal components analysis (PCA) indicated a strong relationship between the price of the products (Figure 2). First dimension explained 86.3% of the variance and all variables grouped together in this dimension. Second dimension explained only 6.9% of the variance. At this dimension, corn segregates form the others. Therefore, corn prices vary slightly different from the price of the other products. Therefore, if it is necessary to choose two products for design a production system between the four, the best combination would be corn with any other production. This result is remarkably interesting, as reinforces the reason to the extensive use of soybean-corn succession in Central Brazil (GIAMCHINI et al., 2017). Probably, the farmers identified this slight increase in economic equilibrium due the commercialization of two products through the year.

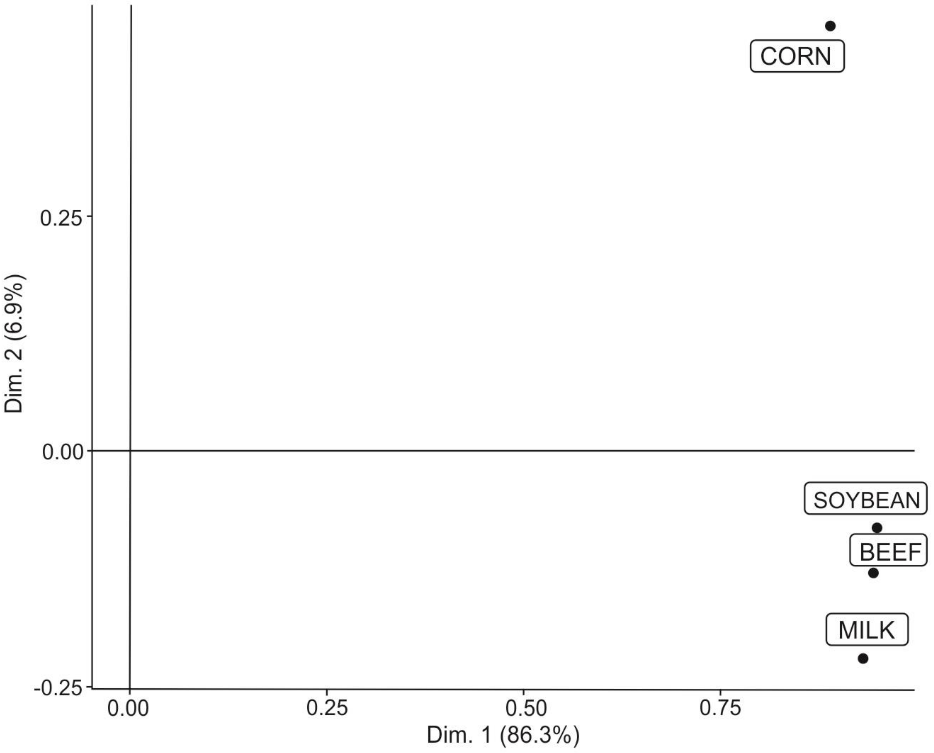

Figure 2. Plot of the first two dimensions of principal component analysis with the price of beef, soybean, corn and milk from 2006 to 2019.

Santos et al. (2017) observed that a variation in corn and soybean prices led to changes in beef prices, as the two products are used as feed for ruminants. These results reinforce our observations here. Therefore, these products have interlinked markets.

CONCLUSIONS

Milk, soybean, corn, and beef area highly positive correlated. Therefore, crop-livestock systems based on these products did not have a significant decrease in price risk. It is important to design systems with other cash crops and other livestock species, looking for the benefits of income diversification and economic stability.

If it is necessary to choose between these products to design a CLIS, the best combination is corn with any other product. Therefore, this study highlights the need of further economic studies aimed to help the design of production systems with higher economic stability.

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TECHNOLOGY TRANSFER OF THE INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS FOR RANCHERS IN THE MUNICIPALITY OF PINDARÉ - MIRIM, MARANHÃO

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ABSTRACT

With this work we aimed to evaluate the perception and adoption of the technology of integrated crop-livestock-forestry (ICLF) in four farms in the municipality of Pindaré-Mirim, Maranhão. We used different tools such as: Organizational Matrix or Strengths, Opportunities, Weaknesses and Threats (SWOT) and Technological Reference Unit (TRU), Visits, Contacts and Informal Interviews, which were used to sensitize, implement and accompany the ranchers. Through the use of rural extension tools, it was possible to achieve success in raising the awareness of four ranchers who adhered to the ICLF systems and to the monoculture system to plant corn. The adoption of ICLF system by Alto Verde and Muniz farms has met the expectations of ranchers, as this sustainable production model is a strategic alternative that provided higher productivity than the conventional corn monoculture system carried out on the Mãe Rainha and Feitosa farms.

Key words: Low Carbon Emission; Sustainable production system; Degraded pasture

INTRODUCTION

The region of the Legal Amazon in the Maranhão state has stood out for the insertion of high-tech agriculture and pasture areas for beef cattle production, with positive impacts in the region in the short and medium term; and reduction of the productive potential of the land in the medium and long term (JÚNIOR et al., 2015). Based on this aspect, livestock has been one of the main points of discussion regarding the use of sustainable practices in the Amazon region.

Pasture areas with different stages of degradation, in 2010, occupied 22.73% of the territory of the Legal Amazon in the Maranhão state (INPE, 2011). This is since there is a predominance of extensive livestock and the incipient use of advanced technologies in the region.

An interesting alternative to contribute to the economic, social and environmental sustainability of the livestock production in the region is the use of the integrated Crop-Livestock-Forestry (ICLF) System, due to its characteristics of encouraging the diversification of cultures and activities on the farms, potential for preservation of the environment and increase in the original productive activity, among other technologies (NOCE, 2017).

For this reason, ICLF systems has been adopted throughout the Brazil, in its different combinations with a tendency to expand, due to the advancement of research and Technology Transfer (TT) actions. Therefore, TT Programs of ICLF need to consider the complexity of these systems in order to effectively be successful (DOMIT et al., 2015), through participatory methods that enable a better understanding of the political, social, economic, environmental and cultural dimensions of communities and the municipalities (VIONE, 2002).

Based on the knowledge of the intrinsic characteristics of the municipalities and properties in a particular way, it will be possible to make use of strategies that can enable the sequential expansion of ICLF systems in the Maranhão state and thus insert it into a panorama of profitable and sustainable production. Based on this assumption, we aimed to promote the transfer of the ICLF technology to ranchers in the municipality of Pindaré-Mirim, in the Amazon region of Maranhão state.

MATERIAL AND METHODS

Technological Reference Unit (TRU) of the ICLF, one of the methodological extension tools, was implemented in 2016 with a partnership between the Muniz farm, Embrapa, BASA, SENAR, SAGRIMA and the ICLF Network Association. Four beef cattle ranching properties located in the municipality of Pindaré-Mirim were monitored. The TRU of the ICLF system was implemented in February 2016, dimensioned in three and a half hectares, destined to the consortium between hybrid corn (KWS 9304), *Brachiaria brizantha* cv. Marandu pasture and Eucalyptus (*Eucalyptus eucalyptus*). The selection of participating properties considered the pre-elaborated evaluation criteria and methodologies, which were: (1) having degraded pasture and proximity to the TRU of the ICLF, through technical visits; (2) the farmer's commitment and autonomy, through an informal interview; (3) physical structure of the farm, through technical visits; and (4) availability of financial resources, through an informal interview. Thus, four farms were selected, namely: Alto Verde, Muniz, Feitosa and Mãe Rainha. However, only the Alto Verde and Muniz farms adhered to the integrated systems with integrated Crop-Livestock (ICL) and ICLF modalities, respectively. At the Alto Verde farm, 10 hectares were allocated to the implementation of the ICL system, with the consortium between hybrid corn (KWS 9304, to produce grain) and pasture with Dictyoneura grass (*Brachiaria humidicola* cv. Llanero), which after a year of its implantation, it was used to beef cattle grazing, the main activity of the farm. For Muniz farm, 3.5 ha were allocated to the implementation of the ICLF system, with hybrid corn (KWS 9304 and AG1051, to produce grains and green corn, respectively) brachiaria grass (*Brachiaria brizantha* cv. Marandu) and eucalyptus. The area was implemented in February 2016. On the other hand, the Feitosa and Mãe Rainha farms opted for conventional corn cultivation using monoculture system, in which 1 ha was used to plant the hybrid corn (KWS 9304 to produce grain) and 4 ha was used to plant RG-03 corn (to produce green corn). Previously, the individual diagnosis of each selected farm was used, through the Organizational Matrix or SWOT (Strengths, Opportunities, Weaknesses and Threats), based on its external and internal aspects that contributed or hindered the performance of its activities. SWOT was built singly with each farmer, where he described, from his point of view, the factors inherent to his farm (VERDEJO, 2006). To accompany the ranchers selected in the project, visit and contact methodologies were used (LOPES, 2016; RAMOS, 2013). The visits were made weekly to the properties, through: technical visits, to provide information, guidance and evaluate the project viability; visits on the farm field, and dynamism visits, to raise awareness, motivate, plan, attend and evaluate actions developed by ranchers (LOPES, 2016). Another TT tool used was contact (LOPES, 2016), which took place through the exchange of orientations and information with ranchers, taking place in person, by telephone, internet, in writing. Thus, it was up to the ranchers, the initiative to establish contact, to solve any doubts that might arise with the planning and / or implementation of the systems in the farms.

RESULTS AND DISCUSSIONS

According to the SWOT Matrix, strongholds represent the strongest internal factors of the property. On the other hand, weaknesses are the internal factors that negatively influence the property performance, so they must be eliminated. As for external factors, opportunities are the forces that positively influence the performance of the corporation. In this sense, the rancher must use these opportunities to his advantage and to his benefit. However, the threats have a negative influence on the organizational performance of the properties, however over a situation that these properties do not exercise control, with this they must be avoided. With regard to strongholds (Table 1), product diversification was considered an economic strategy for ranchers, as it made possible, in addition to the cultivation of pasture to feed the herd, the guarantee of greater autonomy in the manufacture of energetical concentrate, based on corn, used as supplement to the herd. The corn and pasture consortium promotes mutual benefit between agricultural and livestock activities, making the best use of the property's useful area, formerly occupied only by pasture monoculture. Another strong point observed was the collective purchase, with the acquisition of inputs at low cost, greater bargaining power and purchase in large volume. The low cost of implementing the corn crop was mentioned as a fortress, taking into account the non-requirement of the crop in high initial investments when compared to the implementation of the ICLF system in the Alto Verde and Muniz properties. The collective use of implements and machines to implant the areas was essential for conducting activities on the properties, sharing machinery for preparing the soil, planting and fertilizing. Among the weaknesses, the lack of planning affects the organizational process of the properties, considering that this factor is of fundamental importance for a good performance of the activities on the properties, because through it that the ranchers is able to organize the data referring to the whole process that will be run on the farm. The degraded pastures contribute to the unsustainability of the activity, since the fall in grass productivity and the low animal support capacity no longer meet the requirements of the herd. On the other hand, this problem was corrected with the adoption of ICLF system, which allowed the maintenance of soil and pasture quality as well as the diversification of agricultural and livestock activities through the mutual benefits between them. The deficiency in the rural technical assistance made the performance of agricultural activities on the farms unsafe and, in most cases, led to the failure of the results expected by the rancher. The poor conditions of the internal roads made it difficult for inputs and production to flow.

Table 1. Organizational matrix of the productive activity of the four properties monitored in the municipality of Pindaré-Mirim, Maranhão. (1-Alto Verde Farm; 2-Muniz Farm; 3-Feitosa Farm; 4-Mãe Rainha Farm).

STRENGTHS	**OPORTUNITIES**
• Product diversification (corn and pasture): 1, 2; • Collective purchase of inputs: 1, 2, 3, 4; • Internal feed production: 1, 4; • Low cost of implementation: 3, 4; • Collective use of machines and implements: 1, 2, 3, 4; • Dedication to the activities: 1, 2, 3, 4.	• Sale of surplus production: 1, 2, 3, 4; • Access to new technology: 1, 3, 4; • Cattle slaughterhouse in the region: 1, 2, 3, 4.
WEAKNESSES	**THREATS**
• Lack of planning: 3, 4; • Predominance of degraded pastures: 1, 2, 3, 4; • Deficiency in rural technical assistance: 1, 3, 4; • Poor conditions on internal roads: 1, 2, 3, 4.	• Market price fluctuation: 1, 2, 3, 4; • Shortage of labor: 1, 2, 3, 4; • Large number of competitors (many producers): 1, 2, 3, 4.

In relation to opportunities (Table 1), the sale of the surplus farm productivity was a strategy in which the rancher sold his production and guaranteed an alternative income for the properties. In addition, the cattle slaughterhouses present in the region were another opportunity considering the reasonable scale of beef production. The new technologies also allow a change in the model of execution of the activities employed in the area. With regard to threats, the scarcity of labor, price and market competitors was noteworthy. In relation to market prices, these can be considered risk factors, as they undergo fluctuations that result in the success or failure of sales. The scarcity of labor weakens the production sector and thereby eliminates the possibilities of the productive potential of farms. Taking into account the market competitors, it was realized that the greater the competition, the greater the difficulties in selling products, considering unfair competition in this sector.

CONCLUSIONS

Through the tools used, it was possible to achieve success in raising the awareness of ranchers who adhered to the integrated systems (ICL and ICLF) and to the monoculture of corn. The adoption integrated systems by Alto Verde and Muniz farms has met the expectations of ranchers, as this sustainable production system is a strategic alternative that provided higher productivity than the conventional corn monoculture system carried out on the Mãe Rainha and Feitosa farms.

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ECONOMIC VIABILITY OF THE LOW CARBON BRAZILIAN BEEF UNDER MARKET RISKS

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ABSTRACT

The integrated crop-livestock systems (ICL) are alternatives to reduce GHG emissions, while increasing beef and crops production. In particular, the economic viability of new Low Carbon Brazilian Beef (LCBB) protocol remains to be proved for farmers to adopt it. The aim of this study was to analyze the economic viability of the LCBB protocol from an ICL system, under market risks, considering an alternative monetization for the protocol and various scenarios of input and output prices. A deterministic and a stochastic investment analysis was carried out using Monte Carlo simulation from @ Risk®, varying beef, soybean, urea and NPK fertilizer prices. ICL, with and without the LCBB protocol, was economically viable and presented very low market risks, given the past ten years of prices. In general, output prices were most influential on the Present Net Value. LCBB protocol improves the financial results, but implementation and running costs of the certification process must be cautiously established for the protocol to remain economically attractive to farmers.

Key words: Integrated Farming Systems; Investment analysis; Risk analysis

INTRODUCTION

The growing world demand for food, fibers and energy has created opportunities for the expansion of Brazilian agricultural products in the international market and, simultaneously, raised questions about their environmental impacts. Despite the undeniable evolution of beef productivity, with the introduction land-saving technologies, the beef sector has been challenged to adopt more sustainable production systems. Commitments made by Brazil after COP-21, under the Paris Agreement on Climate Change, demand the reduction of greenhouse gases (GHG) by 37% and 43% by 2025 and 2030, respectively; and beef is a relevant contributor to GHG.

The integrated crop-livestock systems (ICL) and, in particular, the recently launched initiative of the Low-Carbon Brazilian Beef protocol – LCBB buy Embrapa (details in ALMEIDA & ALVES, 2020), are alternatives to achieve these goals with government support, through the National Low Carbon Agriculture Plan (ABC Plan).

Despite the technical knowledge about ICL systems, the economic benefits, specially under uncertainties, remain overlooked (MARTHA JR. et al., 2011). Also, there is still definition of a LCBB bonus. The present study aims to analyze the economic viability of the LCBB protocol from an ICL system, under market risks, considering the monetization of the protocol and various scenarios of input and output prices.

MATERIAL AND METHODS

An experimental plot of six hectares with ICL, in Campo Grande-MS, Brazil, was implemented to test its capacity to recover degraded pasture in Savannah-like regions in Central Brazil, while mitigating GHG emissions by cattle. The production system comprised two consecutive cycles of four years (2008-2012 and 2012-2016): one of soybean followed by three of beef cattle. Detailed information on establishment practices is presented in Pereira et al. (2014). Soybean was cultivated in November/08 and in November/12. After harvests, palisade grass (*Urochloa brizantha* cv. Piatã) was sown, and three Nellore heifers (160 kg) were introduced in the experimental plot. In the second cycle, pasture was fertilized annually with 111 kg ha^{-1} of urea and 200 to 300 kg ha^{-1} of 0-20-20 (Nitrogen-Phosphorous-Potassium).

For the economic analysis, an 8-year cash flow was prepared using 2020 average prices and exchange rate (1.0 BRL= 0.194 USD), and considered: Revenues (R), Operating costs (OC), including seeds, fertilizer, chemicals, freight and labor, and Net Benefits (NB). Beef operating costs were estimated at 0.28 USD/kg LWT [1], while the average price for females was 1.41 USD/kg LWT (adapted from CEPEA [2]). Soybean operating costs and production were USD 607.53 and 2,100 kg ha^{-1}, respectively, in cycle 1 and USD 591.18 and 2,916 kg ha^{-1}, respectively, in cycle 2. The R and OC were calculated considering only the meat produced within the experimental plot (453 kg ha^{-1} yr^{-1}, cycle 1; 502 kg ha^{-1} yr^{-1}, cycle 2) and associated costs. By doing this, we assumed the "farm" had a cow-calf operation providing the heifers for fattening. Third party contractors were used to account for labor and machinery costs (i.e., opportunity costs). An investment analysis was carried out and the present net value (PNV) and present net value annualized [3] (PNVa) for ICL, with and without the LCBB protocol, were calculated at an annual discount rate of 8.71%. This was considered the opportunity cost of capital represented by a five-year Pre-fixed Government Bond. The activity is considered economically attractive, if PNV>0. Since there was no negative NB, there was no need to calculate other investment parameters. Given the deterministic nature of the cash flow and the known volatility of commodities prices (MARTHA JR. et al., 2011; VINHOLIS, 2021), a risk analysis was conducted, using shocks on product prices (beef and soybean) and on major input prices (urea and NPK fertilizer) in a stochastic simulation model. The average beef, soybean, urea and NPK prices (random variables in the model) from 2010 to 2020 were obtained from CEPEA and Embrapa (based on paid access to livestock bulletins) and were used to estimate the variables probability distribution function (Triangular distribution, in this cases). All prices were deflated by the General Price Index – Internal availability (IGP-DI). The minimum and maximum prices were identified within each deflated time series, along with the most likely price, chosen as the 2020 value from the original cash flow, were used as parameters in the Monte Carlo analysis that followed. The simulation was carried out using @ Risk® from Palisade, which ran the cash flow1000 times (iterations), using different stochastic prices for each year and each random variable. The result shows the empirical probability distribution of the PNV, from which the risk associated with the economic performance of ICL can be assessed. Additionally, a histogram with PNV values frequency allows for the analysis of the probability distribution.

[1] Beef operating costs were based on a typical stocker beef farm, medium technology in Goiás state (IFAG, 2020) and includes feeding, medication, vaccines, labor, but excludes pasture establishment and maintenance which are accounted for separately in the cash flow.

[2] CEPEA historical beef prices are available at: https://www.cepea.esalq.usp.br/br/indicador/boi-gordo.aspx

[3] PNVa shows a fixed amount to be paid over *n* periods at a given interest rate, which will equal to the total PNV. It is equivalent to a constant annual income and can be calculated, using the PGTO formula from Excel.

RESULTS AND DISCUSSIONS

Deterministic results from the investment analysis showed the economic performance was highly attractive, given the high PNV, irrespective of the implementation of the LCBB protocol. PNV was USD 2,582.85 and USD 2,515.03 for ICL with and without the LCBB protocol, respectively, that is, a difference of USD 67.82 per hectare. As expected, ICL system with a LCBB implemented presented better economic results due to additional margins assured by the premium of 4% paid per "arroba" (i.e., equivalent to15 kg of carcass weight). Analyzing the PNVa, the ICL system producing LCBB resulted in an annual income of USD 508.20 ha^{-1} while ICL without the LCBB protocol accrued USD 494.86 ha^{-1}, an additional USD 13.35. Given the real cost of LCBB accreditation process is still unknown, this additional amount could be interpreted as the roof, in addition to the costs already considered here (USD 2.27 ha^{-1} yr^{-1}) for certification to remain economically viable, although less attractive for farmers. Economies of scale must also be addressed in ICL, as CARRER (2020) points out. A a typical beef farm, according to IFAG (2020, based on CEPEA), has 1.170 ha on pasture, and, if we hypothesize that half can be converted to ICL, the total additional revenue from LCBB would be USD 7,809.75 yr^{-1}.

The distribution of frequencies of PNV is shown on Figure 1 (left) alongside the variables with the largest impacts on PNV (right). The results show there are 90% probability of PNV assuming a value between USD 1,368 and USD 2,140 per hectare, while the mean and the minimum were USD 1,736 and USD 1,109, respectively (Fig. 1). The mean PNVa was USD 342, while the minimum and the maximum were USD 218 and USD 487, respectively. The probability of the farmer getting more than USD 487 ha^{-1} or less than USD 218 is lower than 5%, indicating the ICL with LCBB protocol has low market risks. Figure 1 (righthand side) also shows that the beef price is, by far, the most influential variable in determining PNV results. Our findings corroborate other studies that demonstrated high economic performance of ICL and low risks (MARTHA JR. et al., 2011; VINHOLIS et al., 2020). Martha Jr. et al. (2011) draws attention to high demand for capital in ICL, when farmers need to buy feeders.

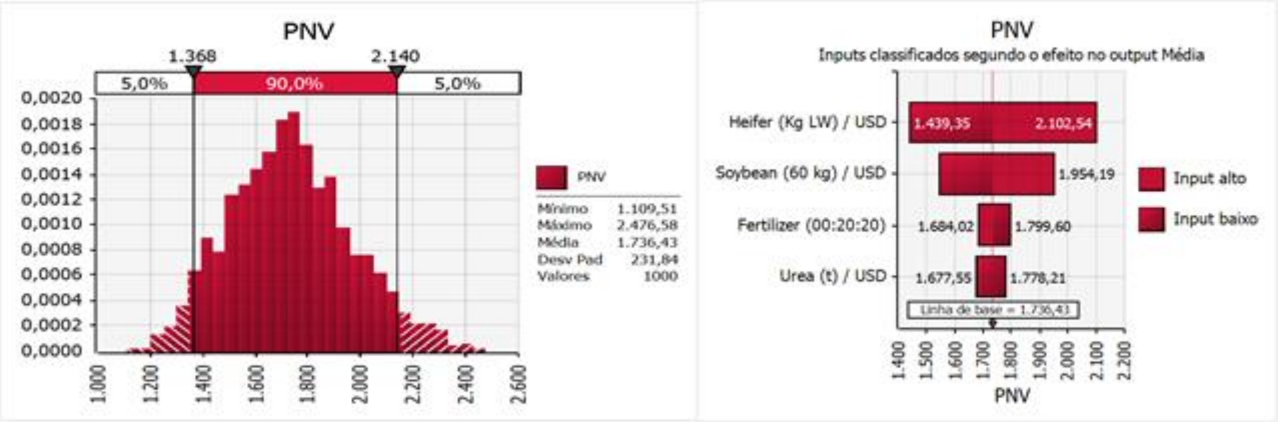

Figure 1. Frequency distribution of PNV for ICL with LCBB protocol (left) and effect of input and output prices on PNV (right).

CONCLUSIONS

Integrated Crop-Livestock systems are economically viable even in pessimist scenario of output and key input prices. LCBB protocol improves financial results, but implementation and running costs of the certification process must be cautiously established for the protocol to remain economically attractive to farmers.

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WCCLF 2021

II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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ECONOMIC ANALYSIS OF CORN CULTURE IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEM

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ABSTRACT

This study aimed to analyze the economic viability of an area of Crop-Livestock-Forest Integration (ICLF), using corn (*Zea mays* L.), *Urochloa brizantha* cv. Marandu and the eucalyptus (*Eucalyptus urograndis*). The work was developed in an ICLF Technological Reference Unit (TRU) of Embrapa Cocais, located in the municipality of Pindaré-Mirim - Maranhão, Brazil. The experimental area was 3 hectares (ha), divided into three sub-areas: Treatment I - single corn planting; Treatment II - Barreirão System and Treatment III - Santa Fé System. After the corn harvest, productivity (P) and economic outcome measures were calculated: Gross Income (GI), Gross Margin (GM), Net Margin (NM), Profit (P), Leveling Point (LP) and Producer Return Rate (RR). All treatments showed profit, with the Barreirão System having the best results, with P of 163 sacks of corn / ha, RB of R $ 6520.00, L of R $ 2576.41, PN in 99 bags of corn / ha and RR of 65.33%. The treatments I and III showed, respectively, P of 135 and 143 bags of corn / ha, GM of R $ 5400.00 and R$ 5720.00, L of R$ 1666.41 and R $ 1793.37, LP in 94 and 99 bags of corn / ha and RR of 44.63% and 45.67%.

Key words: Low carbon agriculture; Consortium; Profitability

INTRODUCTION

Integrated systems are being disseminated in several regions of Brazil as a viable alternative, and the crop-livestock-forest (ICLF) integration system is a production strategy that does not present limitations regarding the size of the property or the technological level of the rural producer. The possibilities for combining the system's components are many and adjustments are necessary, depending on the producer's objective, aspects of the property, edaphoclimatic and market aspects (GONTIJO NETO et al., 2014). The synergism between the components used in the system helps to improve environmental suitability and the economic viability of the farm's agricultural activity. The use of the ICLF system helps to implement a sustainable agricultural system, based on the principles of rotation, succession and consortium between crops, forages and tree species, to produce, in the same area, grains, meat or milk and wood (BALBINO et al., 2011; MUNIZ et al., 2007). The countless possibilities of combining resources and activities provided by ICLF systems make the decision to adopt them extremely complex, especially when a large part of the information disseminated does not include information of an economic nature (COSTA et al., 2014). Given the above, this study aimed to analyze the economic viability of an area of the ICLF system, in the municipality of Pindaré-Mirim in the State of Maranhão, Brazil, using the consortium between maize, the forage species *Urochloa brizantha* cv. Marandu and the eucalyptus (*Eucalyptus urograndis*).

MATERIAL AND METHODS

The study was developed at the Technological Reference Unit (TRU) for the ICLF of Embrapa Cocais, located in the municipality of Pindaré-Mirim-MA (Brazil), Micro-region of Pindaré, at latitude coordinates 3º46′13.60” S, longitude 45º29′42.00” W, and with an altitude of 28 m above sea level. According to the classification of Koeppen [9], the local climate is AW type (hot and humid), with an average annual temperature of 299.15 K and average annual rainfall ranging from 1,600 to 2,000 mm (SEPLAN, 2013; ALVARES et al., 2014). The soil class of the farm where the experimentwas installed is classified as Hapless Plinth (EMBRAPA, 2006). In relation to its relief, this one has variations of soft-waved to waved, being covered originally by vegetation of tropical forest subperenifolia dabótilo-palmácea babaçual, dominant in the Mid-North region of the State of Maranhão (SEPLAN, 2013). The experiment was carried out in the agricultural year 2016/2017, in an experimental area of three hectares, divided into three subareas for the formation of the treatments. The treatments evaluated was: Treatment I -Planting of single corn (monoculture); Treatment II - Barreirão System, is a technology for the recovery/renewal of degraded areas by the intercropping pasture consortium. The planting of corn intercropped with pasture was carried out. The planting of the pasture seed was carried out at the same time as the corn. The sowing of pasture is made between the lines of the maize. The mixture of the seeds of the grass is fertilized with (NPK) at the time of planting; Treatment III - Santa Fé System, is a technology consisting of the intercropping of annual crops, grains or forage, with forage species, mainly brachiaria, in partial or properly corrected soils. The planting of corn was carried out with intercropped pasture. Planting of the grazing seed was carried out at the same time as the maize crop, with no sowing between maize lines and no mixing of grass seeds with fertilizer (NPK). For the implementation of the experiment, soil analysis was carried out throughout the area and fertilization recommendations were applied according to the soil analysis results (Table 1). A no-tillage system was used. Is a technique of conservationist cultivation, where sowing is carried out in a soil that is without the conventional tillage and no harrow. In this technique, it is necessary to keep the soil always covered by crops remains at least 80% of the soil surface or to maintain six tons per hectare of dry organic matter (CRUZ, 2017). In all treatments, KWS 9304 hybrid corn was used, differing in the spreading of maize lines. In treatment I was used a spacing of 0.50 m between rows and 0.25 m between plants, and in the other treatments a spacing of 0.60 m between rows and 0.25 m between plants. For treatments II and III were used for the pasture seeds of *Urochloa brizantha* cv. Marandu, in order to establish a consortium according to the molds of the operations used. In 15 DAE, the application of the post-emergent herbicides Atrazine and Nicosulfuron, with a dosage of 3 and 0.5 L ha^{-1}, respectively, was carried out for the initial control of pasture and broadleaf development. In relation to the tree component used in the consortium, eucalyptus was used to provide income for the long-term system, animal welfare at the moment of grazing and source of organic matter and soil cover. In relation to the arrangement used for eucalyptus, these were planted in double rows spaced 3 m × 2 m and 28 m long (3 m between rows, 2 m between plants). In planting, was used 400 kg ha^{-1} of NPK fertilizer (5-30-15 + Zn), the first cover fertilization was performed 10 days after emergence (DAE) of corn with 120 kg ha^{-1} of urea and 85 kg ha^{-1} of potassium chloride, 10 DAE of corn were carried out and the second top dressing occurred 20 DAE of corn with 200 kg ha^{-1} of urea. In this work, the method of operational costs was used, according to Matsunaga et al. (1976) and Lopes et al. (2004). The following economic performance measures were calculated: Gross income, Gross margin, Net margin, Profit, Leveling point and Rates of return, according to method of Martin et al. (1998) and Rego et al. (2017). The economic indicators calculated were: Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit-Cost Ratio (RBC), according to the method of Evangelista (2007) and Muniz et al. (2007). The data collected from the costs and revenues of each treatment were tabulated and treated with the help of Microsoft Office Excel.

RESULTS AND DISCUSSIONS

Table 1 present costs, revenues and economic efficiency indicators for the implantation of one hectare of corn in the municipality of Pindaré-Mirim - MA.

Table 1. Statement of costs, revenues and economic efficiency indicators between treatments for the 2016/2017 agricultural year in the production of 1 hectare of corn.

	Treataments		
Indicators	**I**	**II**	**III**
Operational Cost - R$/ha/year	2622.09	2820.21	2804.21
Depreciation - R$/ha/year		175.50	
Remuneration of the producer - R$/ha/year		543.63	
Total Operating Cost- R$/ha/year	3341.22	3539.33	3523.33
Oportunity Cost - R$/ha/year	392.37	404.25	403.29
Total Cost - R$/ha/year	3733.59	3943.59	3926.63
Produtivity (bag/ha)	135	163	143
Price of the bag 60 kg - R$		40.00	
Leveling point (Total cost/price of bag)	94	99	99
Gross income (Price of the bag * Productivity)	5400.00	6520.00	5720.00
Gross Margin - R$/ha/year	2777.91	3699.79	2915.79
Net Margin - R$/ha/year	2058.78	2980.67	2196.67
Profit - R$/ha/year	1666.41	2576.41	1793.37
Rate of return - in %	44.63%	65.33%	45.67%
Benefit / Cost Ratio	1.45	1.65	1.46

The percentage of the Total Cost (TC) that represents the Effective Operating Cost (EOC) is 70.23% for treatment I, 71.51% for II and 71.42% for III. Because the EOC represents the majority of the costs of the initial acquisition of inputs required for production. These results are well below those reported by Rego et al. (2017,2018) for all the evaluated systems, indicating that there is a decrease in EOC, which is explained by the purchase of inputs carried out in partnership with other producers, which resulted in a higher discount on the price of inputs. Regarding the composition of the total operating cost (Table 1), taking into account depreciation and producer remuneration, these corresponded to only 19.26%, 18.24% and 18.31% of TC, respectively, for treatments I, II and III per hectare. The opportunity cost found for treatments I, II and III were 10.51%, 10.25% and 10.27% of TC, respectively. The TC of 1 hectare of maize according to data obtained by the Instituto Mato-Grossense de Economia Agropecuária, IMEA (2006), for the Northeast region of Brazil, is US$ 773 and US$ 52 with the high and medium investment technology respectively. In our case (Table 2), the TC of the three Treatments were higher. Evaluating the implantation of the ICLF system, the high TC for the study region in all treatments is justified by the predominance of livestock farming in the region of Pindaré-Mirim according to Rego et al. (2018). Some factors influence such as the high costs of the acquisition of inputs and the lack of machines for agricultural activity. In addition, the region does not have its own local distribution center, and the producer has to pick them about 300 km away from the property. treatment II was the highest productivity, with 163 bags per hectare, followed by treatment III with 143 bags and treatment I with 135 bags. The productivity found for all treatments was higher than that estimated by Conab (2017), for the state of Maranhão in the 2016/2017 harvest, which was 70 bags per hectare and was similar to that found by Teixeira et al. (2012). In relation to the leveling point (Table 1), which is the level of production in which the sales value equals the total cost, in all treatments were found values above the minimum, that is, all treatments had positive profit for the adoption of any of the systems analyzed. These results corroborate with those found by Rego et al. and Teixeira et al. (2012) and can serve as the basis for the ICLF system's recommendation. Regarding the profit margin results (Table 1) found by treatment, all were positive, meaning that the producer is paying all costs. Treatment II was the one with the highest profit margin per hectare. However, all the treatments obtained gains per hectare, having paid the formation of the pasture that will serve as complementary income in the off-season moments. Treatment II obtained the highest rate of return (Table 1) with 65.33%, followed by treatments III and with 45.67% and 44.63%, respectively. This indicator indicates the financial return that the producer can obtain if invests in any of the treatments analyzed. These results differ from those reported by Rego et al. (2018), where the conventional corn system indicated a better rate of return, but are similar to those found by Teixeira et al. (2012). The results obtained in the present work indicate that the ICLF system for the Pindare-Mirim region, after the first year of implantation, is more advantageous than the introduction of maize monoculture. The benefit-cost ratio (RBC) (Table 2) for all treatments was greater than one, which means that any management system employed will bring financial benefits that exceed production costs. These results resemble those found by Teixeira et al. (2012). RBC is consistent as a method for defining decisions to strategically achieve relevant data about desirable and undesirable outcomes. In this way it is possible to measure these elements in a comparative way, thus controlling for the cost to not exceed the benefits (DIAS, 2014).

CONCLUSIONS

The economic indicators of all treatments obtained positive results. The ICLF system, following the model of the Barreirão system, obtained better economic results than the others. Regarding NPV and IRR in all treatments, the results were positive, with superior attractiveness to the savings account investment. This shows that the integrated systems obtained higher returns on invested capital and profitability compared to the single system for the study region.

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FACTORS THAT INFLUENCE THE ADOPTION OF INTEGRATED CROP-LIVESTOCK SYSTEMS BY PRODUCERS IN RIO GRANDE DO SUL

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ABSTRACT

Integrated Crop-Livestock Systems (ICLSs) are production systems that integrate livestock and agricultural production, in the same area but with different time scales. Farmers use ICLS to intensify production in a sustainable way, improving the resilience of the system and offering economical alternatives to the producer and better use of their farms. In the state of Rio Grande do Sul (RS), the adoption of ICLS has been high, in 20.51% of the arable area, equivalent to 1,457,900 ha. Thus, it is essential to know what leads producers to adopt ICLSs in RS, and how processes occur. To elaborate the data, interviews were conducted with 944 rural producers, who differed according to their primary activity (farmers or ranchers). The farmers were classified according to the main crop produced, being corn or soybean. The cattle ranchers were classified according to the breed of animals' aptitude: beef, milk and beef+milk. According to logistic regression, the property primary activity of the property influences the adoption of the ICLS ($P<0.04$), ranchers adopt more integration systems (52%) compared to farmers (44%). Similarly, when assessing the odds ratio, the ranchers have 39% more likely to adopt ICLS than farmers. The profile of the ICLS adopter is originally a rancher. The profile of least adoption is that of corn producers.

Key words: sustainable intensification; cattle farming; technology adoption; ecological transition

INTRODUCTION

In Brazil there are approximately 351 million hectares with agricultural establishments (IBGE, 2017). With the production and technological intensification scale, Brazilian agriculture has experienced a productivity increase for commodities, making the country an important food producer globally (CRESTANA & FRAGALE, 2012).

To increase productivity in conjunction with sustainability in Brazil, strategies have been disseminated to promote improvements in production systems with increased productivity of grains, meat, and organic matter in the soil. One of these strategies is the integrated crop-livestock systems have met this demand (SOUZA FILHO et al., 2019).

FAO (2010) recognized ICLSs as a sustainable, social, environmental and economic production pathway to feed the world's population, estimated to have approximately nine billion people by 2050. The ICLS is defined by the synergistic relations between crops and animal production in areas integrated into different stout-time scales (MORAES et al., 2014; CARVALHO et al., 2015).

The monoculture system, whether with the intensive use of livestock in the same area with the use of an agricultural crop, offers a high operational, environmental and economic risk. Livestock farming can have a reduced financial return compared to agriculture crop, due to large areas occupied for its production, and when poorly managed, it generates negative environmental impacts (CARVALHO et al., 2015). The specialization allows for the systems standardization, and, thus, for a distancing from nature and its original diversity, by simplifying the production systems (DARNHOFER, 2010).

The Southern region of Brazil has established ICLS research, from the perspective of two productive realities, one typically crop-based and the other, livestock-based. In the first, livestock enters the system as an option of income diversification through cover or winter plants interspersed with the cultivation of grain crops in summer. However, in livestock farming, crops are used to recover degraded pasture, by the adoption of practices that enhance soil fertility and the control of unwanted plants, increases pasture productivity in succession and income diversification (MORAES et al., 2002). Based on this functioning of the production systems, the objective of this research was to identify which characteristics lead the farmers and ranchers in RS to adopt the ICLS.

MATERIAL AND METHODS

A database constructed with interviews guided by a questionnaire applied to rural producers throughout Brazil in the 2015/16 crop was used. The questionnaire was applied by the company Kleffmann hired by Embrapa (Brazilian Agricultural Research Corporation) (FARIA, 2016).

In this study, the state of Rio Grande do Sul - Brazil were evaluated. A total of 944 rural producers participated in the questionnaires. The interviews were conducted through questions to the rural producer during on-site visits. The adoption of the ICLS was confirmed according to the producer's answer to the question, whether he adopted it on his property.

The rural producers interviewed were differed according to their primary activity - farmers or ranchers. The farmers were soybean or corn producers, and the main crop was defined by its relative area within the farm, in comparison to other crops. For ranchers, the main activity was defined according to the breed's purpose, within the property, being beef cattle, milk, or both. In addition to the main crop, the other crops produced on the property were described, as well as the size of the property area (ha). The other questions were related to school education level, age, family composition, among other issues.

In this study, we focused on understanding which primary activity of the property (farmers or rancher) is most likely to adopt the ILCS. Also, check whether the main culture affects the decision to adopt the ICLS. Therefore, as the response variable is binary (adopt ICLS: 1; do not adopt ICLS: 0), we use logistic regression analysis (*glm* function; family binomial) to check the odds ratio and the probability to adopt ICLS by rural producers. The analyzes were performed using the R Core Team program (2021).

RESULTS AND DISCUSSIONS

With the use of logistic regression, it was verified that the primary activity of the property influences the adoption of the ICLS ($P<0.04$), ranchers adopt more integration systems (52%) compared to farmers (44%). Similarly, when assessing the odds ratio, the ranchers have 39% more likely to adopt ICLS than farmers.

The introduction of crops in livestock systems affects the production system to a lesser extent than the inclusion of livestock in agricultural systems. The ranchers can lease your areas for crops, where the tenant is the farmer and the owner is the rancher, or the ranchers can hire machinery for planting, cultivating, and harvesting grains. This way, the lease can be a promoter of integration and enhances the adoption of ICLS by ranchers, who are the owners of the land.

Agricultural systems were simplified and standardized for production at scale, facilitating their implementation (DARNHOFER et al., 2010). On the other hand, the inclusion of the livestock component in agricultural properties requires investments and maintenance in fixed structures such as corrals, fences and troughs, a specific area for management and the need to acquire animals at the beginning of the system (CORDEIRO et al., 2015).

The adoption of integrated agricultural and livestock activity presents a lower coefficient of variation in gross margin over time, even when separated in time and space because they do not depend on only one activity and consequently on market fluctuations (BELL & MOORE, 2012). Furthermore, these results may be related to low rates of beef cattle productivity in RS, in general, which makes the activity unprofitable. In this way, the integration with other activities allows an attractive increase in income for beef cattle ranchers (DE OLIVEIRA et al., 2014).

When evaluating the effect of the main culture of the property in the decision to adopt or not to adopt the ICLS, we observed that the corn culture is the one with the lowest frequency of adoption of the ICLS, that is, only 26.6% of the rural producers adopt the ICLS when the main crop of the property is maize (Table 1). We observed that there is no difference between the other activities (beef, milk, beef+ milk, or soybean) in the decision to adopt the ICLS, with an average of half of the rural properties adopting the ICLS when they have these activities on the property.

Table 1. Frequency of ICLS adoption by main crop.

Main Culture	**Frequency (%)**	**P value**
Beef	58.0^a	<0.001
Beef+Milk	40.6^a	
Milk	44.4^a	
Soybean	51.8^a	
Corn	26.6^b	

Letters in columns refer to the difference between main culture produced in the rural propriety.

The explanation for the difference in the adoption of ICLS between soybean and corn producers is the cycle difference between crops. Agricultural zoning allows the planting of corn during all months of the year, but the planting concentration takes place between August and September, a time of higher yields (PEREIRA FILHO et al., 2010). To carry out the space-time planning of properties with corn as the main crop, after its cultivation, a second off-season crop could be made with other grain crops, such as: beans, soybeans, and the corn itself. But it turns out that winter livestock would delay the planting of corn in case it does not occur with soybeans.

The adoption of the intermediate proportion for meat + milk and milk may be related to the size of the properties (on average 15 ha; EMATER/ASCAR, 2019), so the inclusion of crops may not occur, or the integration occurs with crops to the production of silage or grains to feed the animals. The properties of milk become specialized with the properties of corn and therefore less integration occurs.

The profile shown as the biggest ICLS adopter, observed in farmers, allows public agencies to direct resources and establish programs that facilitate the growth of adoption and will enable the maintenance of existing ICLS. On the other hand, the lower adoption of maize-producing properties raises a warning about the unsustainability of overly specialized systems, in addition to demonstrating the need to expand the spread of the benefits of animal entry into agricultural systems. Therefore, public policies focused on promoting these systems must use different strategies for ranchers and farmers.

CONCLUSIONS

The profile of the ICLS adopter is originally a rancher. The profile of least adoption is that of corn producers.

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9. Traceability, certification and emerging concepts

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EMISSIONS ALLOWANCES TRADING SYSTEM – CASE STUDY OF CROP-LIVESTOCK-FORESTRY INTEGRATION PROJECT

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ABSTRACT

Given the uncertainty regarding the future of carbon market, a questioning arises concerning future possibilities of fixed and stock market options. That said, this study covers the dynamics of emission trading in environmental commodities market from a Crop-Livestock-Forestry Integration Project case analysis, with the purpose of exploring the technical and economic feasibility for carbon pricing within the possibility of establishing contracts. In a carried out simulation, the analyzed project presents an increase of carbon mitigation and indicates a technical viability for the negotiation of 65 contracts per hectare. The price of emissions allowance future contracts was demonstrated in three phases of the Kyoto Protocol. Due to the correlations with oil prices and related risks, contracting at ICE Futures Contract is economically unfeasible. However, one of the possible alternatives is the implementation of the trading system in "*Brasil Bolsa Balcão*" through Ex-pit, term-future exchange operations.

Key words: [B]^3; credit; hedge

INTRODUCTION

Environmental commodity was created due to the concern with the decrease of natural resources. In this context, the Emissions Trading System [SCE] is a financial tool implemented for the reduction of greenhouse gas emissions [GEEs], which corresponds to an economic instrument resulted from Environmental Public Policies, through which a limit of carbon emissions is established and converted in allowances that are negotiated between companies.

The [SCE] started operating in 2005 at USA ICE Futures with the purpose of leveraging projects that include Clean Development Mechanisms [CDM], making possible the inclusion of developing countries in these flexibility mechanisms.

According to Bezerra (2005), the concept is based on Article 3.5 of the Framework Convention on Climate Change [CQMC], which predicts the adoption of an international economic system that leads to sustainable development, and Article 11.5 that allows the provision of bilateral negotiation channels that enable the transfer of resources and adoption of efforts between the parties for mitigating actions.

However, Donald Trump's refusal to accepting evidence of the climate emergency reinforced the attitude already taken by United States concerning Kyoto Protocol and has put the treaty's effects at risk. Therefore, his omission undermines global efforts in the fight against global warming (FREITAS, 2017).

As for Brazilian agriculture, this activity contributes to 31% of GHG emissions. However, considering the addition of emissions regarding "changes in land use and forests", the percentage rises to 55% (MCTIC, 2018.), corresponding to a challenge for mitigation mechanisms implementation. Brazilian beef cattle stands out worldwide for presenting the first commercial herd, making the country the largest meat exporter with wide possibilities for growth and improved productivity (ALVES; LAURA; ALMEIDA, 2015).

For this purpose, agroforestry is among the technologies that allow both increase of production and reduction of GHG emissions, corresponding to land use systems in which trees interact with agricultural crops and / or animal livestock, simultaneously or sequentially, in order to increase productivity in a sustainable way (ALVES; LAURA; ALMEIDA, 2015).

However, given the uncertainties regarding future of the carbon, there will be market for trading on the stock exchange? This work aims to examine the dynamics of emissions allowance trading in the environmental commodities market and the technical and economic feasibility for carbon pricing within the possibility of stablishing contracts, considering a practical case analysis regarding a farm that adopts the Forestry Livestock Agriculture Integration.

MATERIAL AND METHODS

Methodology

The work was performed in three phases:

Phase I: bibliographic review; information gathering through web sites (prices of Emission Permission future contracts, prices of Uncle Brent oil barrel, Dollar exchange rate, prices in Euros and Euro Dollars on the New York ICE Futures Exchange); field research in Farm "*Campina*" located in *Presidente Venceslau,* held in August 25, 2016.

Phase II: Training at *EMBRAPA GADO DE CORTE* located in *Campo Grande / MS* accomplished from June 10 to June 21, 2017; Participation in the 1st Carbon Credit Symposium held in *São Jose do Rio Preto / SP* on July 26-27, 2017.

Phase III: Livestock and Forestry Integration Project benchmarking performed during Module VII of Economic Management of Integrated Systems Continued Training Course in iLPF at *EMBRAPA* located in *Campo Grande / MS*, from September 21 to September 22, 2017.

Materials

Database obtained within Bloomberg software; Benchmark questionnaire adapted from the GHG Protocol of the input matrix of emissions products; Sis iLPF Eucalyptus software; Interviews and Dialogues with consultants and researchers;

Stage

Data Modeling - Sis iLPF Eucalyptus - Site Index: "30", Number of lines in row "3"; Distance between lines in row "3"; Distance between lines "18"; Ha-1 trees in the "660" plantation; 1st year initial survival (%) "100". Initial age "1"; Final age "14"; Interval "1"; Diameter class ranges for production "5". Thinning: Age "4" Selective setting the number of trees to "430"; Age "7" Selective setting the number of trees to "250"; Age "14" Systematic setting the number of trees to "0".

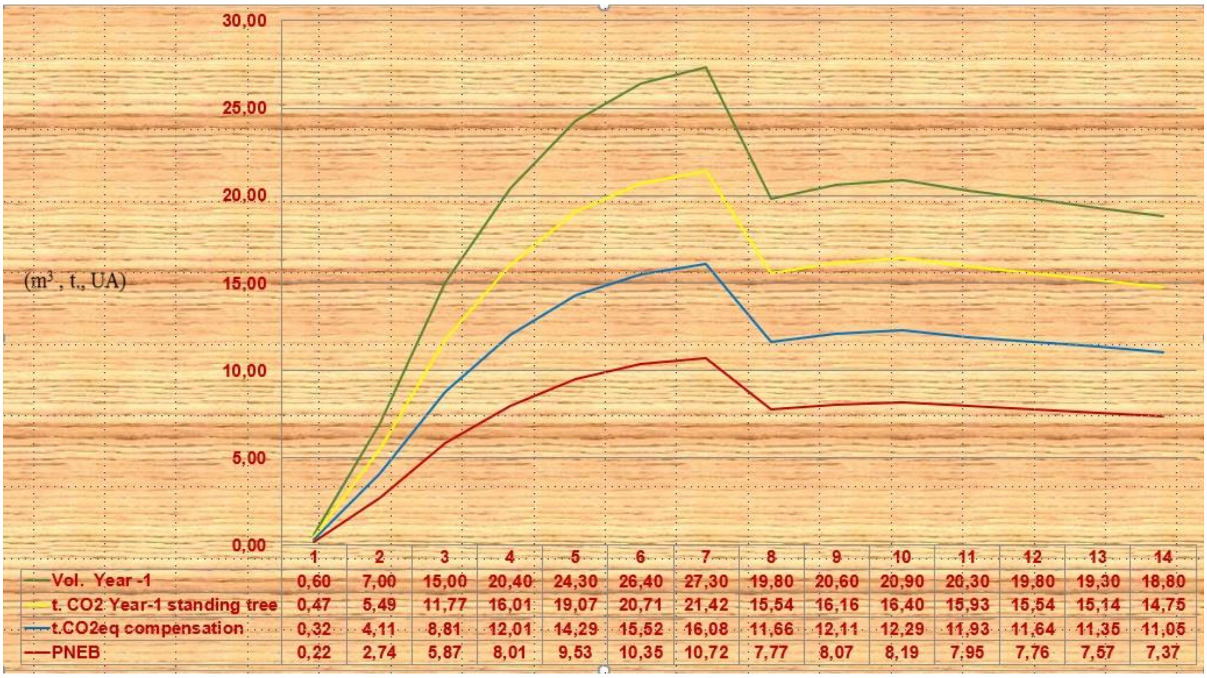
Data Analysis - Excel 2016 Spreadsheet - Calculation of variables - Correlation Coefficient, Determination Coefficient, Indetermination Coefficient, Histogram, Normal Distribution Curve, Values, Probability and Price Hope, Distortion, Kurtosis and Variation Coefficient.

RESULTS AND DISCUSSIONS

Forest production table, CO_2 equivalent [CO_2eq] and methane compensation were prepared for the project using SisILPF Eucalyptus Software, recently launched by EMBRAPA FLORESTAS for precision forest management.

The data refers to a farm located in the north of Paraná state, also known as *Norte Pioneiro*, with an arrangement of 18 meters between rows, 3 rows per row and 3 meters of distance per row (18x3x3) as well as a total amount of 660 trees per hectare.

Figure 1 illustrates the simulated results of the "North Pioneiro Farm" iLPF project. The green line represents the annual volume in m^3 of standing trees, the blue line represents the tons of CO_2 per year of standing trees, the red line represents the amount of methane compensated in t. CO_2eq and the yellow line represents the carbon neutral animal units per hectare, according to the recommendations of the Intergovernmental Panel on Climate Change [IPCC] (2006).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
— Vol. Year -1	0,60	7,00	15,00	20,40	24,30	26,40	27,30	19,80	20,60	20,90	20,30	19,80	19,30	18,80
— t. CO2 Year-1 standing tree	0,47	5,49	11,77	16,01	19,07	20,71	21,42	15,54	16,16	16,40	15,93	15,54	15,14	14,75
— t.CO2eq compensation	0,32	4,11	8,81	12,01	14,29	15,52	16,08	11,66	12,11	12,29	11,93	11,64	11,35	11,05
— PNEB	0,22	2,74	5,87	8,01	9,53	10,35	10,72	7,77	8,07	8,19	7,95	7,76	7,57	7,37

Figure 1. Norte Pioneiro Farm: Forestry production, CO_2 equivalent and methane compensation simulation results. * PNEB = Power to neutralize the GHG emissions of a bovine with 450 kg live weight (~ 1.5 t $year^{-1}$ CO_2 eq.). Source: Original result of the research adapted from the SisILPF Eucalyptus Software.

According to the simulation, a mitigated CO_2eq surplus can be obtained through respecting the stocking rate. Thus, there is a positive balance accumulated through the project life cycle, which can be allocated in hedge contracts of Emissions Trading Allowance System, or used to deduct negative balance from another activity of the project itself.

The potential number of contracts intended for negotiation was obtained from the amount of equivalent carbon accumulated in the wood classified for use in Sawmill I and Sawmill II, not taking into account the wood intended for use as Energy, according to IPCC requirements, as shown in Table 1.

The potential total of hedge contracts for *Fazenda Norte Pioneiro* equals to 65 contracts, which may be a smaller number due to IPCC requirements, which consider only the equivalent carbon mitigated in the wood classified for use in Sawmill I and Sawmill II, being necessary to apply a discount factor in the split of the wood (FDDM).

Table 1. Power number of carbon hedge contracts per hectare.

Destination	m^3 of wood ha^{-1}			Subtotal
	Sawmill I	**Sawmill II**	**Energy**	
Thinning 4th year	0.00	0.00	18.40	18.40
Thinning 7th year	0.80	21.50	37.30	59.60
Final cut of trees	109.60	113.20	39.80	262.60
Subtotal m^3 of wood	110.40	134.70	95.50	340.60
kg MS m^{-3}	60,720.00	74,085.00	52,525.00	187,330.00
kg of C m^{-3}	27,324.00	33,338.25	23,636.25	84,298.50
t CO_2eq ha^{-1}	98.37	120.02	85.09	303.47
Subtotal t CO_2eq ha^{-1}	218.38		85.09*	218.38
t CO2eq EB compensated ha^{-1}				153.17
Balance of t CO_2eq mitigated ha^{-1}				65.22
Total of Contracts				65

Source: Original research results. * Not computed for calculating IPCC requirements.

Price Analysis

The historical series observed the relationship between futures contracts of “EMISSION ALLOWANCES” [MO1], “Carbon Credit” and “BRENT” [CO1] “Barrel of Oil” prices on USA ICE Futures exchange in New York, with the purpose of checking the connection between the commodities that are exposed in Figure 2.

Figure 2. Price Emission Allowances x Brent Oil ICE Futures US.

Throughout the historical series, from April 22, 2005 to September 1, 2017, the following were observed:

1. The correlation coefficient between the price of future contracts for permitting emissions and the price of future contracts for a barrel of Brent oil in dollars, demonstrated by a continuous line in blue, which identifies dependency between these two variables.

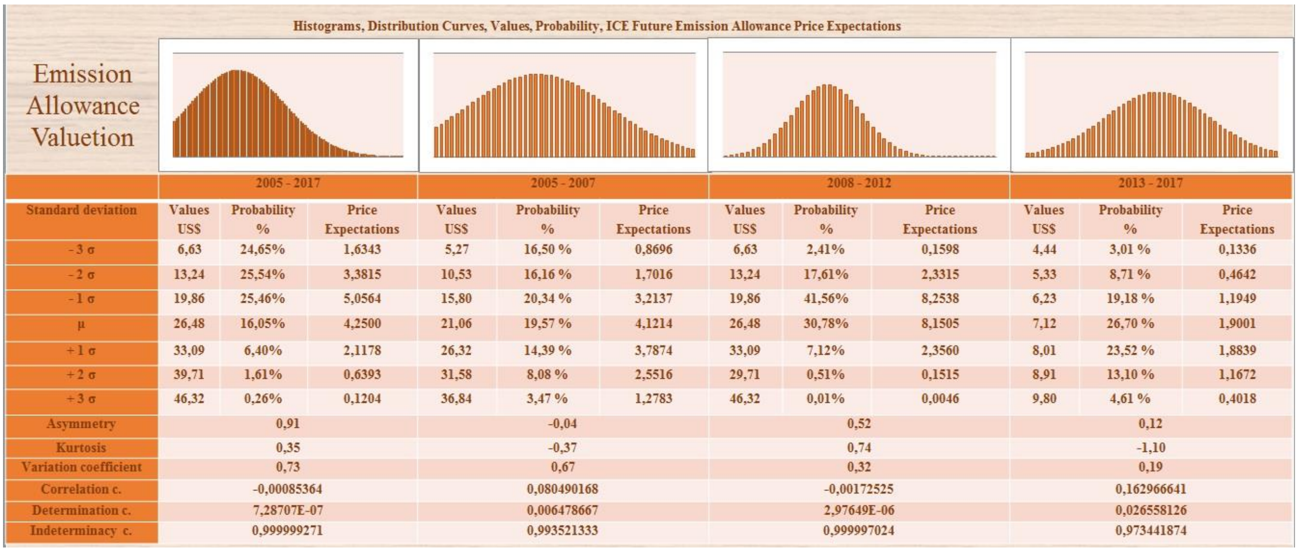
2. The determination coefficient that quantifies the degree of coupling between commodities that can be attributed to “Believe Accreditation”.

3. The indeterminacy coefficient that qualifies the dependency on external factors that can be attributed to scientific skepticism about climate change.

After observing the existing and divided relations in periods comprehended by 2005 to 2007, 2008 to 2012 and 2013 to 2017, histograms, normal distribution curve and price probability and expectation were calculated for each period.

In order to simplify the understanding of the value in US$ (US Dollar), Probability and Price Hope over the historical series and subdivided phases are placed side by side in Figure 3, alongside with the Correlation Coefficient, Determination Coefficient and Indetermination Coefficient.

Comparing the phases described in Figure 3, it is observed that the obtained values in US$ between 2008 and 2012 (phase 2) coincides with the obtained values for 2005 to 2017. However, the probabilities are not repeated. The fact suggests that the accreditation policy of Obama administration was instrumental in setting the prices of emissions allowances.


Histograms, Distribution Curves, Values, Probability, ICE Future Emission Allowance Price Expectations

Emission Allowance Valuetion

	2005 - 2017			2005 - 2007			2008 - 2012			2013 - 2017		
Standard deviation	Values US$	Probability %	Price Expectations	Values US$	Probability %	Price Expectations	Values US$	Probability %	Price Expectations	Values US$	Probability %	Price Expectations
- 3 σ	6,63	24,65%	1,6343	5,27	16,50 %	0,8696	6,63	2,41%	0,1598	4,44	3,01 %	0,1336
- 2 σ	13,24	25,54%	3,3815	10,53	16,16 %	1,7016	13,24	17,61%	2,3315	5,33	8,71 %	0,4642
- 1 σ	19,86	25,46%	5,0564	15,80	20,34 %	3,2137	19,86	41,56%	8,2538	6,23	19,18 %	1,1949
µ	26,48	16,05%	4,2500	21,06	19,57 %	4,1214	26,48	30,78%	8,1505	7,12	26,70 %	1,9001
+ 1 σ	33,09	6,40%	2,1178	26,32	14,39 %	3,7874	33,09	7,12%	2,3560	8,01	23,52 %	1,8839
+ 2 σ	39,71	1,61%	0,6393	31,58	8,08 %	2,5516	29,71	0,51%	0,1515	8,91	13,10 %	1,1672
+ 3 σ	46,32	0,26%	0,1204	36,84	3,47 %	1,2783	46,32	0,01%	0,0046	9,80	4,61 %	0,4018
Asymmetry	0,91			-0,04			0,52			0,12		
Kurtosis	0,35			-0,37			0,74			-1,10		
Variation coefficient	0,73			0,67			0,32			0,19		
Correlation c.	-0,00085364			0,080490168			-0,00172525			0,162966641		
Determination c.	7,28707E-07			0,006478667			2,97649E-06			0,026558126		
Indeterminacy c.	0,999999271			0,993521333			0,999997024			0,973441874		

Figure 3. Histograms, Distribution Curves, Values, Probability, ICE Future Emission Allowance Price Expectations. Source: Original research results

CONCLUSIONS

Technical feasibility of 65 hedge contracts per hectare, depending on the wood split factor.

Economic unfeasibility of the contract at USA ICE FUTURES due to the risks.

Alternative adoption of the system in *Brasil Bolsa Balcão*, BACEN Operation Code 47 939.

The most suitable contract is the Ex-pit “Forward / future exchange” operation.

New works that demonstrate the “Effectiveness of the Hedge” and calculate the base risk.

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IMPLEMENTATION OF LOW-CARBON TECHNOLOGY IN THE BRAZILIAN AMAZON

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ABSTRACT

The Amazon biome still suffers from deforestation and the implementation of sustainable agricultural systems is important for the biome preservation, through the effect of saving land. Public policies and rural development projects allow training and dissemination of knowledge about production systems that bring benefits to producers and the environment. *The Sustainable Rural Project* promotes the implementation of low-carbon technologies in rural properties, allowing for better land management and preservation of biodiversity. Thus, the objective of this work was to identify the main low-carbon technologies that small and medium producers have implemented in the Amazon biome through the actions of the project. The supported technologies were: Agroforestry Systems (AFS); Recovery of Degraded Areas with Pasture (RDAP); Recovery of Degraded Areas with Forest (RDAF); Forest Planting (FP) and; Management of Native Forests (MNF). Thus, more than 1,600 rural producers were impacted on more than 20 thousand hectares in the biome. The main technology deployed was RDAP and the one of least interest was MNF and FP. It was observed that the majority of producers chose not to modify the land use and cover before the project, maintaining the activities that were already common on the property.

Key words: sustainable development; climate change; public policy

INTRODUCTION

The Amazon Forest is the largest tropical forest in the world, with enormous biodiversity, it provides ecosystem services and contributes to climate regulation and the global hydrological cycle (INPE, 2020; RUIZ-VÁSQUEZ et al., 2020). Despite this, about 300,000 km^2 have been deforested in the past 20 years (INPE, 2020). From 2019 to 2020, there was an increase of more than 35% or 9,216 km^2 of the deforestation rate in the Legal Amazon (TERRABRASILIS, 2020).

One of the causes of deforestation in the Amazon is the opening of areas for the expansion of beef cattle and soybean crops (SILVA; BARIONI; MORAN, 2021), with this high contribution to deforestation carried out by a small minority of farmers (about 2% of properties) (RAJÃO et al., 2020).

The challenge of preserving the Amazon can only be overcome with effective changes in production systems and with sustainable rural development policies, which include the economic, environmental, and social spheres (STRASSBURG, 2019).

For this, there is a need to bring the context of climate change closer to agricultural production, improving and encouraging the transmission of information and training, especially in the context of small and medium producers (MELLO-THÉRY et al., 2020). Since the lack of information and technical assistance to producers is one of the major problems for sustainable practices to be adopted more, besides, financial incentives, such as rural credits, are also an obstacle to the adoption of these technologies, mainly due to the initial costs of implementation (CORTNER et al., 2019).

Thus, public policies and projects for the implementation of low-carbon agriculture technologies aimed at smallholders for sustainable development and recovery of degraded areas are paramount in combating climate change (TEIXEIRA et al., 2018).

In this sense, the Sustainable Rural Project was prepared in the form of technical cooperation, based on financing from the International Climate Fund and the UK Department of Environment and Rural Affairs (Defra), with the Ministry of Agriculture, Livestock and Supply of Brazil (MAPA) as its beneficiary, through the Secretariat of Social Mobility, Rural Producers and Cooperatives.

The project had the Inter-American Development Bank (IDB) as executor and financial manager. This Technical Cooperation was financed by the British Government. Brazilian Institute of Development and Sustainability (IABS) was the institution selected to carry out the execution and operational services of administrative and logistical activities of the Rural Sustainable project and the Brazilian Agricultural Research Corporation (Embrapa) the scientific coordinator of the project.

The Sustainable Rural project aimed to improve land and forest management, poverty reduction, biodiversity conservation, and climate protection through financial incentives and technical assistance for the implementation of low-carbon technologies in rural properties (ASSAD et al., 2019). The success of this type of project depends on convincing producers that it is necessary and possible to change their practices in rural properties (NEWTON et al., 2016).

Thus, we sought to identify the main low-carbon technologies that small and medium-sized producers implemented in the Brazilian Amazon biome through the actions of the Rural Sustainable project.

MATERIAL AND METHODS

This study is based on the Phase I Sustainable Rural Project (PRS I) that was carried out in the Amazon biome, with rural producers, distributed in 30 municipalities in the states of Rondônia, Pará, and Mato Grosso, with 10 municipalities in each of these states. Details of the project can be checked at http://mata-atlantica-amazonia.ruralsustentavel.org/ and in the book by Assad et al. (2019).

One of the actions of the project was to identify, support, and financially encourage the implementation of low-carbon technologies in properties of small (modules less than or equal to 4) and medium (modules between 4 and 15) rural producers. Fiscal module is a unit of measure, in hectares (ha), which the value is fixed for each municipality, taking into account several factors, such as the type and income of predominant activity and others. The supported technologies were: Agroforestry Systems (AFS); Recovery of Degraded Areas with Pasture (RDAP); Recovery of Degraded Areas with Forest (RDAF); Plantation of Commercial Forests (FP) e; Sustainable Management of Native Forests (MNF). Each producer could choose the technology that would be best for their reality, being able to choose the implementation of more than one.

Following the scope of the project, 1,604 rural properties were contemplated. In these properties, the technology (s) that the producer (s) implanted (AFS, RDAP, RDAF, FP, and MNF) and the soil cover before the technology (s) were identified, it can be: crop, pasture, forest, and others that do not include the mentioned activities.

For these issues regarding technologies and previous coverage, it was identified by area of intervention, that is, if the producer adopted more than one technology on his property in different areas, it was analyzed separately. The data were presented through descriptive statistics.

RESULTS AND DISCUSSIONS

With the actions of the project, 2,036 interventions were carried out resulting from the implementation of AFS, RDAP, RDAF, FP, and MNF technologies in the 1,604 properties, that is, in some cases, one (a) producer implanted more than one low-carbon technology in different areas of your property. The main technologies deployed were RDAP (56.5%), AFS (26.9%), and RDAF (14.7%), in areas referring to 13,657; 5,313 and 936 ha, respectively. On the other hand, FP and MNF represented the lowest percentage of implantation (1.4% and 0.5%, respectively) (Table 1).

Table 1. Number of technologies deployed (n) and the total area in hectares for each technology.

Implanted technology	n	%	area (ha)
AFS	548	26.9	5,313
RDAP	1,151	56.5	13,657
RDAF	299	14.7	936
FP	28	1.4	68
MNF	10	0.5	44
Total	2,036	100.0	20,019

n: number of interventions (technology deployed) and; %: percentage of interventions in each class. AFS: agroforestry systems; RDAF: recovery of degraded areas with forest; RDAP: recovery of degraded areas with pasture; FP: forest planting and; MNF: management of native forest.

Of these 2,036 interventions, only 10 were related to MNF, where no land-use changes were made, only sustainable forest management. Therefore, these interventions were not considered in previous coverage.

In this context, pasture was the previous coverage of most of the areas where the technologies were implemented, being AFS (63.7%), RDAP (93.1%), RDAF (72.0%), and FP (78.6%). The forest was the second-largest previous cover in the areas that implemented RDAP (4.0%), RDAF (19.7%), and FP (17.9%). For the areas that implemented AFS, the crop was the second-largest previous cover (15.7%), after pasture. The coverage before the implementation of the four technologies was distributed among other uses, as shown in Table 2.

Concerning the implementation of technologies, most producers implemented RDAP, in an area of more than 13 thousand hectares, which previously were mostly degraded pastures with livestock. These results demonstrate that rural producers in the Amazon still opt for livestock practices. Data from the IBGE Agricultural Census (2017) showed that livestock, in addition to being the predominant activity in the biome, was also the one that grew the most in recent years, so worrying about the recovery of degraded pastures is essential for maintaining the activity and environmental quality.

Table 2. Previous coverage of areas deployed with low-carbon technologies.

Implanted technology	Coverage prior to technology deployment	n	%
AFS	Crop	86	15.7
	Pasture	349	63.7
	Forest	39	7.1
	Other	74	13.5
RDAP	Crop	1	0.1
	Pasture	1,072	93.1
	Forest	46	4.0
	Other	32	2.8
RDAF	Crop	3	1.0
	Pasture	216	72.0
	Forest	59	19.7
	Other	21	7.0
FP	Crop	0	0.0
	Pasture	22	78.6
	Forest	5	17.9
	Other	1	3.6

n: number of interventions performed. AFS: agroforestry system; RDAF: recovery of degraded areas with forest; RDAP: recovery of degraded areas with pasture; FP: forest planting.

With RDAP it is possible to recover areas, previously unproductive or with low productivity rates, reducing the opening of new areas of the native forest through deforestation, resuming the physical, chemical, and biological quality of the soil, also improving the productive and economic capacity of the properties, mainly when performed with integrated crop-livestock systems (MACEDO, 2009; REIS et al., 2019; SALTON et al., 2014; VILELA et al., 2011; WILKINS, 2008).

AFS was the second most deployed technology by rural producers with more than 5,000 ha, largely replacing livestock areas (previous coverage). There was a good representation and acceptance of technology by producers in the Amazon, given several possible environmental and economic benefits, because with the diversification of products it is possible to increase income (PINHO; MILLER; ALFAIA, 2012; POMPEU et al., 2012; VOSTI et al., 1998; YAMADA; GHOLZ, 2002).

RDAF, the third technology most deployed by producers in the biome. The reforestation of degraded or unproductive areas can collaborate with the reduction of deforestation in the Amazon region, and at the same time help in the environmental regularization of rural properties (Piketty et al., 2015), which may have influenced producers to adopt the technology, after all, environmentally regulated properties have easier access to credit (L’ROE et al., 2016; ROITMAN et al., 2018).

The lesser implantation of FP technology by producers cannot be understood as less important or inefficient. Therefore, it is believed that the lower availability of area (small and medium producers) and the need to increase income with the primary activities already adopted, made the technologies less attractive to producers. Another important point that may have led to the lesser adoption of the FP is the slow economic return concerning other activities such as livestock and farming (SIMMONS; WALKER; WOOD, 2002).

Even though the project enabled the proper management of native forests (MNF), with the possibility of return, the acceptance was very low. It is understood, therefore, about the need to strengthen projects, public policies, and training for maintenance and, consequently, the preservation of the native Amazonian Forest.

CONCLUSIONS

From the results obtained, it was observed that the producers chose not to modify the use and cover of the soil before the project, maintaining the activities that were already common on the property. Therefore, most are producers who do not seek to change their production system and obtain new knowledge from other cultures.

Even so, the implementation of low-carbon technology has impacted more than 1,600 rural producers on more than 20 thousand hectares in the Amazon biome. This will enable the dissemination of knowledge and possibilities for improvements in production systems, through sustainable production, which preserves native forests, improves producers' income and quality of life.

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AGROFORESTRY AS A MEANS TO ACHIEVE INTERNATIONAL ENVIRONMENTAL LAW GOALS

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ABSTRACT

Over the years, agroforestry practices have been internationally recognized for its socio-environmental and economic benefits. Thus, agroforestry has become an important means to achieve several international environmental law goals, including sustainable development goals. This paper demonstrates it through the analysis of the main international environmental law conventions and instruments.

Key words: agroforestry; international environmental law; sustainable development

INTRODUCTION

For some time now, global environmental and development agendas have converged to take into account the economic, environmental and social dimensions of sustainable development. Gradually, agroforestry begins to be recognized as a key element for the achievement of several international sustainable development objectives defined in particular by Agenda 21, by the Millennium Development Goals (MDGs) and by the Sustainable Development Goals (SDG). By enabling efficient and multifunctional land use, agroforestry is able to promote sustainable agricultural intensification. Various studies show that agroforestry is capable of ensuring food security, reducing rural poverty, promoting gender equality, improving water quality, combating climate change, promoting sustainable agriculture and sustainable forestry, conserve biodiversity, promote sustainable land management and promote sustainable production and consumption, some of the international sustainable development objectives.

MATERIAL AND METHODS

To carry out this work, the main international conventions and international legal instruments on environmental law were analyzed. In the website of each convention, a research was done using the keyword "agroforestry" and each document found was analyzed in detail, including communications, decisions, thematic programs, technical papers, working papers, academic publications and workshops. In addition, a bibliographic search was made on the international legal recognition of agroforestry benefits.

RESULTS AND DISCUSSIONS

The importance of agroforestry has already been affirmed by some of the main international conventions aimed at protecting the environment: the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention to Combat Desertification (UNCCD).

The CBD has confirmed the importance of traditional knowledge for the conservation and sustainable use of biodiversity. The convention recognized that traditional farming communities and their farming practices have made a significant contribution to the conservation and enhancement of biological diversity and that these can make an important contribution to the development of more sustainable agricultural production systems. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) has also recognized the essential role of farmers and local communities in the conservation of agricultural biodiversity.

The CBD has already noted the great socio-economic and environmental potential of agroforestry practices on several occasions, in particular through certain work programs and thematic programs. The primary goal of the Expanded Program of Work on Forest Biological Diversity, for example, is to implement the ecosystem approach, particularly through agroforestry, and goal 4 of the Program of Work on Island Biodiversity is to promote agricultural systems capable of increasing productivity while protecting the environment, such as the agroforestry system. Through a thematic program, the adoption of SAF was stimulated to fight poverty in arid, semi-arid and dry sub-humid areas of Latin America and the Caribbean. In addition, Parties agreed to undertake national and international research on agroforestry and use the results to identify and disseminate good practices that promote the conservation and sustainable use of forest and agricultural biodiversity.

During the International Day for Biological Diversity in 2008, the CBD Secretariat recognized agroforestry as a sustainable farming practice that promotes participatory management of biodiversity, the most effective way to maintain and develop traditional knowledge. In the same year, at one of its side events, the COP recognized that forest plots and other secondary forests, agroforests and plantations play a key role in biodiversity conservation, both at the inside and outside protected areas.

Still within the CBD, a Symposium was held in Tokyo on the importance and potential of agroforestry for the national and global promotion of sustainable development in relation to the Satoyama Initiative. The initiative emphasizes the sustainable management of human-influenced landscapes, such as agricultural land and secondary forests, where people have lived and used natural resources for centuries.

In addition, the CBD is a partner in the Consultative Group on International Agricultural Research (CGIAR) Research Program on Forests, Agroforestry and Trees. This is the world's largest research on the development of a program geared towards strengthening the role of forests, trees and agroforestry in sustainable development, food security and climate change mitigation. The research is divided into four branches: tree genetic resources to bridge production gaps and promote resilience; improving the way trees and forests contribute to the livelihoods of smallholders; sustainable value chains and investments to support forest conservation and equitable development; landscape dynamics, productivity and resilience; and forests, trees and agroforestry for climate change adaptation and mitigation.

With regard to the implementation of the Strategic Plan for Biodiversity 2011-2020 and the achievement of the Aichi Biodiversity Targets, parties to the CBD were encouraged "to recognize the importance of traditional knowledge of indigenous peoples and local communities for a sustainable agriculture that corresponds to their vision of the world (cosmovision) and supports the diversification and ecological rotation of crops and agroforestry, and to promote community and family agriculture, alongside agroecology, in order to promote sustainable production and improve nutrition." The role of dietary diversity from agroforestry systems in promoting the health and nutrition of local populations was also highlighted. Finally, the importance of agroforestry in promoting respectful habitats. pollinators was affirmed in Decision XIII /15.

Both parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC) have agreed that agroforestry practices are a component of smart agriculture in face of climate change. In 2008, the UNFCCC Secretariat developed a technical paper on the challenges and opportunities for mitigation in the agricultural sector. This document recognized that agroforestry practices have great potential to promote carbon sequestration and carbon emission reduction at non-prohibitive costs "the expanding role of agroforestry offers the potential for synergies between mitigation programmes and adaptation to climate change (VERCHOT et al., 2007). In many instances, improved agroforestry systems can reduce the vulnerability of small-scale farmers to inter-annual climate variability and help them adapt to changing conditions." The same technical paper asserts that adopting agroforestry practices can help promote biodiversity and wildlife habitats, adapt to climate change, and reduce poverty. In addition, a document by the Consultative Group on International Agricultural Research (CGIAR) and its Climate Change, Agriculture and Food Security (CCAFS) Research Agenda on the top ten innovations for agriculture, recognizes the essential role of agroforestry in the diversification of farms and the improvement of resilience.

The potential of agroforestry has also been recognized by the United Nations Convention to Combat Desertification (UNCCD). Parties to the Convention stated that the purpose of the Asian Thematic Program Network on Agroforestry and Soil Conservation is to promote agroforestry and soil conservation in Asia in the context of combating desertification and reducing the effects of drought by strengthening local, national, regional and sub-regional capacities and international cooperation.

The scope of agroforestry has been affirmed by the main international conventions concerning the protection of the environment, mainly by the CBD. Since 2002, the CBD has successively affirmed the benefits of agroforestry practices and the interest of this practice in achieving several environmental, social and economic objectives. There is an international tendency to consider agroforestry practice as an instrument capable of minimizing important environmental problems and ensuring the achievement of several international objectives related to sustainable development.

It is important to clarify that international conventions are considered a source of international law and they produce legal effects between stakeholders. Thus, the binding nature of conventions *vis-à-vis* national states depends on their ratification in domestic law. Brazil has adopted the moderate dualist theory, which requires the approval of the National Congress and the promulgation of a decree by the President of the Republic for international rules to be valid in domestic law. Brazil has ratified the CBD, the ITPGRFA, the UNFCCC and the UNCCD. Thus, the obligations established in these agreements are binding and must be respected.

CONCLUSIONS

The importance of agroforestry for the achievement of several international sustainable development goals has been scientifically proven and its benefits have been internationally recognized by some international conventions. Agroforestry is recognized by international environmental law as a capital instrument to achieve several goals, such the conservation and sustainable use of biodiversity and soils, the implementation of the ecosystem approach, the fight against poverty, sustainable use and consumption, improved livelihoods of smallholders, fight against climate change, provision of ecosystem services, diversification of agricultural production, food security, health and nutrition promotion and of local populations and the promotion of pollinator-friendly habitats.

However, implementing such a system can be tricky in different contexts and various obstacles can be found. Therefore, there are technical, economic, social and legal conditions for the establishment of successful agroforestry systems. These conditions include in particular the viability of consortia between species, the complementarity between agricultural and forestry production and harmonized legislation compatible with the complexity of agroforestry systems.

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BIG EARTH OBSERVATION DATA AND MACHINE LEARNING FOR MAPPING CROP-LIVESTOCK INTEGRATED SYSTEM IN BRAZIL

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ABSTRACT

The adoption of crop-livestock (iCL) integrated systems has been pointed out as an important strategy for increasing production based on sustainable intensification of land use in Brazil. Mapping and monitoring the iCL areas would allow us to know the expansion rates and the adoption level of the integrated system, being an important instrument for public policy management. However, due to the time-space variability from integrated production systems, developing methods based on remote sensing remains a major challenge. In this sense, this work discusses the application of Big Data and machine learning concepts in Earth Observation Data as a strategy to compose a methodology for monitoring the iCL in Brazil. We tested the capacity of the Random Forest (RF) classifier applied to MODIS time series to iCL detection in the Mato Grosso State, Brazil. For this, we evaluated the classification accuracy for the years between 2012 and 2019, totaling 3,864 images processed. The overall accuracy founded was between 0.77 and 0.89 and an fscore average of 0.85 was found for the iCL class. The generated maps showed a trajectory of sustainable intensification, with the expansion of the iCL area from 1,100,000 ha in 2012/2013 to 2,597,000 ha in 2018/2019, an increase of 135%. The results indicate that the use of the RF classification technique with MODIS times series has great potential to compose an iCL monitoring methodology, requiring parallel and cloud computing applied to advanced algorithms.

Key words: agricultural sustainable intensification; MODIS time series; Machine learning

INTRODUCTION

FAO's global projections for 2050 indicate that the world population will still grow in the coming decades and that world agricultural production will have to increase by about 70% compared to 2005 production to meet the growing demand for food. Considering the low availability of areas for agriculture expansion, projections point out that about 80% of the agricultural production increase to meet this demand will have to occur through increased productivity and/or the intensification of production systems (FAO, 2009).

Considering the ongoing global climate change, with direct consequences for agriculture, a scenario of uncertainty, food insecurity, and production instability at the global and country-level is established. The scenarios signal increased environmental pressures as deforestation and greenhouse gas emissions. Overexploitation of water resources and degradation of soil quality will cause the loss of the productive area, in addition to the land competition, increasing global inequality and generating strong competition among producing countries. Thus, the major challenge for producing countries is the need to increase agricultural production from intensifying production systems and at the same time avoiding deforestation and reducing greenhouse gas emissions.

Going in this direction, on the UN Climate Convention, that took place in December 2009 in Copenhagen, Denmark, Brazil took a voluntary measure to reduce GHG emissions in the order of 36.1% and 38.9% with the international community setting reduction targets for each sector of the Brazilian economy.

In this sense, at the UN Climate Convention, which took place in December 2009 in Copenhagen, Denmark, Brazil, facing the international community, took a voluntary step to reduce its GHG emissions in the order of 36.1% and 38.9%, setting reduction targets for each sector of the Brazilian economy.

Fulfilling its commitment, the country signed the National Climate Change Policy and the National Climate Change Fund (Climate Fund) in the same year for adaptation and mitigation actions. For the agricultural sector, to consolidate a Low Carbon Economy in Agriculture, the Sector Plan for Mitigation and Adaptation to Climate Change (ABC Plan) aims at management practices that reduce the emission of greenhouse gases. The ABC Plan constitutes an explicit state policy for reducing carbon emissions both by its paradigmatic scope, established targets, and by the amounts of public investments.

However, a decade after the launch of the ABC plan, the challenge is still to create efficient mechanisms for monitoring these initiatives. As the study “The Governance of the ABC Plan”, produced by FGV's Agribusiness Center (GVAgro, São Paulo), concluded, the absence of instruments to monitor the application of resources and the goals of mitigating greenhouse gases has caused serious governance problems for the plan. Today, the estimation of the implementation of these systems is made by costly surveys in time and resources, such as the survey conducted by Gil (2015), who, through interviews with 134 producers and specialists in a period of 6 months, extracted information about the expansion of iCL systems in the municipalities of the state of Mato Grosso (MT) for the 2012/2013 crop year. Another study, conducted by the Klefman Group, which in 2017 generated the iCLF report in numbers (EMBRAPA, 2017), which also conducted interviews, conducted an iCLF inventory by states of Brazil. Surveys like that not allowing annual monitoring, as well as require a huge amount of data collection work.

Monitoring the expansion of the integrated system is essential to plan the agriculture sector in Brazil, besides enabling the monitoring of GHG emission reduction targets established by Brazil (BUSTAMANTE et al., 2012; RAJAO; SOARES-FILHO, 2015).

Considering this evidence, this study aims to evaluate methods based on the use of remote sensing in contribution to the establishment of a methodological protocol for monitoring Low Carbon Agriculture in support of the governance of the ABC Plan. The present work takes part in the GeoABC Project: Methodologies and technological innovation for satellite monitoring of low carbon agriculture in support of Brazil's ABC Plan.

MATERIAL AND METHODS

The Mato Grosso (MT) state was chosen because, containing three biomes: Amazônia, Cerrado, and Pantanal, it presents a great variability of environments and climatic gradient, which made it possible to test the robustness of the developed method. The state is one of the main national producers of cattle and soybeans and its expansionist model has often been criticized for its impacts on environmental resources, especially in tropical forests (ARVOR et al., 2017) and savannah areas (MYERS et al., 2000).

According to data from the municipal agricultural survey, IBGE (SIDRA, 2019), the agricultural production of 95% of the agricultural state area in the year 2019 corresponded to the production of 3 main crops: soybean with 58.47%, corn with 30.22%, and cotton with 6.65%. According to this information, we focus our efforts on mapping the pasture soybean system, with or without the presence of corn. Thus, we focus our efforts on mapping the pasture after the summer soybean crop, with or without the succession of corn.

The approach of this study was based on the use of machine learning techniques, performed in cloud computing for the annual mapping, where each map represents the crop succession system for an entire crop year, totaling 07, between 2012/2013 to 2018/2019. The MODIS time series of the spectral bands NIR and MIR were used together with the NDVI and EVI vegetation indices, representing a feature space of 92 images for each year and each image tile (6 total). We used the Random Forest classifier (BREIMAN, 2001) applying 100 random trees, associated with a learning/validation dataset containing approximately 25,000 pixels. The platform used was the Google Earth Engine, which consists of a catalog of data ready for analysis with high-performance cloud processing accessed and controlled through an API (application programming interface) accessible on the Internet (GORELICK et al., 2017). A hierarchical structure was applied, which was composed of 04 levels presented below, following the structure already existing in version 5 of MapBiomas:

- Level 0: In this first level, a mask was applied to the class “Soy” of the MapBiomas collection 5.0;

- Level 1: In the second level, a binary classification was carried out, containing the class (SC) that represents soy in a single system, and the class (DC) that represents the succession of any other type of crop after soybean harvest;

- Level 2: For the third level, the mapping universe was isolated to the DC class mapped in the previous level, which was stratified in the three most common systems in the state, that is, soybean in succession with cotton (SA), soybean in succession with corn, millet, sorghum or sunflower (SCe) and soybeans with *brachiaria*, with or without the presence of corn, millet or sunflower (iCP);

- Level 3: The fourth level is composed of the iCP1 class, which represents pasture in succession of soy and the ILP2 class that represents pasture in succession of soy intercropped with corn.

RESULTS AND DISCUSSIONS

The overall accuracy at all three levels is between 0.70 and 0.96. The 01 level showed greater stability, with less variation each year. Levels 02 and 03 showed the lowest accuracy in 2013/2014. The mapping of iCL zones, shown at level 02, showed a consumer precision between 0.8 and 0.94 and a producer precision between 0.68 and 0.88. If, on the one hand, the prevalence of error of omission underestimates the area implanted with iCLs, on the other hand, it suggests an increase in the certainty of the mapped areas. The study chose to produce a more conservative mapping to avoid classifying Soybean+Corn areas as iCL. Conversely, iCL areas may have been classified as Soybean+Corn.

Sequential systems associated with soy are currently prevalent in Mato Grosso and had already been pointed out by other authors (ARVOR et al., 2012; KASTENS et al., 2017; PICOLI et al., 2018; Spera, 2017) preferentially for corn, which has been replacing millet, followed by cotton as the second ILP. based on the result found with this methodology, sustainable intensification by integrated systems more than doubled in the state, from ~ 1,100,000 ha in the crop year in the year 2012/2013 to ~ 2,600,000 ha in the year 2018/2019. It was possible to observe that among the sequential cultivation options, ILPs have been gaining more importance, going from 18.6% to 28.9%, as cotton increases its proportionality from 4.6% to 11.1%. Among the analyzed period, the SCe system loses its proportional importance, falling from 76.9% to 60%, suggesting a phase of increase in intensification in an integrated way between crop-livestock system.

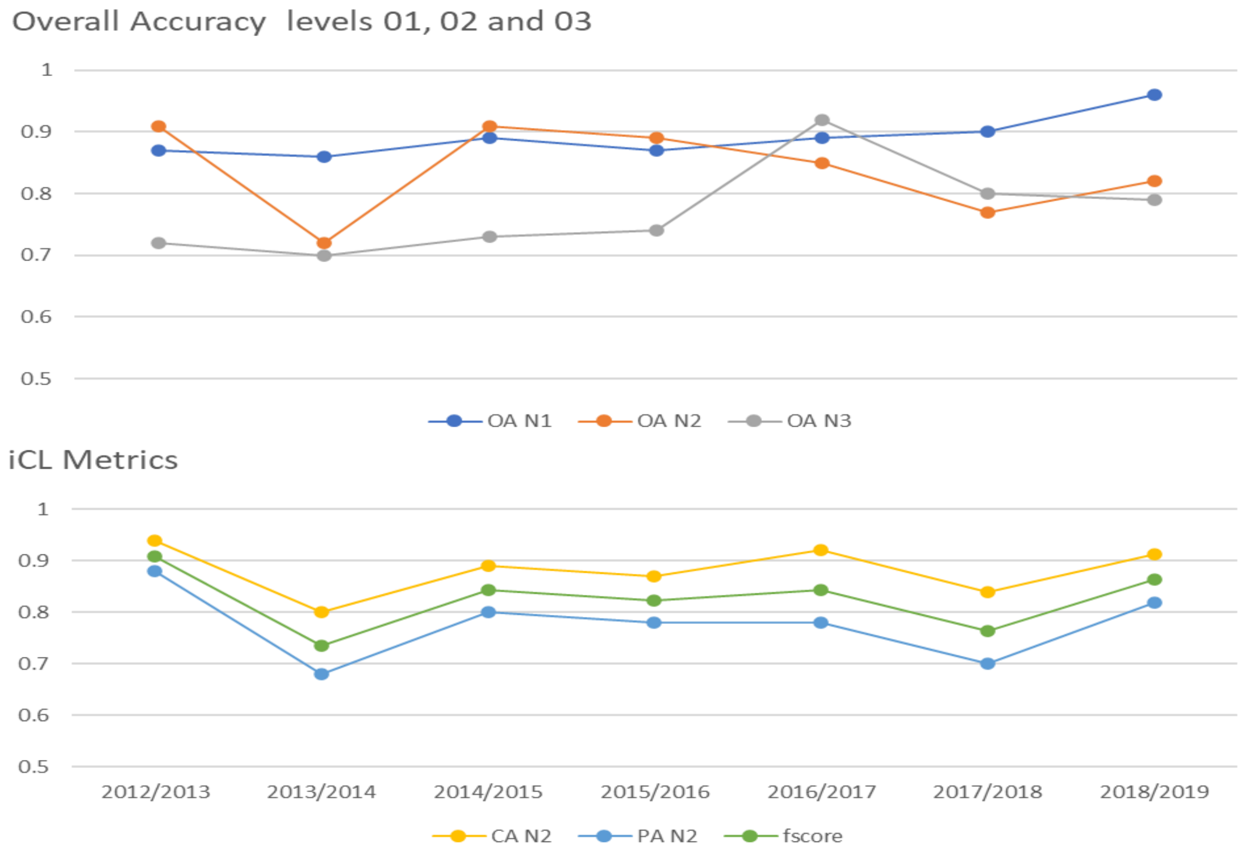

Figure 1. Annual evolution of the F-score of the classes of cultivation system of Level 01 (continuous line), Level 02 (large points) and Level 03 (small points), calculated on the scale of the State of Mato Grosso.

It was possible to observe in previous sessions that the integration of Integrated Systems in Mato Grosso is gradually occupying the space of conventional systems, showing a significant increase in this state. To facilitate spatial reading, two maps were created with the Kernel Density Index, where each pixel in the iCP area was exported to point shapes. In the first agricultural season of the analyzed series, it is possible to identify greater importance in the Middle North region, with a greater concentration of iCP areas between the towns of Sinop and Sorriso, but with areas well dispersed in the north-south axis of the region. There are spots of concentration of zones, limited however in the West, South-East and Center-South regions. Insignificant areas are found in the North-East and North-West regions (Figure 2). For the 2018/2019 campaign, it is possible to identify the consolidation of the Middle North region as the most important, but a more dispersed pattern is presented. A sharp increase is seen in the South East and North West regions, an increase in the North West region and one starting in the North region. In the Center-South regions and in particular, in the West, the gain in surface area is not significant to the point of presenting visual differences (Figure 2).

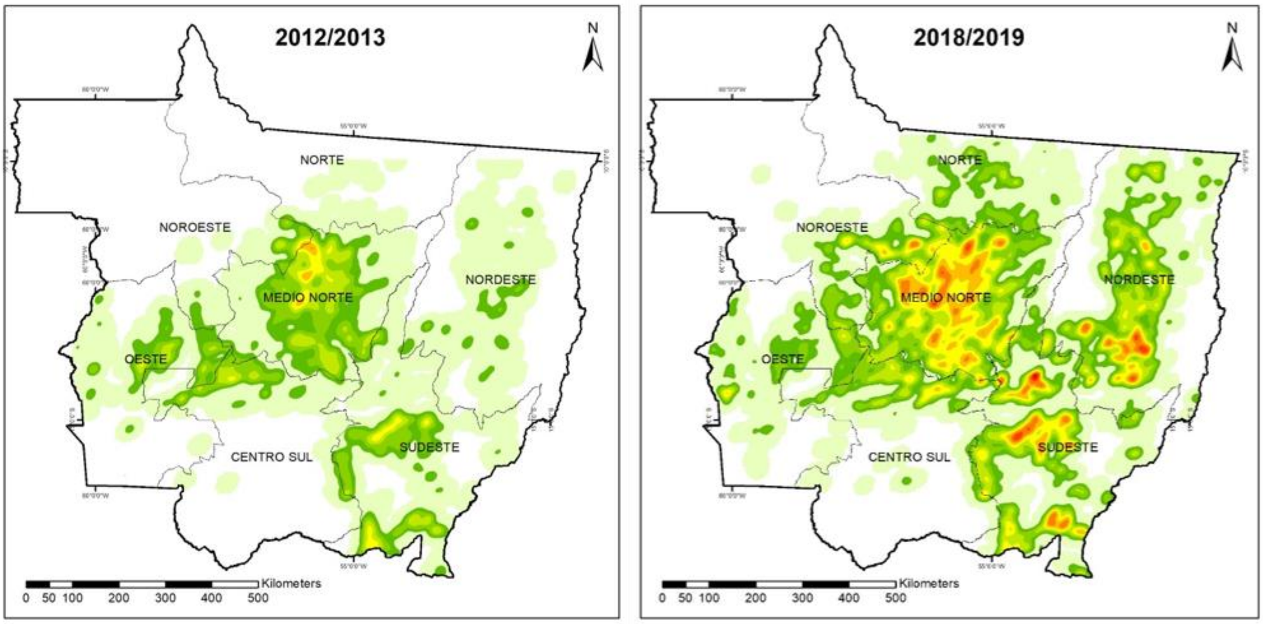

Figure 2. Kernel density maps for dispersion analysis. (a) The density of the areas implanted in the crop year 2012/2013 and (b) Density of the areas implanted in the year/harvest 2018/2019.

CONCLUSIONS

The results indicate the expansion of the integrated livestock farming systems in the state of Mato Grosso in the period of 2012/2013 to 2018/2019.

The estimates of area occupied with iCL are compatible with the surveys performed but it is still a great challenge to find reliable estimates for validation, especially for integrated systems.

The composition of the time series using MODIS data showed great potential in mapping iCL systems, including the approach to the use of an increased depth of variables. The limitations of spatial resolution, which lead to the lower accuracy of the areas to be mapped, as well as the difficulty of detecting small plots in the field, are tolerable limitations due to the substantial gain of temporal resolution

The techniques tested and the modeling performed in this study are promising to make up a methodology for monitoring complex sequential crop systems, especially integrated livestock-farming systems (iCL).

ACKNOWLEDGMENTS

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10. Speaker Contributions

CHALLENGES FOR THE FUTURE OF THE CROP-LIVESTOCK-FOREST INTEGRATION IN BRAZIL

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ABSTRACT

The sustainable intensification of production systems will play a prominent role in the future agenda of public research and development institutions. Brazil has made substantial progress over the past few years in the use of sustainable technologies and systems integration. In the last 30 years, the country has developed a sustainable production model that integrates agricultural, livestock, and forestry production in the same area. The Integrated Crops-Livestock-Forestry (ICLF), already occupies approximately 17 million hectares throughout the national territory and has been expanding. Research data show that it is possible to produce, sustainably and competitively, grains, pasture, wood, and meat in the same area. Thus, the ABC Plan and its second phase, the ABC + Plan, aims to continue strengthening strategic actions in sustainable technological solutions for production in the field and improving the income of rural producers, with a focus on facing agriculture and livestock changes of the climate, mainly in the implantation of ILPF.

Key words: Carbon market; crop-livestock-forest integration; agricultural sustainability

INTRODUCTION

Estimates indicate that in 2050 agricultural production will need to grow globally by 70%, whereas in developing countries this growth will need to be approximately 100%, all of this to feed a growing population that some estimates indicate to be in the order of 2 billion people. In addition to increasing agricultural production, humanity has to face and develop innovative solutions to problems such as scarcity of agricultural land, soil erosion, water and soil conservation, climate change, carbon sequestration, among others.

With these challenges that humanity will have to face in the coming years, the Brazilian Agricultural Research Corporation (Embrapa), a world reference in agricultural research and technology, has been acting since 1973 to provide solutions for the sustainable development of agriculture, through generation, adaptation, and transfer of knowledge and technologies.

Embrapa leads a national agricultural research network that, cooperatively, researches in the different geographical areas (Figure 1) and fields of scientific knowledge. In addition to the forty-three Decentralized Research Units, the network consists of 17 State Research Organizations Agriculture (Oepas), universities and research institutes federal or state level, private companies, and foundations in a broader scientific-technological cooperation field.

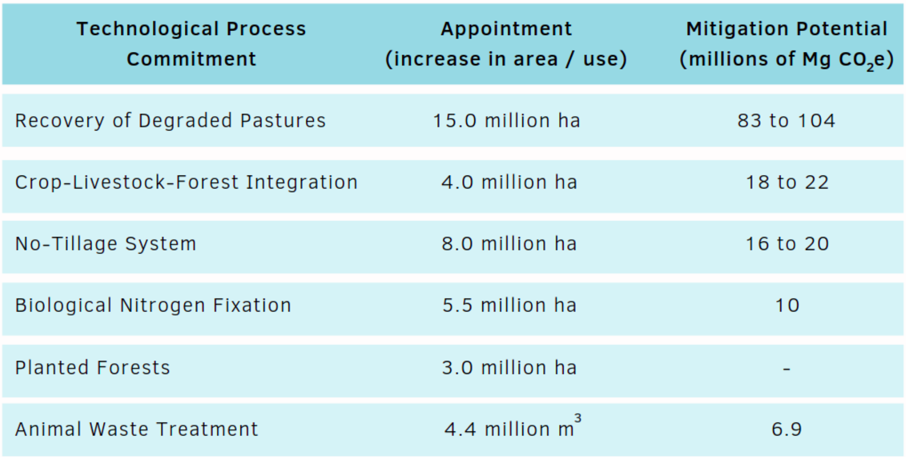
Figure 1. Geographical areas of the forty-three Decentralized Research Units

Technologies developed by Embrapa help transform Brazilian agriculture. Until the 1960s, Brazil imported most of the food that is consumed. Investment in science, the network of institutions, the implementation of public policies, and the entrepreneurship of Brazilian farmers boosted the use of technology and the adoption of good practices in the field, with a huge impact on consumption options, in reducing costs with food and exports. All this history have three main landmarks: the no-till planting in 70's decades, following by the first and second harvests in the '90s, and the crop-livestock-forestry integrations nowadays, that put the country as a reference in science and technology for agriculture and as one of the largest food producers in the world, capable of exporting to around 200 countries.

However, Brazilian agriculture still faces many problems, such as deforestation to open new areas for agricultural production, negative image of agricultural activity inside and outside Brazil, high greenhouse gas emissions in the sector, and difficulties in international negotiations. related to the sector. As a result, at the 15th United Nations Conference on Climate Change, in 2009, Brazil committed to reducing greenhouse gas emissions by 36.1% to 38.9% by 2020, avoiding emissions on the equivalent of 1 billion tons of CO2. Thus, the ABC Plan (Low Carbon Emission Agriculture - or Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture) was launched in 2012, after 2 years of work with several specialists for its structuring.

With the ABC Plan, the country pledged to work to reduce the deforestation rate by 80% in the Amazon and by 40% in the Cerrado, to increase energy efficiency, with the use of biofuels, hydroelectric plants, and alternative sources of biomass. Also, the program established goals for the adoption of technological strategies in agriculture, such as the recovery of degraded pastures, crop-livestock-forest integration, no-till, biological nitrogen fixation (FBN), and waste treatment; and consequently, targets for reducing greenhouse gas mitigation for each of these technologies (Table 1).

Table 1. Technological Process, relative national commitment (increase in the area of adoption or use) and mitigation potential by reducing GHG emissions (millions of Mg CO2e).



Technological Process Commitment	Appointment (increase in area / use)	Mitigation Potential (millions of Mg CO_2e)
Recovery of Degraded Pastures	15.0 million ha	83 to 104
Crop-Livestock-Forest Integration	4.0 million ha	18 to 22
No-Tillage System	8.0 million ha	16 to 20
Biological Nitrogen Fixation	5.5 million ha	10
Planted Forests	3.0 million ha	-
Animal Waste Treatment	4.4 million m^3	6.9

After 10 years of its execution, the ABC Plan has brought many positive results. As for the recovery of degraded pastures, more than 4 million hectares were recovered with the official credit of the ABC Plan, plus another 7 million hectares were recovered from different sources of financing or even resources from producers, reaching approximately 11 million hectares of recovered pastures, which approached the target set at the beginning of the 15 million hectares project.

Concerning the ICLF, 6.0 million hectares were implemented by the ABC program, exceeding the established goal by 2.0 million hectares, the evolution of the technology implementation in Brazil can be seen in figure 2. The no-till system, which aimed to reach 8.0 million hectares, exceeded the target and reached approximately 13.0 million hectares. Concerning biological nitrogen fixation, 10.0 million hectares were implemented with the technology, exceeding the target of 5.5 million hectares. Also, 3.0 million forests were planted. Finally, about the treatment of waste, the program reached 40.0 million m³ of treated animal waste, against the target of 4.4 million. The summarized results are shown in Figure 3.

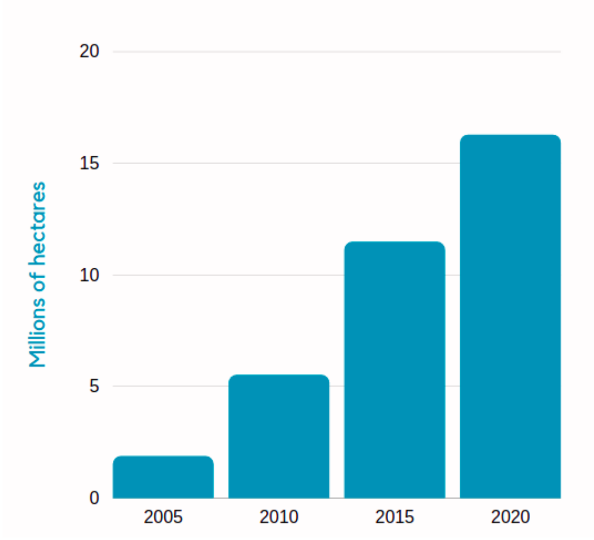


Figure 2. Growth of ICLF in Brazil.

More than 4 million ha were recovered with the ABC's official credit until 2018, and at least another 7 million ha were managed with different sources of financing or the producers' own resources, reaching close to the goal of 15 million ha.

The program reached 40 million m³ of treated animal waste, against the target of 4.4 million m³.

By 2017, nitrogen fixation reached 10 million ha, compared to the target of 5.5 million ha.

Direct planting, which aimed to reach 8 million ha, reached approximately 13 million ha, exceeding the target.

Adoption reached 6 million ha, exceeding the target by 2 million ha.

Figure 3. Results achieved by the ABC Plan, after 10 years of execution.

Despite the positive results in almost all goals, greater investment is needed in training technicians, extension workers, project developers, and rural credit operators to work and take the technology to the farmers, technical assistance and information is essential on the practices and benefits of the ABC Plan programs, as well as informing farmers the most efficient way to use the financing available in their establishment.

The Plan ABC+ is the second phase of the Sectoral Plan for Adaptation and Low Carbon Emission in Agriculture, with targets until 2030, was launched by the Federal Government on April 2021 and stands for advancing sustainable technological solutions for production in the field and improving the income of rural producers, with a focus on tackling agriculture and climate change the ABC+ restructures the concepts and strategies of the ABC Plan. For the government, the plan maintains its commitment to sustainability in the production of food, fibers, and energy, promoting resilience and increasing the productivity and income of agricultural production systems, while also allowing the reduction of greenhouse gas emissions. In the areas of agricultural use, ABC+ aims to promote the recovery and conservation of the quality of soil, water, and biodiversity, valuing local specificities and regional cultures, expanding the set of initiatives of the ministry for the promotion of sustainable agricultural production, including strategies as adoption and maintenance of conservation practices; maintenance of integrated systems; genetic improvement and increase of biological diversity of cultivated variables; integrated risk management; climate forecasting and territorial zoning and early warning; analysis of socioeconomic, and environmental performance and technical assistance.

Considering all these aspects, Brazil must face the biggest challenges for increasing the area of CLF in Brazil, which encompasses the rural credit to ensure implementation capability by producers, technical assistance to guarantee that the best technologies are going to be used and spread, a flow marketplace and research & development. However, regarding research and development, other challenges need to be overcome, with include:

- Recover and incorporate degraded pasture areas in different biomes by adopting regionally typified ICLF systems;

- Establish the specificity of management in each Brazilian biome regarding the tree component and its interactions with pasture and crops in ILPF systems to strengthen the implementation of the forest component;

- Strengthening research in ICLF areas related to animal thermal comfort, carbon sequestration, nutrient cycling, and soil, and water conservation;

- Strengthen research to expand options for tree species and pastures validated in Brazilian biomes for use in ICLF;

- Enable simultaneous sowing of crops and pastures in ICLF;

- Add value to ICLF systems by measuring ecosystem services offered.

To overcome these challenges, some strategies must be taken, such as: strengthening international cooperation; strengthening educational and research institutions, investing in robust databases, ensuring more public and private investments, and structuring new partnerships, and strengthening already established partnerships, such as the public-private partnership Rede ILPF.

With the possible world food crisis, Brazil gains prominence and importance as a great producer and supplier of food for humanity. However, it must overcome many challenges to produce sustainably, respecting the environment and the human being. Thus, one of the most viable innovations is the integration-crop-livestock-forest (ICLF), which combines the different agricultural, livestock, and forest production systems, which can be done in intercropping, in succession or rotation, mutually benefiting the activities. ICLF is one of the main technologies adopted in the ABC Plan (Low Carbon Emission in Agriculture Plan), of the Federal Government, for mitigating greenhouse gas emissions in agriculture and for sustainable development, having been considered one of the most important technologies promising to achieve the goals of the ABC Plan established by the country.

LOW CARBON BRAZILIAN BEEF PLATFORM

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INTRODUCTION

Emissions of greenhouse gases (GHG) in the world have been of great concern to the scientific community. Emissions of gases, mainly from carbon dioxide, nitrous oxide and methane, are considered agents that drive climate change. Global organizations, such as the UN, through the IPCC, have called attention to precautions and proposed targets to minimize these emissions. Several global colloquia have brought together countries to debate the issue and propose emission reduction targets, especially regarding more industrialized and developing countries.

The ranking of the countries that emit the most presents China and the USA as the largest emitters of GHG, with Brazil in 6th place (1420.58 Mt CO2e, 2018), when considering the changes in the use of land and forests, represented by deforestation (CLIMATE WATCH, 2021). In Brazil, although agricultural activities represent around 25-27% of total emissions, the estimated enteric fermentation of cattle, derived from agricultural exploitation, represents around 60% and changes in land use values close to 45% of the total of agriculture and livestock, respectively (SEEG, 2021). A great effort has been made to reduce the rate of deforestation in recent years, but it still needs several steps in the legal and operational field to achieve better results.

In view of the continental dimensions of Brazil, and the vastness of the area occupied by pastures and the respective agricultural exploitation, with a contingent of more than 200 million head of cattle, actions in this area are a priority in order to improve production efficiency, with lower emissions per unit of product to be consumed and guarantee of sustainable production.

In this sense, since 2010, with the launch of the ABC Plan (Brazilian Low Carbon Agriculture Plan), by the Ministry of Agriculture, Livestock and Food Supply (MAPA), Brazil has been taking initiatives through public policies, and financial support to producers, who encourage agricultural production in six lines of action. These aim at reducing and or mitigating GHG emissions and include six main activities: the recovery of degraded pastures, the use of crop-livestock and crop-livestock-forestry integrated systems, no-till systems, biological nitrogen fixation, and treatment of residues from animals (ALMEIDA et al., 2012).

As the Plan progressed, and the Paris Agreement in 2015, goals were proposed for territorial areas to be reached and the number of GHG that could be mitigated with the implementation of the ABC Plan. It was estimated that by 2020 these areas should reach about 35.5 M ha and the corresponding mitigation of 133 to 163 Mg CO2e. However, according to MAPA data, between 2010 and 2018, these technologies were adopted in 52 M ha and mitigated approximately 170 Mg CO2e, exceeding the target by 15%.

At the time of the execution of the ABC Plan, initiatives in the research area and even in the private sector were stimulated with the objective of proposing the so-called concept brands, with specific, auditable and certifiable characteristics of agricultural production, which in addition to being in accordance with the rules general aspects of the ABC Plan, could create specific niches for meat production with low carbon emissions.

History of the Low Carbon Brazilian Beef Platform

In the context of global demand for quality products from more efficient, productive agricultural systems and with less environmental impact, associated with the theme of GHG, the Brazilian Agricultural Research Corporation (Embrapa) has been developing protocols for livestock products that attest by means of validated indicators through scientific research, which were the result of systems with mitigation or even neutralization of the GHGs issued. Thus, the brands Carbon Neutral Brazilian Beef - CNBB (ALVES et al., 2015) and Low Carbon Brazilian Beef - LCBB (ALMEIDA; ALVES, 2020) emerged, the first in the world, which triggered initiatives from other countries.

In 2011, Embrapa proposed a major national research project called the Pecus Research Network (http://www.cppse.embrapa.br/redepecus/), whose objective was to deepen knowledge and develop technologies for producing low-carbon meat and milk, as well as establishing methodologies, estimating GHG emission parameters in production of meat and milk under Brazilian conditions. Several research actions of the project made a great contribution to the knowledge of these emissions, whether related to methane in the enteric digestion of cattle, emission of nitrous oxide in pastures, according to different cultural treatments, nitrogen fertilization management, etc. The project generated and expanded the installed capacity of knowledge by researchers and technicians, allowing the formation of a structured base of human and material resources for future work and advances in this area of knowledge.

Carbon Neutral Brazilian Beef

An unprecedented initiative by Embrapa, in 2015, proposed the first concept brand in beef production at the Institution, the so-called Carne Carbono Neutro (CCN) or Carbon Neutral Brazilian Beef (CNBB), which has as main objective the production of beef, in the growing and fattening phases, with the total neutralization of methane emitted by grazing animals. The main focus of neutralization lies in planting trees on pastures, in an organized manner in number and spacing, which allow profitable agricultural exploitation, animal comfort and well-being and logging with different plant species in a sustainable manner (ALVES et al., 2015; ALVES et al., 2017). A detailed, auditable and certifiable protocol has been proposed for this purpose. Several Technological Reference Units have been implemented in different locations in the country (ALMEIDA et al., 2016; GONTIJO NETO et al., 2018; ALMEIDA et al., 2019; BORGHI et al., 2020; NOGUEIRA et al., 2020; SILVA et al., 2021) and farms are already starting to enroll in the program, in partnership with national slaughterhouses, in order to obtain a special production seal of the so-called CNBB/LCBB. The CNBB seal was launched in the Brazilian market in 2020, by Marfrig Global Foods, and the certification program is available (http://ranimal.cnabrasil.org.br/), as well as, some socioeconomic studies (PEREIRA et al., 2019; ZANASI et al., 2020; SPERS et al., 2021).

Low Carbon Brazilian Beef

This concept brand began its studies in 2018, pioneered by Embrapa, with the participation of dozens of researchers from more than 14 Research Centers in its national network. It is expected that, after the launch of its general guidelines in 2020 (ALMEIDA; ALVES, 2020), the publication in the second semester of 2021, of the requirements for certification at the field level, in order to allow the enrollment of producers in the program, aiming at obtaining the respective concept brand seal. The main objective of this brand is to allow producers of beef cattle to be reared and fattened, comply with a series of legal requirements, good agricultural practices, and reach levels that allow the mitigation, even if partial, of the methane emitted by the cattle. Once the main requirements are met, the main focus is on carbon sequestration in the soil, which must be maintained in ranges considered adequate, both in terms of content and in stock. The objective is to maintain standards of carbon and soil quality above degraded pasture areas, and even areas with native vegetation, providing in addition to improving soil quality, the maintenance of agricultural production in a sustainable manner. The first results of the protocol validation and socioeconomic studies were presented at this Congress (PEREIRA et al., 2021; SILVEIRA et al., 2021).

Native Carbon

The protocol for the beef production of Carbono Nativo or Native Carbon started in 2019 by Embrapa and is still being concluded. The basis for this concept brand is centered on the silvopastoral systems for GHG mitigation, especially the emission of methane, by the introduction of native or existing trees in the pasture. It aims to enhance the natural landscape and the carbon incorporated by trees of native species (MAURO et al., 2020).

Low Carbon Brazilian Beef Platform

Accounting for the carbon footprint, emissions, mitigation, neutralization of GHG in beef production systems is strategic for consumers, producers and governments looking for business opportunities in the context of sustainability, productive efficiency, climate change, environmental impacts, well-being animal health, food security and international credibility.

With the advent of the creation of different brands, the demand for the creation of other concept brands that aim at different stages of agricultural and livestock creation and by-products has been an increasing demand in the expansion of the brands. The need to align these brands with the tax incentive, credit and benefits policies made the creation of a platform that would house all these ideas a necessity (ALVES et al., 2019; VIEIRA et al., 2020).

Thus, the creation of the Low Carbon Platform in the production of beef cattle, an unprecedented Brazilian initiative, is a set of different concept brands formed with the content of application of current environmental legislation and good agricultural practices, and socioeconomically viable in meat production. Agricultural practices must be certified and cover aspects such as: soil, pasture, animal and tree management, which aim to neutralize or mitigate the emission of GHG for sustainable agricultural production. In figure 1, an example of a flowchart operation of the concept brands for beef and attributions of the parties involved is presented.

After this initiative with beef cattle, Embrapa started studies for the development of low carbon protocols for other products, such as soybeans (NEPOMUCENO et al., 2021), milk and coffee.

These initiatives are in line with the new sectorial Plan for adapting to climate change and low carbon emissions in agriculture with a view to sustainable development from 2020 to 2030, called ABC + (BRAZIL, 2021).

Figure 1. A flowchart operation of the concept brands for beef and attributions of the parties involved.

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EVOLUTION OF INTEGRATED CROP-LIVESTOCK AND CROP-LIVESTOCK-FORESTRY SYSTEMS IN BRAZIL

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ABSTRACT

The use of integrated systems in Brazil started in the beginning of 20th Century. Since then, with the evolution of researches focused on the soil-plant-animal-forest interactions, several integrated systems have been shaped in association to farmers. The main benefits provided by the synergies among crops and pastures are: increase animal productivity by restoring pasture yields, increase crop productivities by improvements in the soil's physical, chemical and biological properties and the interruption of biotic cycles of weeds, pests and diseases. The main positive impacts on the environment are related to soil and water conservation, increases in soil organic carbon and land-saving effect. From an economic standpoint, mixed systems allow a more rational use of inputs, improvements in cash flow and reduction of the economic risks. The greater nutrients cycling from forages associated to more efficient use of fertilizers by crops saves fertilizers and reduce the production costs. Integrated crop-livestock (ICL) and crop-livestock-forestry systems (ICLF) might be considered as a key strategy to promote sustainable intensification in agriculture.

Key words: sustainable intensification; soil conservation; land-saving; Brazilian Cerrado

INTRODUCTION

The conversion of monocultures (the dominant practice) to polycultures should be understood as a gradual process of transformation to a more complex productive model. This complexity results from several positive and negative interactions between the integrated agricultural system's components (annual crops, pastures and trees). The increasing interest in crop, livestock forest integration is based on the potential benefits that result from synergies between the systems. Some examples of these effects are improvements in soil physical, chemical and biological properties; greater infiltration levels, greater soil water stocking levels as well as improved carbon sequestration resulting from increased soil organic matter; soil erosion decreases as well as less soil nutrient losses resulting from greater plant coverage levels and improved soil structures resulting from productive pastures; greater fertilizer use efficiency resulting from greater nutrients cycling by the system's perennial components (forages and trees); greenhouse gas emissions mitigation as well as other results.

In this context, integrated crop, livestock forest systems (ICLF), in its various modalities, is considered a key strategy to maximize the use of natural resources, by combining increased productivity with environmental conservation of already deforested land use in Brazil. Crop, livestock, forest integration is a production system that integrates, in consortium, rotation or succession, different agricultural, livestock and forest productive systems, in the same area, in such a way that there exist synergies between the components (the total is greater than the sum of the parts). Nowadays, the total area cultivated with integrated systems in Brazil is estimated at 15 million hectares (REDE ILPF, 2021).

The beginning of the researche in integrated systems: the Brazilian Cerrado perspective

Crop-livestock integration (ICL) has been used since 17th century in Europe to increase agricultural production. However, most likely, the intensive use of fertilizers and mechanization reduced the need for integration (LEMAIRE et al., 2014). In Brazil, the use of integrated crop-livestock production systems started by influence of European immigrants, when they adapted this concept to subtropical and tropical conditions. At the beginning of the 20th Century, in Rio Grande do Sul state, the integration started with cattle grazing the stubble of lowland irrigated rice. This integrated system model has been used until these days. Since the 1970s, other crop-livestock models have been developed in the northern region of the state, integrating soybean and maize crops with winter pastures for grazing beef and later with dairy cattle. In the 1990s, the first research on silvopastoral and agrosilvopastoral integration started, expanding knowledge, and developing technologies focused on the management of soil-plant-animal-forest interactions (RIO GRANDE DO SUL, 2017).

At Embrapa, since its inception, research has been carried out to evaluate production systems of annual crops such as soybeans, corn and rice in rotation with pastures. Embrapa Cerrados, in its beginning, had already consolidated in its research philosophy the need to develop “alternative agricultural production systems, which mitigate risks and maximize results through a continuous activity able to use (all year) the resources of land, capital and, mainly, labor, with man as the ultimate concern”. Since then, Embrapa has included in its “research, for food and fiber production, the entire agro-silvo-pastoral-socio-economic spectrum” (EMBRAPA, 1978).

The consortium of forage grasses with grain crops, a common practice in crop-livestock integration, was first adopted in Cerrado for establishing pastures at the beginning of agricultural development of the region (Table 1). The intercropping of upland rice with forage grasses was one of the agricultural practices adopted by ranchers for the establishment of pastures (EMBRAPA 1978). They also seeded forage grasses in succession to upland rice crop with or without fertilization. In more fertile soils, *Panicum maximum* cv. Colonião was simultaneous cropped with maize (MACEDO; ZIMMER, 1993). After the establishment, the pastures were usually overgrazed and consequently the degradation process started. The areas located in more fertile soils close to roads and warehouses started to grow annual soybean crops in the summer, and nothing was planted in the autumn-winter (dry period). At that time, the practices of crop rotation or the maize crop in offseason was not usual (MACEDO, 2009). The plows and harrows were used for soil preparation. This system accelerated the occurrence of pests, diseases, and soil degradation. In order to restore the productivity of these pastures implanted through rice-pasture integration, the upland rice crop was, again, the pioneer in the recovery of degraded pastures in the Cerrado. However, this type of production system was not named “Crop-Livestock Integration”. The terms “sequence of crops or crop-pasture rotation” were used.

Table 1. Timeline of cropping systems in a 4 years long experiment at Embrapa Cerrados

System/Year	Year 1	Year 2	Year 3	Year 4
S1	Pasture	Pasture	Pasture	Pasture
S2	Rice + Pasture	Pasture	Pasture	Pasture
S3	Rice	Rice	Rice + Pasture	Pasture
S4	Soybean	Soybean	Soybean	Rice

Source: Annual Technical Report of the Cerrado Agricultural Research Center: 1976-1977. Embrapa (1978).

In the 1980s, the practice most used by ranchers to recover degraded pastures was only plowing, which actually provided positive effects only in the short term with a subsequent and rapid decrease in the pastures yields (VILELA et al. 1989). As a result, in 1988 a study was conducted at Embrapa Cerrados whose objectives were to evaluate the effects and final costs of different consortium strategies of grain crops with forage for recovering degraded pasture of *Brachiaria decumbens* (CARVALHO et al., 1990). The main results found in this work were that the use of plowing, by itself, did not provide effects on pasture recovery. However, this practice associated to the application of limestone and corrective fertilization was feasible, from a technical point of view. Among the crops, corn presented the highest grain production, due to its greater capacity to compete with forage in the initial development phase.

In the same period, Embrapa Arroz e Feijão also started studies on the renewal of pastures with the rice, corn or sorghum intercropped with *Brachiaria brizantha* cv. Marandu. Parallel to these studies and following the strategy recommended by this Embrapa unit, validation of the pasture renewal system through the rice consortium with *B. brizantha* was implemented at Fazenda Barreirão, in Piracanjuba, state of Goiás. In honor of this farm, the system was named the Barreirão System (KLUTHCOUSKI et al., 1991). Due to the success of this recovery / renewal system for degraded pastures, the states of Mato Grosso, Minas Gerais and Goiás adopted the Barreirão System as an official government program (YOKOYAMA; STONE, 2003).

The deficit of forage in the off-season (“dry season”) and the production of straw in quantity and quality for No-Tillage were the main drivers for the development of another crop-livestock integration system, named Santa Fé. The Santa Fé System is another Embrapa Technology honoring a farm, located in Santa Helena de Goiás, GO. (KLUTHCOUSKI et al., 2000). This system recommends the intercropping of grains (corn and sorghum) with *Brachiaria* genus forages. However, due to problems of forage competition with soybeans and difficulties in harvesting, this crop was not included in the Santa Fé system. Since then, the oversowing of *Brachiaria* seeds in soybeans has been considered one of the alternatives to overcome these problems. The consortium of forage grasses with annual crops has become an usual practice to anticipate the establishment of pasture in rotation with grain crops in ICL systems. These days, the main ICL alternatives are: sowing forage grasses (*Brachiaria sp., Panicum maximum*) between the lines of the soybean crop (KLUTHCOUSKI et al. 2000; Machado, 2017); and oversowing of forage grasses at the end of the soybean cycle (KORNELIUS et al., 1987). The oversowing of these forages in the corn crop (stages V2 to V4 and R4 to R5) has also been successfully adopted by farmers.

The Barreirão and Santa Fé systems attracted the attention of technicians, researchers and research and teaching institutions. Since then, numerous researches were developed on the ICL theme, focusing mainly on the synergism of the system's components (crop and livestock). The São Mateus System innovates in the strategy of recovering degraded pastures in sandy soils through crop-livestock integration, focusing on the chemical, physical and biological correction of the soil (Salton et. al., 2013). Initially, the chemical correction of the soil is carried out and a temporary pasture of *Brachiaria brizantha* is implanted aiming at improvements in soil’s physical and biological traits (due to the development of the forage roots) and straw production for soil no-till of soybean crop. The accumulated forage mass might also be used for grazing throughout 6 to 9 months and, in this case, the meat production can partially or fully offsets the initial costs. At the beginning of the rains, the pasture is desiccated with herbicide and, 20 days later, soybean is sown.

The Santa Terezinha farm, in Uberlândia, MG, has practiced, in sandy soils, the crop-livestock integration since 1984 (Table 2). In early 1978 beef cattle ranching was the only activity in the farm. From 1984 on, grain crops were grown in rotation with pastures in order to recover degraded pastures. The main rotation system consisted of conventional soil preparation to crop soybeans during the first two years, followed by the establishing the forage grass intercropped with maize in the third year.

Table 2. Evolution of crop-pasture rotation and pasture stocking rate at Santa Terezinha farm*, Uberlândia, MG.

Year	Area (%)			Heard	Stocking rate[2]
	Degraded pasture	Crops	Recovered pasture	(head)	(head/ha)
1983	100[1]	0	0	1,094	1.1
1988	29	42	29	821	1.4
1992	0	59	41	1,150	2.8
1996	0	64	36	1,200	3.2
2003	0	30	70	1,800	2.6

[1]The initial grazing area equal to 1,000 ha. [2]Estimated stocking rate for the rainy season, during the dry season the animals also occupy the crop areas to use the corn and soybean remains. *In the farm, the soil Neossolo Quartzarênico (Areia Quartzosa) predominates. Adapted from Vilela et al. (2008).

In the early 1990s, due to the reduction of soil organic matter contents (convetional tilling) associated to the need to simplify soil preparation and planting operations, the no-till system started to be used in the farm. The Santa Terezinha (Uberlândia, MG state) and Cabeceiras (Maracaju, MS state) farms were the first to adopt the ICL system in the Cerrado, contemplating crop-pasture rotation in time and space.

In the Santa Brígida system (OLIVEIRA et al., 2010) the forage legumes (pigeon pea) were incorporated into the *Brachiaria* maize consortium, another evolution in ICL systems. This system aims to produce forage with greater nutritional value and also to increase the nitrogen supply in the soil through the biological fixation of legumes, which potentially reduce the need for nitrogen fertilizers in the next crops.

Currently in the Cerrado there are several crop-livestock integration systems, modulated according to the profile and objectives of the farm and to the regional and farm peculiarities, such as: climate and soil conditions, infrastructure, producer experience and available technology. In this region, three types of crop-livestock integration stand out: a) livestock farms in which the introduction of grain crops (rice, corn, sorghum, soy) in pasture areas aims to recover pasture productivity at lower costs (amortization of recovery costs through the sale of grains); b) farms specialized in grain crops that adopt forage grasses to improve the soil cover for the no-tillage system and, in the off-season, they can use the forage for cattle feeding (“off-season cattle”); and c) farms that systematically adopt pasture and crop rotation to intensify land use and benefit from the synergism between the two activities (VILELA et al., 2011).

In 2017, the amount of roundwood extracted for industry and fuel from native forests in Brazil was 40.7 million m^3 and of planted forests was 226.6 million m^3 (SFB, 2019). Nowadays, the forests planted area for commercial purposes in Brazil is around 10 million hectares (1.17% of the Brazilian territory) (IBGE, 2019). By 2030, the estimated world consumption of logs will be 2.4 billion m^3, which means an increase of approximately 45% in relation to consumption in 2005 (FAO, 2009). Therefore, the major question is not whether there will be wood in the future, but where it will come from, who will produce it and how it will be produced?

Given this scenario, the crop-livestock-forestry integration systems become a viable alternative for the recovery of low productive or degraded areas. The tree component is an advancement in crop-livestock integration, and it takes place in the initial phase of implementation of the system, usually with agriculture (PULROLNIK et al. 2019).

The modal ICL system in the Cerrado region: the off-season cattle model

In an analogy to the second cropping period (planting maize just after the soybean harvesting), this double cropping system with cattle has been named "off-season cattle" or "off-season pasture". The “Off-season Cattle” model refers to cattle feeding (breeding, raising and fattening) by taking advantage of the forages accumulated from the consortium with maize or soybean after harvesting (Vilela et. al. 2018). The main "Off-season cattle" alternatives used by producers can be seen in Figure 1. The choice of one these alternatives depend on the operational characteristics of the farm such as infrastructure, fences, waterworks, etc. and climatic conditions which are favorable to maize, sorghum and soybean crops.

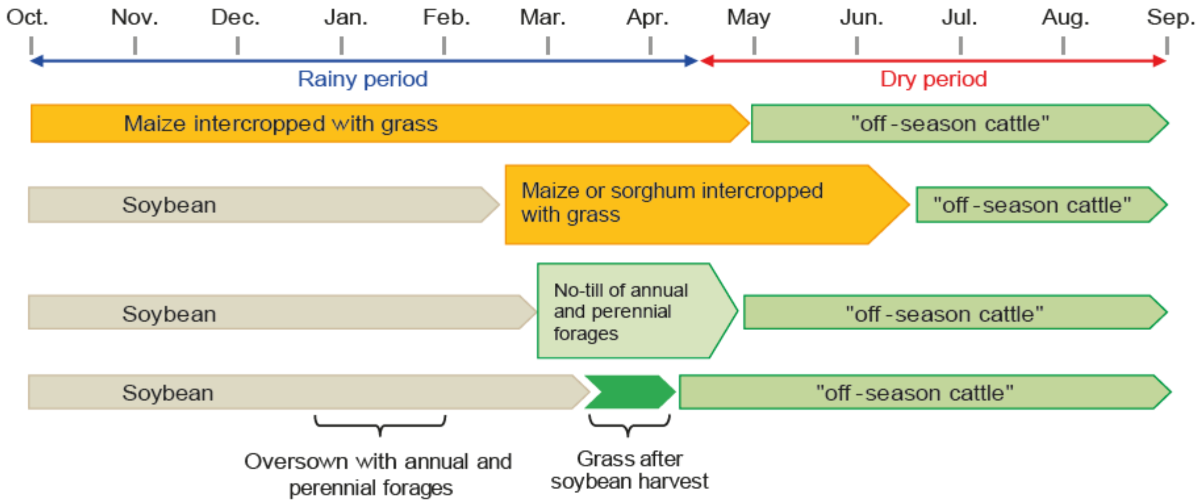

Figure 1. Potential arrangements of integrated crop-livestock in the “off-season cattle” model in different regions of the Cerrado.

This system has increased in Cerrado region because of benefits of pastures, as cover crop, on soybean productivity (up to 780 kg/ha more) in succession and also because the possibility to produce up to 6.9 @ of beef carcass in the fallow. Taking advantage of this some crop farmers have started to raise cattle because of the extra income provided by livestock in the off-season. This is another ICL case of land use diversification and intensification. Currently, the land occupied with this ICL system in the Cerrado region is estimated at 3 million hectares (EMBRAPA, 2020).

Potential benefits of ICLF systems

In well-managed systems in Brazil, positive impacts of integrated crop-livestock systems include: a) increases by 15 to 20% in soil organic matter in comparison to organic matter levels of native Cerrado; b) increases by 90% in phosphorous use efficiency, in the long term, in comparison to that verified in soybean-corn rotation; c) productivity gains of soybeans by 10 to 15% when in succession to fertilized and higher productivity pastures; d) average increases in animal productivity in the fattening stage by about 4 times (600 kg of liveweight/hectare/year in relation to the breeding-fattening stage of tradition livestock (120-150 kg of live weight hectare/year; e) animal productivity average increases in the breeding stage by about three times (300 kg of weaned calves/hectare/year in comparison to traditional livestock (85-110 kg of weaned calves/hectare/year.

In environmental terms, there are medium and long-term benefits of pastures on grain crops, among others, due to positive impacts on conservation of natural resources and to improvements in soil quality observed during the pasture phase. Therefore, soil and water conservation tend to benefit from crop-pasture integration, since water and soil losses are substantially lower than those verified in conventional planting crop cultivation systems (soil plowing) and no till planting; therefore, leading to greater water table recharge. Gains in productivity and efficiency provided by integrated systems also positively impact the use of natural resources, by reducing pressure to clear new areas of native vegetation and minimizing competition for land use (land-saving effect). Because of the numerous benefits provided by forages (grasses and legumes), these should be also be considered as key components in the development of new plant and livestock systems.

CONCLUSIONS AND PERSPECTIVES

Research results in integrated crop, livestock, and forest systems throughout Brazil allow us to conclude that crop and pasture rotation in grain production systems is an effective solution to improve soil chemical, physical and biological qualities. Such externalities occur as a result of increases in organic matter and improvements in soil structure. Verified synergies between crops and pastures are responsible for grain and meat productivity gains taking place in these mixed systems.

In livestock production, integrated crop-livestock systems are an interesting alternative that enables correction of soil fertility in Brazil. The positive effect that pastures have on subsequent grain crops can also be directly observed by higher grain productivity levels, in particular when pastures fertilization takes place in the livestock phase.

From an economic standpoint, increases in crop and pasture productivity should be considered as well as more rational use of inputs, machinery and labor, improvements in cash flow and increases in liquidity. As a result of the greater diversification of activities in rural properties, it is possible to reduce the risks that the business faces. For example, without irrigation it is possible to obtain up to four harvests per year: soybeans and short cycle corn planted together with forages and pastures during the dry season – straw for soil coverage in no till. The possibility of having a smaller demand for use of inputs such as fungicides, herbicides and insecticides in integrated crop-livestock systems brings short-term economic benefits that are easily estimated. Similarly, nutrients cycling by forages and the greater efficiency in soil nutrients use by grain crops in integrated crop-livestock systems, in comparison to that of single crops, generates savings in fertilizer use and, as a result, leads to reductions in production costs.

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REDE ILPF ASSOCIATION ACTIONS

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ABSTRACT
Brazilian agriculture has been developing a lot in the last 40 years. Science has evolved, rural producers have also evolved and the emergence of new ways of producing sustainable agriculture gains prominence. In this context, the Crop-Livestock-Forest Integration has been gaining prominence for the increase of productivity taking into account the aspects of sustainable development, at the same time that it solves the problem of degraded pastures in Brazil. The Rede ILPF Association is a public-private partnership, formed by Embrapa, Bradesco, Ceptis, Cocamar, John Deere, SOESP and Syngenta. Its main mission is to promote the adoption of the Crop-Livestock-Forest Integration technology for the benefit of society. The Rede ILPF is a Think Tank that works for the sustainable development of agriculture, starting from the promotion of research projects and technology transfer, training of technicians, alignment of the private sector to the demands of producers, certification of properties, and development of financial mechanisms. With these activities, the Rede ILPF aims to subsidize the elaboration of public policies and international negotiations, promote the opening of new differentiated markets and disseminate good production practices to consumers.
Key words: Public-private partnership; crop-livestock-forest integration; agricultural sustainability.

INTRODUTION: A EVOLUÇÃO DA AGRICULTURA NO BRASIL

The evolution of agriculture in Brazil in the last 50 years is not a matter of chance, it is the result of a lot of dedication, science, technology, and working together.

A major milestone was the creation of Embrapa in 1973 and, in the same period, many rural producers in Brazil started to work with the No-Tillage System. The adhesion of this system in Brazil was extremely important, as it is a tropical country with a high rate of precipitation. With the No-Tillage System, it was possible to preserve and conserve agricultural soils from erosion. In addition, the No-Tillage System was responsible for mitigating emissions of 1.5 tons of CO2e/ha/year, being a system that in addition to conserving soil and water, is also a system that can bring benefits to climate change. In comparison, conventional planting systems are responsible for the emission of an average of 0.5 tons of CO2e/ha/year.

Currently, in Brazil, we have 60% of the planting areas with No-Tillage Systems, with vegetation cover, protecting the soil, water and sequestering carbon, it is important to highlight the role of rural producers in adopting this conservation system.

In the 1990s, what was called “safrinha” started, which started to reach productivity so high that we no longer call “safrinha” but “the second crop”. An example of this is the production of corn, which in the second harvest, corresponds to two-thirds of the total production. Or even the production of cotton, which is 100% produced in the second harvest. This second crop system is also very important concerning climate change, mitigating emissions of an average of 0.5 tonnes of CO2e/ha/year.

Over the years and technological developments in rural properties, also in the 1990s, the movement of the Integrated Crop-Livestock-Forest (ICLF) grew.

Our Great Innovation: The Integrated Crop-Livestock-Forest

The Integrated Crop-Livestock-Forest (ICLF) is a technological package of management and techniques that integrates different components of agricultural, livestock, and forest production in the same area, in a consorted, rotated, or in succession way, in which a component promotes effects on others and vice versa. The ICLF was idealized to recover degraded pastures and to avoid deforestation. Not only, but the ICLF is also one of the main technologies adopted in the Low Carbon Emission Plan in Agriculture (ABC Plan) to mitigate greenhouse gas (GHG) emissions in agriculture, being able to mitigate up to 5.0 tons of CO2e/ha/year.

Also, the ICLF is a technology that promotes sustainable development, involving social, environmental, and economic complexities, ensuring several benefits, such as nutrient cycling, soil conservation, animal welfare, biodiversity maintenance, greenhouse gas mitigation, and productive efficiency, which consequently, ensures an increase in producer income and job creation; very important socio-economic benefits generated by the ICLF.

Due to its countless environmental, social, and economic advantages, efforts have been made in recent years for the adoption and implementation of the ICLF in Brazil, involving cooperation between public, private, and third sector institutions, through research and development, transfer of technology, investments, training, and innovation.

Embrapa (Brazilian Agricultural Research Corporation) was the pioneer institution in the diffusion and implementation of the ICLF in degraded areas and it has been standing out in the national and international scenario for the development of sustainable agricultural production practices.

The Rede ILPF Association

In this context, a Public-Private Partnership (PPP) was created between Embrapa and 3 other companies in 2012. The first format of this PPP was a project financed by the companies and executed by Embrapa. The main objective of this project was to disclose the ICLF throughout the country and expand the adoption of the technology. This partnership was called "Rede de Fomento ILPF" (which means ICLF promotion network). With the evolution of the work and the success obtained, it was sought to innovate the management model of this partnership. Thereby, in 2018, it went from Rede de Fomento ILPF to Rede ILPF Association, having as associates the private companies Bradesco, Ceptis, John Deere, Soesp, Syngenta; the Cocamar cooperative; and the public company Embrapa.

Rede ILPF has the mission to Promote and encourage the adoption of ICLF for the benefit of Brazilian society, as part of an effort, aiming at the sustainable intensification of Brazilian agriculture. The Association values revolve around commitment, cooperation, innovation, transparency and belief in a better world. The Rede ILPF has the vision of becoming the biggest reference in sustainable agricultural technology, being able to contribute to the environmental preservation and food security in a changing world.

To achieve the vision and develop continuously, the Association focuses its efforts on technology transfer, training in technical assistance, and communication. Also, it has been dedicated to internationalization, adding value through certification and innovation, aiming to raise resources in international funds.

Current Scenario and Trends

With all these efforts and partnerships involving rural producers, science, technology, the private sector, and the public sector, today we have an area of 17 million ha of ILPF in Brazil. In addition, we are increasingly joining efforts to reach the target set for the year 2030, of 35 million ha.

The productivity benefits in these areas with ILPF have been significant, such as the best thermal comfort for the animal, as the presence of trees reduces the animals' body temperature by at least 3%; and the production of better-quality fodder. All this combined with other diverse advances in the agricultural sector, such as genetically modified organisms, investment programs in fleet renewal, and improvement of agricultural machinery, and with the movement of producers in search of greater productivity, the agricultural scenario has been strongly changing. from the country. Brazil is responsible for the production of 275 million grains and approximately another 200 million head of cattle, and in the coming years, we are seeing a stronger movement in agricultural production, which respects the environment and is aligned with sustainable development.

Even in the context of the pandemic, in which we have a dramatic economic and social scenario around the world, the agricultural sector is managing to sustain Brazil's GDP and we are experiencing increasing agricultural production. This is all possible because of the strong investment by producers in wanting to improve their productivity, whether by improving their equipment, through processing and storage of production, investment in solar energy, irrigation, and more advanced technologies in the field.

Another important aspect to highlight, as an accelerator in the process of sustainable intensification of agriculture in Brazil, is the participation of young people in the field and agricultural activities. Many young people who left rural areas to study or seek better employment conditions in the urban environment, with the pandemic, are gradually returning to rural areas and becoming interested in the agricultural activities carried out by their family or by their region of origin. These young people are bringing more innovation to the field, a mentality of greater connectivity, greater use of technology, and greater search for innovation. Concerning the United States and the European Union, Brazil has the lowest average age of rural producers, with an average age of 45 years.

Concerning the connectivity and the digital influence on agricultural activities, Brazil is also ahead of the United States, with 12% more rural producers connected and entering the digital world.

In addition, the logistics for the outflow of agricultural production in Brazil have changed. In this year 2021, for the first time, Brazil is exporting 50% of the grains produced by the ports of Arco Norte Brasileiro, representing a 30% reduction in freight costs.

All this history presented, shows the great evolution of the Brazilian agricultural sector and shows our total capacity to innovate and improve agricultural productivity, even more, being concerned with sustainable development, combined with important innovations for the carbon market in the sector. With all these new trends on and off the property, the Brazilian agricultural sector will have the possibility to increase its production without advancing to areas of native vegetation and becoming an important country for world food security.

II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS
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CARBON MARKET POTENTIAL IN CROP-LIVESTOCK-FOREST INTEGRATION SYSTEMS

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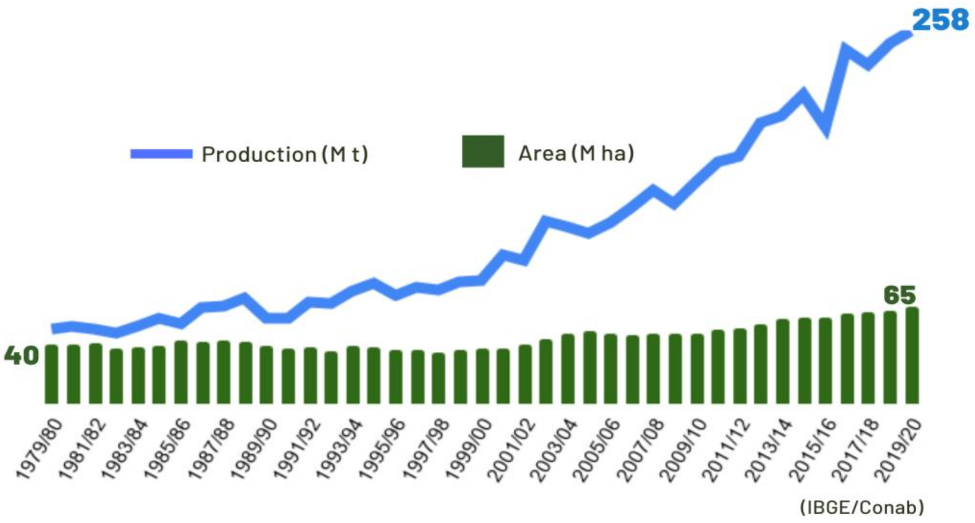
ABSTRACT

The crop-livestock-forest integration is an opportunity to deal with today's challenges. With an increasingly globalized and dynamic world, thinking about innovative environmental solutions requires a systemic approach that manages complexities in a sustainable, responsible and ethical manner. ILPF has enormous potential for grouping a set of agricultural and ecological processes that work synergistically for sustainability. One of the greatest potentials for the ILPF is the conversion of degraded pastures, which allows an increase in production, productivity and income to the producer without the need to open new areas of native vegetation. All of this, in line with an unprecedented environmental preservation, re-signifies the very concept of sustainability that can make Brazil become the first agro-environmental power on the planet.

Key words: Carbon market; crop-livestock-forest integration; agricultural sustainability

INTRODUCTION

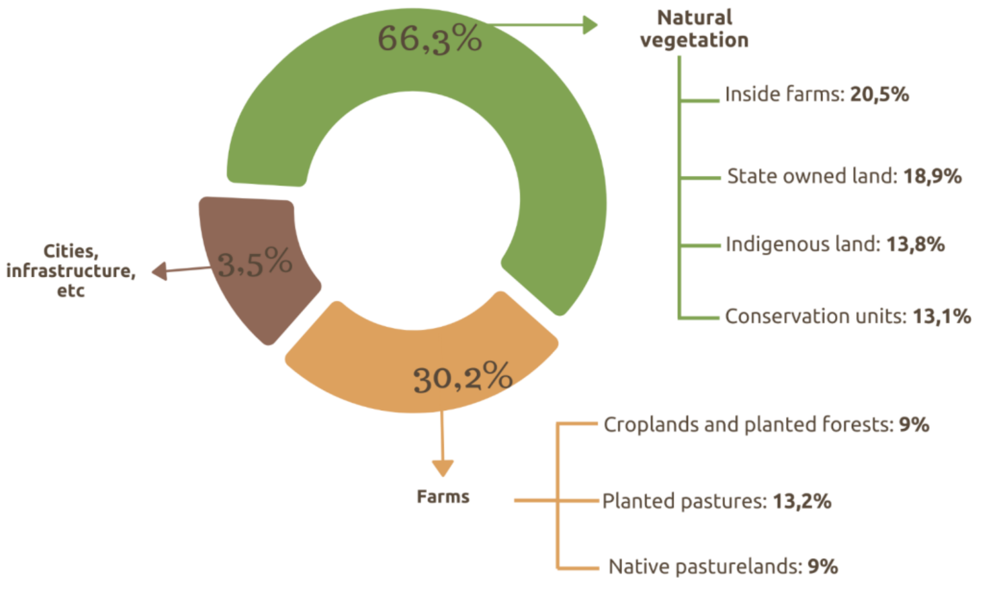
Brazil is an agricultural power. Leader in the world production of oranges, grains, cattle, chicken, corn, and pigs that might contribute to the world food security. This Brazilian agricultural power has been developing in the last forty years, where Brazil enhances agricultural production by 390% while increasing the area by only 25 million hectares reaching a yield of 200 %, as shown in Figure 1.



(IBGE/Conab)

Figure 1. Brazilian agriculture forty years of evolution.

There are many ways to develop expressive agricultural numbers, however, Brazil developed agriculture based on science, entrepreneurship, private sector cooperation, public policies, and rural credit. This results in competitive agriculture while preserving nature, nowadays Brazil holds 66 % of its territory (Figure 2) with various natural vegetation uses, which comprises: conservation units, state-owned land, indigenous land, and preserved vegetation inside private farms, that is, many farmers should produce while keeping protected areas. Even so, Brazil can improve a lot, there are huge opportunities. Brazil has today 180 million hectares of pastures, which encompasses the territory of the UK, Germany, France, Spain, and Portugal together, and at least 50% of this area are degraded (Figure 3). That is, Brazil has an area equivalent to Norway and Sweden to improve moving towards global food security, sustainable development, and a comprehensive and integrated view on the use of resources. To accomplish that we need to understand that a complex world needs integrated solutions because to deal with globalization, population growth, natural resource depletion, climate change, and degraded soil vs productive land requires a systemic approach that manages these complexities in a sustainable, responsible and ethical manner.



SOURCE: EMBRAPA, 2017

Figure 2. Brazil percentage of main land uses.

Integrated Crop-Livestock-Forestry as a Systemic Solution

The Crop-Livestock-Forest Integration (ICLF) is a set of technological and management solutions that integrates different components of agricultural, livestock and forest production in the same area, in a consortium, rotated or in succession, in which a component promotes effects on others and vice versa. ICLF was designed to recover degraded pastures and to prevent deforestation. Not only, ICLF is one of the main technologies adopted in the Low Carbon Emission in Agriculture Plan (ABC Plan) and contributes to the preservation and improvement of the physical, chemical and biological properties of the soil.

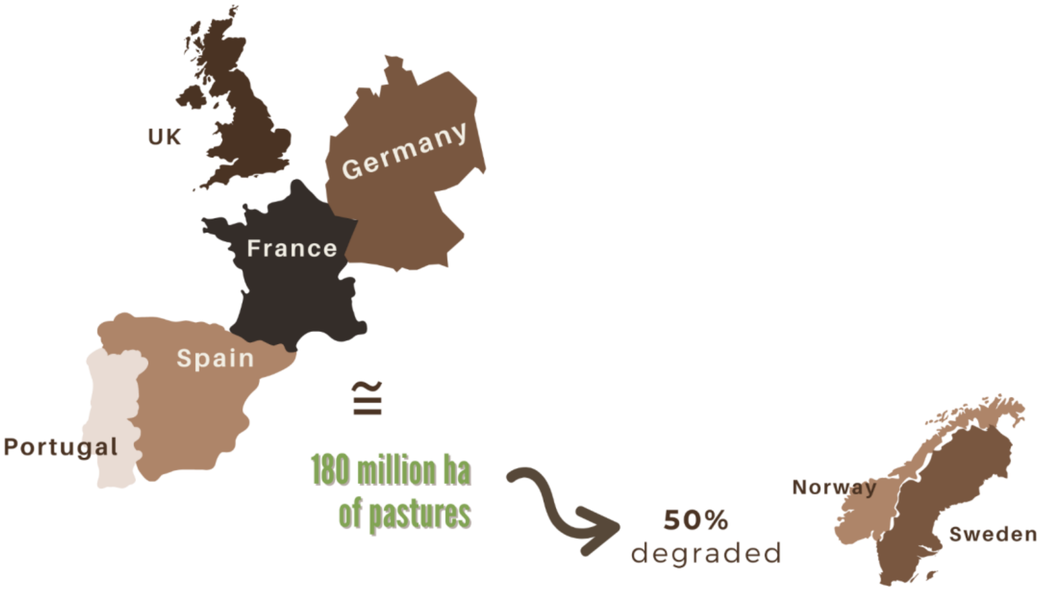


Figure 3. Pasture area in Brazil and its comparative size.

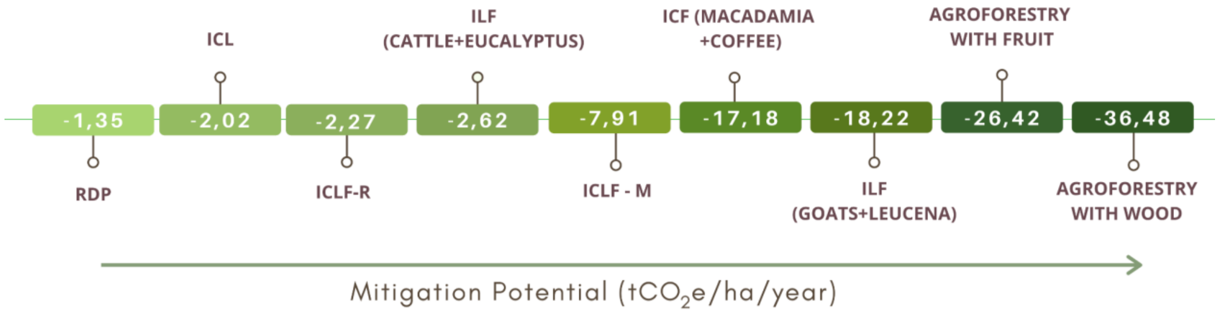
Thus, this technology provides an increase in productivity and income from activities agriculture, as well as the reduction in the deforestation of new forest areas and the reduction of greenhouse gas emissions, due to the great potential to sequester carbon due to accumulations of forage, forest and organic matter in the soil.

The ICLF is an environmentally promising technology in the set of possible sustainable intensification strategies for Brazil, with the potential to recover vast areas of degraded pastures, while mitigating GHG emissions (CORTNER et al., 2019). Thus, promoting a better use of areas, avoiding the deforestation of native vegetation for agricultural production (FERRANTE; FEARNSIDE, 2019; RAJÃO et al., 2020; SANAULLAH et al., 2020). Besides that, the ICLF is also related to the promotion of zero hunger and sustainable agriculture and action against climate change, which are part of the United Nations' 17 Sustainable Development Goals (SDGs), thus being a collaboration mechanism with global actions to end with poverty, protect the environment and the climate, and guarantee peace and prosperity for society.

By avoiding the pressure to open new areas for agricultural expansion, it allows a reduction of more than 80% of the area needed to produce the same amount of meat and reduces GHG emissions by 44% compared to degraded pasture (CASTELÕES, 2015) . It can also provide a greater tendency to protect against fire, due to crop rotation and pasture consumption by animals (BALBINO et al., 2012).

When compared to the other technologies of the ABC Plan, the ICLF is the most promising. With a mitigation potential of 5 Mg CO2e ha^{-1}, ICLF surpasses the No-Till System, which has a mitigation potential of 2.25 Mg CO2e ha^{-1}, and biological nitrogen fixation, with 1.8 Mg CO2e ha^{-1} (REIS et al., 2016). This is because the ICLF system promotes an increase in carbon in the soil, thus acting as a carbon sink and reducing CO2 emissions into the atmosphere (CARVALHO et al., 2010).

The main advantage of the system for mitigating GHG emissions is the inclusion of the tree component. Studies show that in the ICLF system a single tree accumulates an average of 30.2 kg of C. $year^{-1}$, which is equivalent to the sequestration of 110.5 kg of $CO2.year^{-1}$ from the atmosphere for each tree inserted in the system, considering that all tree components (leaves, branches, bark, stem, excluding only the roots) storing carbon (DE SOUZA et al., 2019). Recent data surveys and modeling show great mitigation potential for different combinations and technologies of ICLF systems (Figure 4).



Source: Rodrigues et al. in prep.

Figure 4. CO2 balance among different ICLF systems and degraded pasture recovery.

Integrated Crop-Livestock-Forestry as a Regional Development Approach

The Government of Brazil instituted a new National Policy for Regional Development (PNDR), through Federal Decree no. 9.810 of May 30, 2019, with the purpose of reducing economic and social inequalities. To do so, creating opportunities for economic development, income opportunity and improving the quality of the population will be the challenge for governmental and non-governmental actions. In view of this reality and what the decree proposes, it is necessary to develop productive processes in a sustainable manner, especially in regions with strong specialization in production of agricultural or mineral commodities. The PNDR guidelines recognize the regional capacities, specificities and local leadership in the formulation of strategies for development, bringing regional development from local actions. The ICLF ahead this reality is suitable for deployments for different ways of strengthening the systems existing local productive resources and according to agricultural skills.

The technology stands out for the production of several products, such as grains, meat, milk, fiber, wood and energy, among others. ICLF shows itself as an alternative for production in the same area (in consortium, rotation or succession), however, through this development from local actions, it is challenging to get the producer to carry out various activities in the same area. However, this diversification becomes important, as it will promote the increase in regional production through the greater rotation of products in local commerce, increasing the income not only of the producer, but the local economy, promoting the dynamization of various sectors of the regional economy.

Currently there are properties of different sizes and abilities using conventional systems, requiring regional studies on the feasibility of combining from different species to different local realities, identifying the difficulties of commercialization of agricultural, livestock and forest products and / or great distances between consumer regions and processing agro-industries, hampering the success of the system.

It is necessary to expand and adapt public policy mechanisms so that farmers are able to overcome economic and operational barriers, the need for technological knowledge, investment in the training of technicians and in the training of higher education professionals and vocational schools in this area.

It is important to offer producers suitable alternatives that can increase the sustainability of production systems and for that, economic and productive viability is fundamental. The increase in regional productivity can be achieved by integrating properties, through the sale or exchange of products, whether agricultural, livestock or forestry. This can be a suitable integration model for small size properties and medium, which lack economies of scale and labor-related advantages. Thus, ICLF technology is an important path for development mainly by combining environmental, economic and productive sustainability.

Therefore, it should be encouraged that the regions define priorities for this technology, according to its territory, as a way of promoting the implementation aimed at the main regional challenges. This is of fundamental importance to provide the construction of regional projects, allow the promotion of credit and seek the capture of other resources, promote technical assistance and rural extension, foster monitoring, among other aspects that provide regional development.

How we Want to Be in 2030

The area of ICLF has been increasing throughout the years, by 2030 we want to reach 50% more productive systems developed including 3 million hectares of certified and monitoring ICLF systems. And a total of 30 million hectares with ICLF and productive pastures that are going to double the Brazilian production of grains, meat, and milk, because we believe that it is possible to produce and preserve.

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TRENDS IN INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS IN EUROPE

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ABSTRACT

Integrated crop-livestock-forestry systems in Europe are typically referred to by the term agroforestry. Agroforestry is an important European land practice comprising 15.4 million hectares, equivalent to 8.8% of the utilised agricultural land in the European Union in 2015. Silvopastoral systems such as dehesas, montados, and wood pasture are the dominant form of agroforestry, but there are significant areas of the grazing or intercropping of high value trees, and silvoarable systems. Important drivers for increasing the area of agroforestry are the enhancement of biodiversity and landscape, animal welfare, soil conservation, and carbon sequestration. The major barriers include the complexity of management, mechanization and labour costs, and unfavourable subsidy regimes. The interest in agroforestry occurs across farming types, but it is particularly strong in the organic and agro-ecological sectors. Targets set by European governments to achieve net zero greenhouse gas emissions by 2050 is ensuring increasing interest in agroforestry, but measures and tools that allow farmers to derive financial value from the environmental benefits of agroforestry still need to be developed.

Key words: agroforestry; Europe; carbon sequestration; wood-pasture

INTRODUCTION

Integrated crop-livestock-forestry systems in Europe are typically referred to as agroforestry systems. Agroforestry has been defined as "the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions" (BURGESS; ROSATI 2018). In a major European Union (EU) project on agroforestry, called AGFORWARD (www.agforward.eu) that took place from 2014 to 2018, four principal types of agroforestry were recognized based on the starting point of the farmer (Figure 1).

1) Firstly, there are established agroforestry systems of high nature and cultural value defined as systems that "integrate woody vegetation with livestock and/or crops and which are valued for their biodiversity and their cultural heritage (MORENO et al. 2018). Many of these are two-layered wood pasture systems comprising scattered large trees and an understorey of native grasses used for livestock production, such as the dehesas in Spain and the montados of Portugal. Other examples include silvopastoral systems in Sardinia and Valonia oak systems in Greece. In cooler parts of Europe such as Brittany in France and England, hedgerows are recognized for their biodiversity and cultural value. Wood pastures also cover significant areas in Romania and Bulgaria.

2) The second type is agroforestry for high value tree systems. These are systems that "integrate understorey crops or grazing within existing high value tree systems such fruit orchards, olive groves, or high value timber plantations" (PANTERA et al. 2018). Examples of high value fruit trees are olive, carob, pine-nut, walnut, almond, chestnut, apple, and pear, and high value timber trees include walnut and wild cherry.

3) The third type is agroforestry for arable systems, where the dominant enterprise is arable crop production. These are often new systems comprising trees planted in relatively straight lines so that standard arable machinery can still be used to plant, manage and harvest the arable crops. The width

of the alleys in the systems studied in the AGFORWARD project ranged from 6 m to 96 m (KANZLER et al. 2018).

4) The fourth type is agroforestry for livestock systems. A prime reason for including trees is to improve animal welfare by providing protection from the sun, wind, or predators, with farmers also recognizing the benefits in terms of biodiversity and carbon sequestration (HERMANSEN et al. 2017). A recent trend has also been the increased interest in trees as a source of fodder, with particular interest in white mulberry (Morus alba) and common ash (Fraxinus excelsior). However unfortunately, common ash is subject to a new fungal disease called Hymenoscyphus fraxineus.

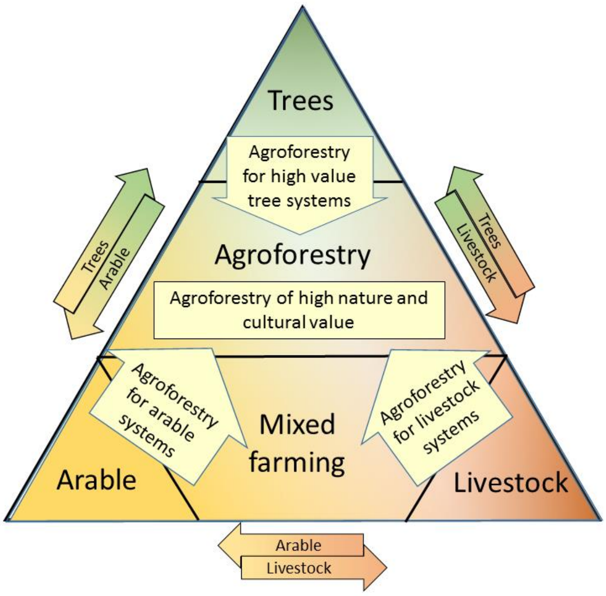

Figure 1. In the context of promoting agroforestry, the four types of agroforestry considered in the AGFORWARD project were: existing agroforestry systems of high nature and cultural value, and agroforestry for high value tree, arable, or livestock systems (BURGESS; ROSATI 2018).

Extent of Agroforestry in the European Union

Den Herder et al. (2017) describe a systematic analysis of the extent of agroforestry across the European Union in 2015 using “LUCAS” Land Use and Land Cover survey data (Figure 2). The analysis determined that the total area under agroforestry was about 15.4 million ha which represents about 3.6% of the territorial area and 8.8% of the utilised agricultural area at that time. The dominant agroforestry system was livestock agroforestry which covered about 15.1 million ha. High value tree agroforestry and arable agroforestry covered 1.1 and 0.3 million ha, respectively. The analysis also highlighted that agroforestry systems tended to be most common in Southern Europe including Portugal, Spain, Southern France, Italy, Greece, Romania, and Bulgaria (Figure 2).

The above analysis has been important as it highlighted the importance of agroforestry as a European land use and since the publication of the results, agroforestry has been receiving greater attention in policy decisions. The development of a systematic method of calculating the area of agroforestry means that it is possible to determine if the area of agroforestry is declining, staying the same, or increasing. The intention is to update the analysis in a new European agroforestry project called AGROMIX (www.agromix.eu).

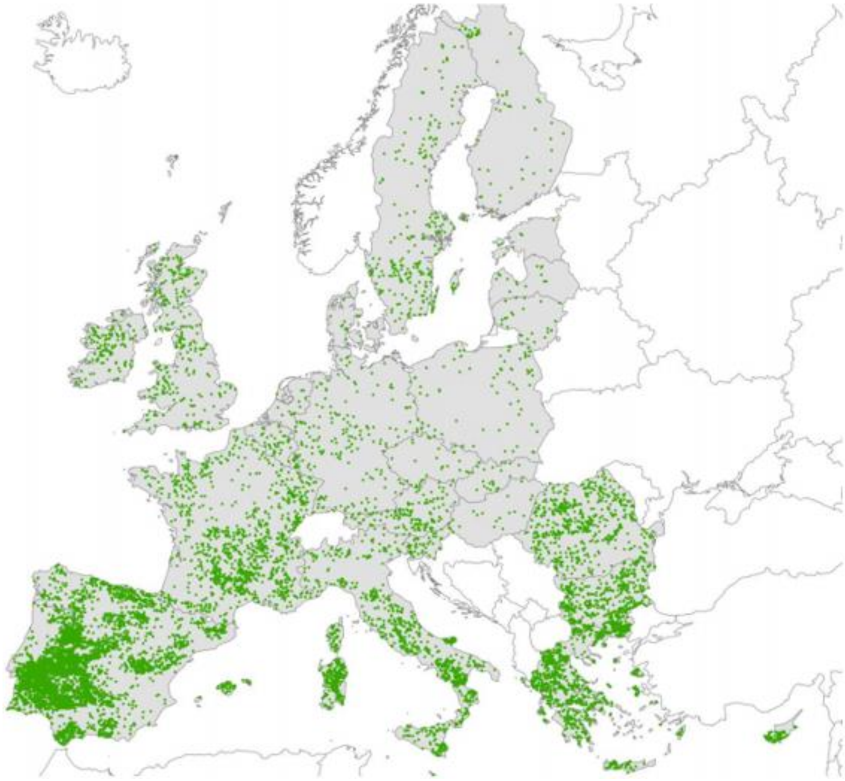

Figure 2. Distribution of agroforestry in the Europe Union in 2015 (DEN HERDER et al. 2017)

The Drivers for Agroforestry

There are many reasons why European farmers do or do not undertake agroforestry. García de Jalón et al. (2018) examined the key positive and negative perceptions of agroforestry across the four types based on the feedback of 344 stakeholders across eleven European countries. The results were analysed in terms of their effects on environmental. production, management, and socio-economic effects. There were positive attributes which can be considered as drivers or motivations for agroforestry and negative attributes which may act as barriers. The five key drivers motivating the practice of agroforestry tend to be related to enhancing production or the environment, with the five most highly rated attributes being biodiversity and landscape enhancement, soil conservation, enhanced animal health and welfare, income diversity, and carbon sequestration (Figure 3).

Biodiversity and landscape aesthetics: agroforestry systems of high nature and cultural value, such as wood pastures, are valued for their biodiversity and cultural importance. A meta-analysis by Torralba et al. (2016) demonstrated the increased biodiversity of European agroforestry compared to either agriculture or forestry alone. Recent European research using public participation geographical information systems (PPGIS) has also demonstrated that the high level of cultural services provided by urban, forest and water areas, and mosaic landscapes including agroforestry (FAGENHOLM et al. 2019).

Enhanced animal welfare: improving animal health and welfare is an important driver in agroforestry systems including livestock or poultry. For example, trees can provide shade from the sun and shelter from extreme cold temperatures. Species, such as hens, which are adapted to tree cover can also show more natural behaviour if they have access to trees (ZELTNER; HIRT 2008).

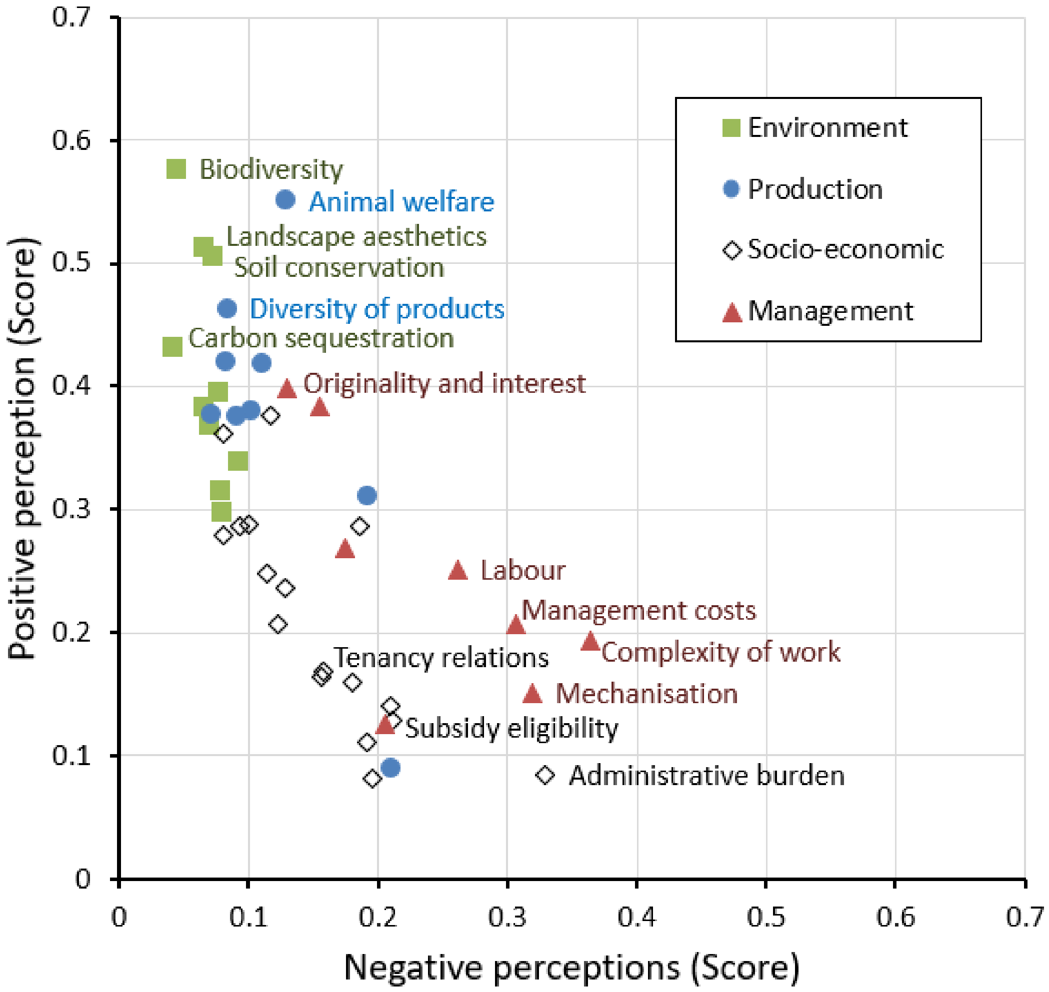

Figure 3. Mean normalised scores received from 30 stakeholder groups (comprising 344 stakeholders) for positive and negative attributes (related to the environment, production, socio-economics or management) of four agroforestry types (See Figure 1) across Europe (data from Garcia de Jalon et al. 2018a). Only the attributes with the highest positive and negative scores are labelled for clarity.

Soil conservation: particularly in the integration of trees in arable systems, soil conservation was seen as a key environmental benefit. Adding trees in the landscape can reduce soil erosion by reducing wind speeds and the amount of cultivation and by providing high levels of canopy cover.

Diversity of products and income: many stakeholders perceive that agroforestry can lead to a greater diversity of products and thereby revenue sources than agricultural production alone. Particularly in Mediterranean areas, the revenue from agroforestry systems can be greater than an agricultural system without trees (KAY et al. 2019a; GARCIA DE JALON et al. 2018b), but even still the level of profitability can still be low (ROLO et al. 2020).

Carbon sequestration: agroforestry can increase the level of carbon sequestration of European agricultural systems. However, the level of sequestration can vary by two orders of magnitude depending on the type of agroforestry. For example, the incorporation of hedgerows may result in an additional sequestration of 0.09 C ha−1 a−1, whereas systems where the trees achieve full canopy cover may sequester an additional 7 t C ha-1 a-1 (KAY et al. 2019b). Kay et al. (2019b) calculated that planting agroforestry in priority areas could offset between 1 and 43% of European agricultural greenhouse gas (GHG) emissions. Closely related to carbon sequestration, is the tendency for agroforestry areas to be less prone to fire damage than areas of shrubland (DANIANIDIS et al. 2020).

This effect is likely to become more important as climate change results in higher temperatures and drier conditions in summer. A key issue related to carbon sequestration is the need to develop auditing and monitoring methods and agri-environmental measures where farmers can receive financial benefits for increasing carbon storage. If ecosystem services such as carbon sequestration can result in increased income for farmers, then one would expect greater implementation of agroforestry than at present (KAY et al. 2019a; GIANNITSOPOULOS et al. 2020).

Barriers to Agroforestry

Despite the positive attributes of agroforestry, many farmers lack the opportunity, capacity or willingness to expand tree cover on their farms. The three main negative perceptions of agroforestry were related to the complexity of work and management costs; mechanization and labour costs, and the administrative burden and subsidy eligibility (Figure 3), and other research has highlighted land tenure can be important.

Complexity of work and management costs: agroforestry management is more complex than the management of agricultural systems or forestry systems alone. For example, a farmer integrating sheep to an apple orchard will need both tree and livestock management skills and he or she will need to, for example, modify grazing to ensure sheep are removed at least 60 days before any apple harvest to prevent faecal contamination. One way to remove the complexity is, for example, an orchard owner to enter a collaborative venture with a sheep farmer. However, the maximisation of financial benefits in such agreements require low contract and transport costs (BURGESS et al. 2017). Although some farmers highlighted the complexity of agroforestry as a negative attribute, other farmers were attracted to agroforestry because it provided greater "originality and interest" (Figure 3) than agriculture alone. Hence farmers can respond to complexity in different ways.

Mechanisation and labour: increased labour productivity is an important driver of land management changes in European agriculture, with productivity per unit labour increasing substantially faster than output per unit land in countries such as the United Kingdom (BURGESS; MORRIS, 2009). Compared to livestock production with no tree cover, agroforestry can necessitate more labour due to tree management operations and difficulties in machinery use (BROWNLOW et al. 2005). Similarly, when trees are integrated with arable production in Europe, farmers typically choose wide alley widths.

Administrative burden and subsidy eligibility: in European Union, the Common Agricultural Policy (CAP) and, more typically, national interpretations of the policy can increase the administrative burden of agroforestry systems relative to tree-only or agriculture-only systems. In the CAP, farmers typically receive a basic payment per hectare of agricultural land that they farm. Depending on the level of tree cover, this basic payment can be removed or reduced. Hence some farmers are concerned that increasing the level of tree cover will result in reduced support. There are some indications that this disincentive may change in the future as the level of basic payments decline and a greater proportion of governmental support is focused on agri-environmental measures and public services.

Land tenure: in 2003, the proportion of agricultural land farmed by the owner ranged from 20-40% in Belgium, France and Germany to 60-80% in Austria, Denmark, Finland, Ireland, Italy, Spain, Portugal and the UK (FAO, 2006). In most countries the proportion of agricultural land farmed by owners declined from 1995 to 2003 (FAO, 2006). Farmers who do not own the land they farm can face greater financial risks of investing in trees than farmers who can be assured of their ownership of the land when the tree mature. Hence tenant farmers may need additional support to expand the area of agroforestry.

Trends in Agroforestry

The development of integrated crop-livestock-forestry systems (i.e., the agroforestry transition) varies across the world dependent on the history and the place (DEWI et al. 2017). In a study of Brazilian agroforestry, Ollinaho and Kröger (2021) refer to “good”, “bad” and “ugly” agroforestry transitions. They explain that “ugly” agroforestry transitions can cause deforestation or the degradation of primary or semi-natural forests. The extent of agroforestry leading to deforestation in Europe is likely to be relatively low. For example, the rate of European afforestation has been greater than the rate of deforestation since 1900-1910, and although the net annual rate of change reached a maximum in 1970-1980, there remains a net annual increase in forest cover (FUCHS et al. 2015). In this context, the primary drive is to increase tree cover on agricultural land rather than increasing agricultural activity in forest areas, and hence agroforestry tends to result in positive environmental outcomes.

In their analysis in Brazil, Ollinaho and Kröger (2021) also contrasted between “good” agroforestry transitions that focus on small farm businesses, low inputs, and local tree species and “bad” transitions that focus on large businesses, substantial use of external inputs, and exotic tree species. In Europe, there are a mix of agroforestry systems and practices and what is “better” or “worse” will vary with the context, the criteria for evaluation, and the alternatives. Within the AGFORWARD project, many implementing agroforestry were organic farmers, but there were also farmers that used mineral fertilizers and agrochemicals. Farmers of both small and large businesses were also often more interested in planting either fruit trees or a range of tree species rather than relying only one tree species. The benefits of planting a diversity of tree species are also highlighted by Di Sacco et al. (2020).

There is increasing interest in agroforestry in Europe that is moving beyond the arena of scientific conferences and political speeches to on-the-ground action. Some of this interest has been promoted through the availability of agroforestry handbooks (e.g., RASKIN; OSBORN, 2019) and the activities of the European Agroforestry Federation (EURAF). However, momentum is also being driven by the targets of national governments to achieve net zero greenhouse emissions by 2050. In addition, farmer organisations, such as the National Farmers’ Union in the UK, are seeking to achieve net zero GHG emissions from agriculture by 2040 (NFU, 2019). Hence it is likely that over the next 20 years, farming systems across Europe will increasingly need to demonstrate that they are not a source of net GHG emissions. This is likely to have particularly major effects on the dairy, beef, and sheep sectors where methane emissions from rumen fermentation and nitrous oxide from manure are significant sources of GHG. Although tools to quantify and to help reduce GHG emissions and to increase carbon sequestration are available, policies that allow farmers to derive financial value from the environmental benefits of agroforestry on agricultural land are still required.

CONCLUSIONS

Integrated crop-livestock-forestry systems in Europe are typically covered by the term agroforestry. The area of tree cover in Europe is increasing and the integration of trees on agricultural land is increasing biodiversity and landscape aesthetics, animal welfare, soil conservation and carbon sequestration. The setting of national targets in Europe to achieve net zero greenhouse gas emissions by 2050 means that there is an expanding and increasing interest in the science and implementation of integrating trees with crop and/or livestock production in Europe. The measures to capture the environmental value of agroforestry are still being developed.

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ILPF SCENARIOS AND TRENDS IN LATIN AMERICA

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ABSTRACT

One of the great challenges of global agrifood systems is their transition to sustainable low-carbon systems that contribute to food security and sovereignty. This work, aimed at identifying the scenarios and trends of ILPF (Integrated Crop-Livestock-Forestry Systems) and SSP (Silvopastoral Systems) in Latin America and the Caribbean (LAC), is based on understanding the effects of the global climate transition on livestock production systems and how ILPF/SSP, as a set of technologies, techniques, and practices, can contribute to the challenges that this transition determines. Consequently, it is necessary to take a comprehensive look at the financial, environmental, social, economic, and productive implications of population growth, the increase in the demand for protein for human consumption, and the current and future effects on natural capital and its ecosystem services under climate change scenarios, as well as the opportunities and challenges associated with low-carbon development, both for producers, value chains and agricultural systems.

The work is based on the identification of ILPF status and trends in a regional context (LAC), and highlights the positive environmental, social, and economic effects of these, with technical reference data generated by silvopastoral initiatives in Colombia.

Key words: Silvopastoral; GHG mitigation; Climate transition; Low carbon livestock

INTRODUCTION

The denomination of Integrated Crop-Livestock-Forestry systems (ICLF), in Brazil, has different names in Latin America, the most commonly used being Silvopastoral Systems (SSP).

SSPs have varied definitions, differentiated according to the emphasis placed on their components, such as the ecological, productive, and environmental functions they fulfill, especially the technical aspects that emphasize their productive responses in animal production and, in particular, their conception and integral management and agro-ecological, productive, environmental, social and food security interactions they fulfill, with a clear orientation towards their sustainability (GIRALDO, 2019a).

In most countries of Latin America and the Caribbean (LAC), the high demand for beef and/or dairy products is more closely linked to the expansion of areas dedicated to livestock production than to increased productivity and efficiency in the sector. In other sporadic cases, livestock expansion into new areas has been the result of displacement by other agricultural activities, as in the case of soybean and oil palm production in several South American and some Central American countries (PEZO, 2019). Consequently, there is urgency for the intensification of livestock systems in Latin America, but at the same time recognizing the need to attenuate and mitigate the impacts of climate change.

The greatest challenge facing the livestock sector in LAC is its conversion to sustainable production systems, under the silvopastoral alternative, where livestock live among trees and shrubs, boosting their productivity and offsetting their greenhouse gas (GHG) emissions since the GHG balance is positive at the production unit level. It has been documented that the technological adoption of SSPs by livestock producers contributes to counteract the negative environmental impacts of traditional extensive livestock systems (due to greater carbon sequestration and reduction of enteric methane and nitrous oxide emissions), Giraldo (2019a), benefits that are oriented to the transition of livestock farming through its reconversion, towards its productive, environmental, economic and social sustainability. Under these circumstances, SSPs fulfill a very varied role and benefits, among which are:

- Silvopastoralism improves the economic income of producers when timber trees are combined, through balanced management of the timber and animal component in the long term, having as main objective the commercial silvicultural crop for fiber, poles, and timber, and livestock as a complementary activity.
- Increased production of forages of higher nutritional quality, reducing the need for external supplementation based on concentrates (GIRALDO, 2019a);
- Increase (up to 3-4 times) in livestock production per hectare (THORNTON; HERRERO, 2010; GIRALDO, 2019a);
- Increased carbon storage in the aerial and subway compartments of the system (MONTAGNINI et al., 2013, GIRALDO, 2019a);
- Improved soil properties due to increased nutrient uptake from deeper soil layers, increased nutrient availability from leaf litter, and increased nitrogen supply by N2-fixing trees (VALLEJO et al., 2010, CUBILLOS et al., 2016);
- Enhanced soil resilience to degradation, nutrient loss, and climate change (IBRAHIM et al., 2010, HARVEY et al., 2013);
- Improved water retention and infiltration capacity of the soil contributing to the regulation of the hydrological cycle by reducing runoff intensity (JOSÉ, 2009, RÍOS et al., 2007);
- Improved animal welfare by reducing animal heat stress, increasing milk and meat production (GIRALDO, 2019a).

SSP scenarios in Latin America

The cattle population in Latin America practically doubled in the last 50 years, from 201 to 418 million head, coinciding with the increase in the pasture area from 461 to 560 million (FAOSTAT, 2017). Consequently, the stocking rate increased from 0.44 to 0.75 animals/ha, values that are well below what would be an optimal stocking rate for most tropical and temperate zone pastures, except for semi-arid ecosystems (GIRALDO, 2019a). On the other hand, the demand in human nutrition for animal protein has increased rapidly in the last 50 years, both globally and in Latin America, as a consequence of population growth, the improvement in per capita income levels, and the migration of a part of the rural population to large population centers concentrated in cities (PEZO, 2019).

In the case of beef, LAC contributes 30% of global demand, with South American countries Brazil, Argentina, Uruguay, Paraguay, and Colombia contributing 80%, the remaining 20% coming from Mexico and Central America. For milk, in Central America and the Caribbean, all countries except Costa Rica, are net importers of milk, while South America went from net importer in 1993 to exporter in 2013, with Argentina and Uruguay being the main exporters (PEZO, 2019).

In response to these increases in demand, in most cases the areas devoted to pastures have expanded, at the expense of forests due to their deforestation, since the increases in productivity and in the efficiency of the productive parameters of cattle ranching (i.e., kg of product per animal (g/animal/day) and kg of product per area (kg/hectare/year), and in the carrying capacity of pastures (i.e., heads/hectare) have been limited (PEZO, 2019), are strongly dependent on pasture degradation, as a result of inadequate technical decisions in the efficient management and utilization of pastures and forage resources for feeding ruminant animals (GIRALDO, 2019b).

To meet the high future demand for animal protein, the productive capacity of livestock as a protein supplier must be reconverted and increased, mainly from developing countries, whose potential for productive efficiency and development is much greater than that of highly developed nations. Also, the availability and sustainable management of natural resources in these countries present great challenges and the greatest opportunity to supply the world's new food demand.

For livestock production systems to be sustainable and competitive in Latin America, it is necessary to rehabilitate extensive areas of degraded pastures that have the potential for intensive livestock use, releasing those that have a greater vocation for other purposes, such as reforestation with forest planting, conservation and the provision of ecosystem services (PEZO, 2019; GIRALDO, 2019a). In recovered areas, the management and efficiency of the intensive use of productive resources (i.e., soils, water, animals, pastures, pastures, trees, forage woody, and crops) must be improved, to increase the productivity of pastoral agroecosystems, agroforestry (crop-forest-animal and/or agricultural crops), including silvopastoral and agrosilvopastoral or the Integração de Lavoura, Pecuária e Floresta -iLPF-, (BUNGENSTAB, et al., 2019), but at the same time improving resilience to climate change, increasing carbon sequestration and reducing GHG emissions by the livestock sector (GIRALDO, 2019a).

There is no single technological alternative that can lead to the sustainable intensification of livestock farming under future climate change scenarios; rather, synergies must always be sought between different technologies, agricultural practices, and regulations, which can be of a normative-institutional, social, economic, environmental and technological nature. The above highlights the need to respond to many challenges and opportunities to achieve the sustainable intensification of livestock systems low in GHG emissions in Latin America, aimed at their decarbonization, through mitigation to generate products such as beef and milk for their carbon neutrality. The above, because the actors associated with global agricultural commodity markets, which represent 1.5 trillion dollars (FAO, 2020), must proactively manage the so-called "climate transitions", i.e. the rapidly evolving responses of policies, businesses, consumers, and civil society to the climate crisis, which would catalyze a process of decarbonization of the livestock chain in Latin America.

Moreover, the global agricultural sector, which contributes 23% of anthropogenic greenhouse gas (GHG) emissions worldwide, exposes the LAC livestock sector, its producers, and funders to emerging climate transition risks, related to policy, reputation, market, and technology, which they must proactively manage.

Under this perspective, risks and opportunities are very important for the agricultural sector, highlighting the following points as climate transition risks in the livestock sector worldwide (ORBITAS, 2020a):

1. Livestock sector growth strategies based on the conversion of forests to pasture land have no future.
2. Companies that depend on expanding their land in forested areas face a significant amount of assets that depreciate considerably, which could become unusable.
3. Greenhouse gas (GHG) pricing and regulations will disrupt agricultural business models.

SSP trends in Latin America

The recent publication, "Analysis of climate transition risks. Colombian beef", recently prepared by Orbitas and in Navigating climate transition risks, in 2020, (ORBITAS, 2020b), specifically examines how "climate transitions" will substantially influence Colombia's beef industry in the coming decades. The findings identified have implications for the LAC cattle sector, depending on the particularities of the sector, in each of the South and Central American countries. The highlights of this analysis are:

- The livestock sector's high GHG emissions intensity, inefficient land use and association with deforestation expose it to three climate transition trends: declining global and regional growth in consumer demand for beef; restrictions on deforestation, which increase competition for land and

land value; and the costs of GHG emissions associated with the conversion of forests to pasture and hence livestock production. This trend would manifest itself in declining production as rising land and production costs stimulate conversion to more profitable agricultural uses.
- The increase in local beef prices (up to 2.3 times higher), in a high climate transition scenario, to achieve the temperature targets to global warming of 1.5°C and in production costs, even in the face of slower growth in demand, leave livestock farming in a vulnerable situation concerning imports and product substitution (mainly chicken, pork and fish). This high climate transition scenario implies higher GHG prices, significant local demand for certified sustainable beef, as well as significant declines in global and regional beef consumption.
- Large commercial cattle ranchers (> 500 animals), could face GHG emission costs up to six times higher than expected production costs within 20 years.
- The influx of low-cost imports could fundamentally alter beef supply chains.
- The sector can counter these risks by adopting sustainable strategies, particularly silvopastoral systems (SSP). Since livestock conversion to SSP can generate very high internal rates of return (IRR) of 32% to 37% for an investment of approximately USD 2000/ha, with a payback period of only three to four years. With climate transitions, the relative benefits of silvopastoral systems are even greater.

Also, for a medium-sized and small dual-purpose farm quite common in LAC, relative to traditional techniques it is identified that:

- GHG emissions and associated costs are up to 44 % lower for large meat marketing players.
- Surcharges for sustainable certification increase revenues by up to 23%.
- New revenues from carbon sequestration, available for small and commercial farms, are up to USD 485 per hectare.

Consequently, given the enormous exposure of the LAC livestock sector to climate transitions and the significant opportunities offered by sustainable practices, the following actions are recommended: Provide for lending to and investing in beef producers to adopt sustainable practices, especially by providing technical assistance and capital to small and medium livestock producers. Further expand large-scale silvopastoral investment programs, linked to government-supported financial products, which means that the LAC livestock sector has a better chance of avoiding the much worse physical and economic effects of global warming.

One of the sustainable practices in the livestock sector for the productive and environmental reconversion of cattle farming in LAC is the SSP, which integrates trees, shrubs, pastures, and livestock managed in an integrated manner. SSP technology provides ecosystem services, increases productivity and efficiency in milk and/or beef production, diversifying the income of producers (GIRALDO, 2019a; CHALÁ et al, 2019).

Compared to cattle farms with treeless pastures where cattle graze, silvopastoral systems capture and store more atmospheric carbon, improve soil properties, increase environmental resilience, reduce runoff and promote greater biodiversity. SSPs provide livestock with higher nutritional quality forage to feed cattle, and more diverse forage, which increases dairy and beef productivity. The higher quantity and quality of forage also allows producers to have more animals per hectare (animal carrying capacity), which allows for more efficient use of land. By providing a diet based on higher quality forage, SSPs also reduce GHG emissions per animal, which implies lower emissions intensity, and by providing shade from trees, they improve livestock welfare and reduce climatic stress from high temperatures, reducing health and disease risks from high rainfall and soil moisture, which are manifestations of climate change. SSPs also improve the economic performance of producers by increasing dairy and beef productivity, adding additional sources of income such as timber sales and carbon sequestration certificates, while reducing the need for costly off-farm inputs such as fertilizers, herbicides, and insecticides (GIRALDO, 2019a; CHALÁ et al, 2019).

CONCLUSIONS

The exposure of the LAC livestock sector to climate transactions, dominated by small producers and characterized by low economic profit margins, high GHG emissions, will have large financial implications according to the different climate transition scenarios (Historical, Modest, and High). However, achieving the environmental average temperature targets concerning global warming of +4; 3 and 1.5 degrees Celsius respectively for each climate change scenario, in line with global trajectories, there are immense opportunities under these different climate transition scenarios (ORBITS, 2020).

The main opportunity lies in the immense potential of sustainable livestock farming with silvopastoral technology to protect against future cost increases and price volatility by reducing emissions, increasing productivity, diversifying income sources, and expanding market access.

Adopting a "sustainable and/or low-carbon" beef and dairy label in LAC can counteract the slowdown in beef demand. This approach would create a premium product that would justify higher prices. Consumers, in the case of Colombia, may be willing to pay a price premium of 23% for organic meat, 25% more for meat obtained respecting animal welfare, and 10% for beef labels that address environmental impacts. A maximum price premium of 50% could be achieved if multiple consumer concerns were met (CHARRY, et al, 2019).

Sustainable livestock farming based on SSP increases profitability and diversifies income sources. Livestock conversion to silvopastoral in the northern region of Colombia generated 6 times more income and multiplied profits by 8, which implies internal rates of return (IRR) of 32-37% and a payback period of only 3-4 years for an initial capital investment of between USD 2000 and 4000 (Orbitas, 2020b). In the Andean region, SSPs show more modest economic results by increasing the IRR from 19% in traditional livestock systems (without trees) to 27% in systems based on silvopastoral for beef and milk production, with a benefit-cost ratio (B/C) between 1.16 and 1.45 (GIRALDO, 2019a).

These increases in profitability are due to the diversification of income sources (from additional trade in timber, carbon credits, and livestock products (milk and/or meat). This would be even greater in scenarios of climate transitions, due to the lower costs of emissions, and possible price premiums for the supply of meat and/or milk with a low carbon seal, which would give added value to economic efficiency and climate change mitigation by the livestock sector (GIRALDO, 2019a; ORBITAS 2020b), however, these results may be lower on farms whose productive parameters such as carrying capacity and livestock productivity are higher. All of this aimed at a low-carbon livestock sector in LAC.

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INTEGRATED CROP-LIVESTOCK-FORESTRY SCENARIOS AND TRENDS IN NORTH AMERICA

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ABSTRACT

Integrated crop-livestock systems and silvopasture management are approaches to gain synergy between agricultural enterprises by enhancing nutrient cycling, avoiding environmental degradation caused by specialized systems, restoring soil organic matter with greater utilization of perennial grasses in typical agricultural operations, and enhancing biodiversity of plants and animals on the landscape. Agricultural changes in North America during the past century have been dramatic and have led to highly specialized operations with separation of crop and livestock operations. A return to integrated systems would offer potential solutions to (1) the environmental degradation derived from specialized agricultural systems, (2) maintain the necessary biological diversity needed to withstand emerging diseases and pest outbreaks, (3) rebuild declining rural communities as a result of the global network of agricultural trade, and (4) create a more resilient agricultural approach to mitigate against rising CO2 in the atmosphere and to better adapt to the threats of climate change. Examples of integrated crop-livestock-forestry systems in North America are summarized with references to obtain more information. The diversity of climate conditions and soil resources in North America offers abundant opportunities for developing these stewardship approaches to agriculture.

Key words: Grain production; Grazing cover crops; Sod-based rotations; Silvopastures

INTRODUCTION

Agriculture in North America was transformed in the past 100 years from widespread small-scale, family farm operations with a diversity of agricultural enterprises on any one farm to greater specialization of crop and livestock operations separate from each other (Hendrickson et al., 2008). A look back to the agricultural issues of importance during the early years of the 20th century provides us with some recurring themes that are still appropriate today. Spillman (1902) described the issues as:

> “The most successful system of farming is that which gives the largest profit, leaves the soil in condition to yield maximum crops, and brings to the farmer and those dependent on him the largest measure of happiness. In conducting a farm upon such a system, the farmer must continually answer for himself the questions: What crops shall I grow and what area of each? What care shall I give these crops and the soil upon which they grow? What disposition shall be made of the produce of the fields? If the crops are to be sold, then when and where? If they are to be fed, then to what classes of stock and to what number? What manures and fertilizers shall be applied to the soil, to what crops, in what season, in what quantities? What provision shall be made for the protection of growing crops from insect pests and fungous diseases, for storing crop products, for the protection and care of livestock? When and where shall livestock and their products be marketed? The repeated answering of these and other similar questions constitutes farm management—a business in which is found the application of many sciences, but a business so broad and complex that it must rest mainly on the accumulated experience of generations of those who have

> followed it. Conditions of climate, proximity to market, the character of farm labor, social conditions, and that great enigma, the soil, have all been determining factors in the development of the systems of farming that have been gradually evolved in the various sections of the country."

Spillman (1902) went on to raise of a few more ecological issues that have yet to be fully resolved:

> "In fact the systems followed on different farms represent every gradation between the farm where a single crop is grown and the product is all sold off the farm, and that on which no crops are grown, but large quantities of feed are bought and fed, if indeed the latter may be called a farm."
>
> …"It may be safely assumed that the development and maintenance of soil fertility is the most important problem in farming. With soil fertility assured the future of agriculture may be considered safe."
>
> …"It will perhaps be conceded that a worn-out soil can not easily be brought back to its original fertility without the aid of livestock."
>
> …"Too often, however, this system degenerates into the original system of soil robbery practices on all new and fertile lands the world over since agriculture had its beginning."

Natural resources

Agricultural land in North America is diverse in production and capacity as controlled by the inherent geospatially defined edaphic and climatological conditions. Climate ranges from the tropics in Mexico to temperate regions of vast areas in the USA to tundra in Canada. Soils of all orders are present in North America. Depending on the type of agricultural operation, all three major environmental factors of temperature, precipitation, and soil type may dictate success and/or the need for significant management manipulations to have potential for success. At a finer geographic level, cultural traditions, infrastructure, marketing, and economics are key factors in agricultural success.

Historical changes

Country-level statistics were used to construct a broad geographic and historical depiction of agriculture in North America (Table 1). The following key features emerged from these data, including (1) agricultural land area remained relatively stable in Mexico and Canada, but declined significantly in the USA, (2) distribution of agricultural land use is most dominant in the USA and least prevalent in Canada, (3) agricultural land area per capita has been declining in all countries, (4) average cereal yield increased 2-3 times in all countries from 1961 to 2003, and (5) food production remains a high priority in all countries.

Table 1. Broad agricultural characteristics and changes over time in countries of North America.

Characteristic	Year	Mexico	USA	Canada
Agricultural land (Mha)	1961	98	448	70
	2003	104	414	68
Land area in agriculture (%)	1961	11.7	19.7	4.5
	2003	13.0	19.3	5.0
Agricultural land per capita (ha)	1961	0.56	0.98	2.24
	2003	0.23	0.59	1.44
Cereal yield (kg/ha)	1961	1105	2522	985
	2003	2964	6025	2760
Food production index (%)	1961	27.8	48.4	38.0
	2003	106.1	101.5	95.7

Data from NationMaster (2021).

Food production index covers food crops that are considered edible and that contain nutrients relative to the base year of 1999-2001.

During the past century, the Economic Commission for Latin America and the Caribbean (ECLAC), USDA-National Agricultural Statistics Service, and Statistics Canada have been recording farm inventories, sales, and farmland activities to assess changes in agriculture on private lands in North America. The US Census of Agriculture has been conducted every 4 to 5 years since 1920 and every 10 years since initiation in 1850. Current number of farms has declined 70% since a peak in 1935 (USDA-NASS, 2021). Current farmland acreage has declined 22% since a peak in 1950. Farmland acreage in 1850 was only 25% of the peak in 1950. Figure 1 illustrates how the declining number of farms and relatively steady farmland acreage has led to increasingly greater average farm size over the past century in the USA. A similar trend for fewer farm operations occurred in Canada, i.e. from 481 thousand operation in 1961 to 194 thousand operations in 2016 (Statistics Canada, 2021). Total cropland acres increased in Canada from 50 million in 1921 to 62 million in 1961 to 93 million in 2016, resulting in 129 acres per farm in 1961 and 479 acres per farm in 2016. Farmland devoted to primary grain crops (corn, rice, sorghum, and wheat) in Mexico remained relatively stable at 22.7 million acres in 1980 and 22.3 million acres in 2018 (ECLAC, 2021).

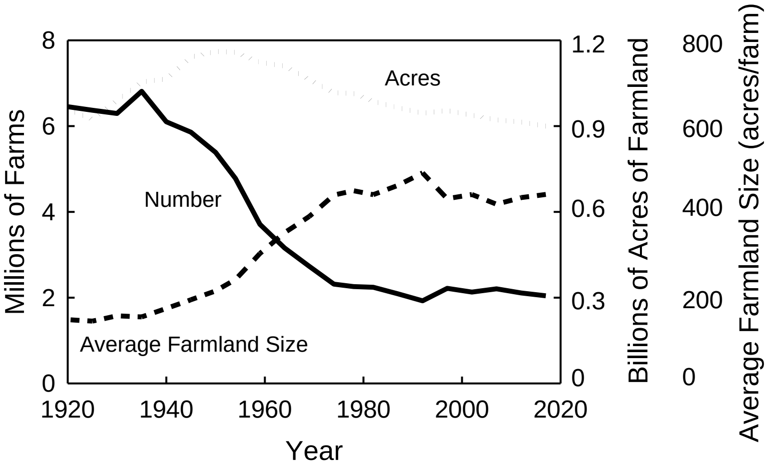

Figure 1. Historical changes in number of farms, acres of farmland, and average farmland size in the USA. Data from USDA-NASS (2021).

Historical changes in livestock inventories over the past century were equally dramatic as number of farms with beef cattle and broiler chickens exhibiting large increases and dairy cattle showing overall decline (Figure 2). Swine fluctuated widely over the past century with large perturbations caused by World War II and a variety of virus outbreaks. The density of livestock per farm changed dramatically from 1964 to 2017 – beef inventory increased from 25 to 44 head per farm, dairy inventory increased from 13 to 175 head per farm, swine inventory increased from 50 to 1089 head per farm, layer inventory increased from 283 to 1584 hens per farm, and broiler chicken inventory increased from 55 thousand to 271 thousand birds per farm. Beef cattle was the only enterprise that did not increase exponentially over the past 50 years.

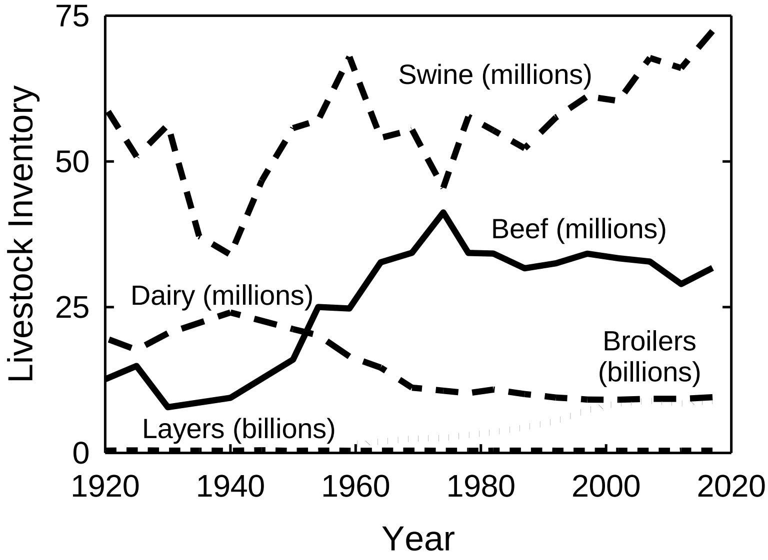

Figure 2. Historical changes in livestock inventories by animal type in the USA. Data from USDA-National Agricultural Statistics Service, Washington DC.

Dramatic increases in livestock inventories over the past 50 years were associated with large increases in livestock sold per farm – cattle and calves sold increased from 32 to 98 head per farm per year, hogs and pigs sold increased from 104 to 3627 head per farm per year, and broilers sold increased from 55 thousand to 271 thousand per farm per year.

Likewise, with greater specialization in the livestock sector over time, there was specialization in the grain production sector as well. Average corn grain production increased from 62 Mg per farm in 1964 to 1231 Mg per farm in 2017. Average corn grain yield increased from 3.9 Mg/ha in 1964 to 10.9 Mg/ha in 2017. Average wheat grain production increased from 45 Mg per farm in 1964 to 464 Mg per farm in 2017 and productivity increased from 1.7 Mg/ha in 1964 to 3.1 Mg/ha in 2017. Average soybean production increased from 33 Mg per farm in 1964 to 391 Mg per farm in 2017 and productivity increased from 1.5 Mg/ha in 1964 to 3.2 Mg/ha in 2017. Average cotton production increased from 10 Mg per farm in 1964 to 281 Mg per farm in 2017 and productivity increased from 582 kg/ha in 1964 to 982 kg/ha in 2017. It might be tempting to associate greater productivity over time in field crops with the specialization that took place, and there may be some contribution of greater knowledge of grain production factors to this increase, but likely the vast majority of the effect was due to genetics, management techniques, and external inputs like fertilizer and pest controls. However, it may be that excessive nutrient inputs were a more direct consequence, as the quality of rivers, lakes, and coastal estuaries declined during this period as well (Diaz and Rosenberg, 2008). Excessive environmental impact of specialized agricultural systems is one of the main drivers for renewed interest in integrated crop-livestock-forestry systems in North America (RUSSELLE; FRANZLUEBBERS, 2007; FRANZLUEBBERS et al., 2021).

Contemporary agriculture

Distribution of farms in the USA is widespread, but Figure 3 illustrates that yearly precipitation generally has a large influence on density of farms, which associates equally well with human population density. Some of this distribution is also related to the type of soils present, as the highly productive Mollisols dominate in the central part of the country despite less than adequate precipitation. This soil effect is also present in Canada, in which a large number of farms are present in the Prairie Provinces with chernozemic soils.

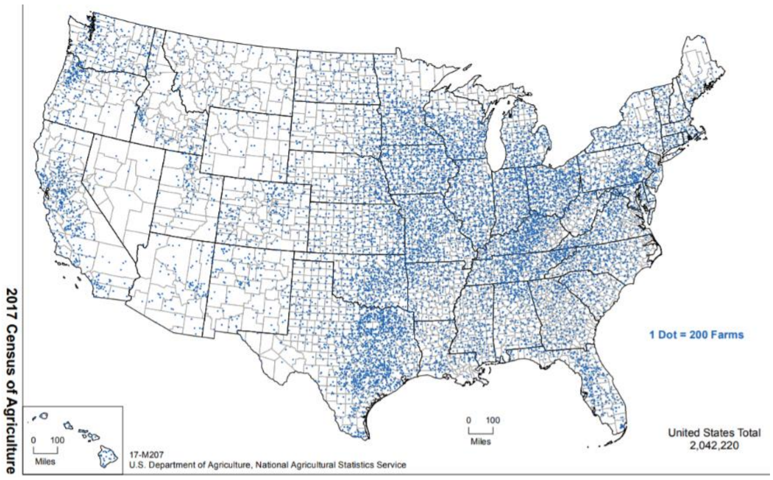

Figure 3. Geographic distribution of farms in the USA. Created by USDA-NASS (2021).

The 2017 Census of Agriculture indicated that 15% of the largest farms (>500 acres each) controlled 81% of the farmland in the USA (USDA-NASS, 2021). The largest 4% of farms controlled 58% of all farmland. On the other end of the spectrum, 70% of all farmers occupied <10% of all farmland in the USA. In 1862, half of the USA population lived and worked on farms. This scenario clearly shows that consolidation of farming operations is the norm in the USA. In 2017, 11% of total employment in the USA occurred in the agricultural and food sectors. Direct on-farm employment accounted for only 1.3% of employment in the USA. Employment at food service and eating-and-drinking places was nearly 5 times greater than on-farm employment.

Conservation agricultural management is growing in acceptance in North America, but there is still much room for growth. Figure 4 shows that the percent of cropland under no-tillage management varies greatly by region. Certainly, there are some local zones of high adoption of this type of management, and this is often due to farmer networks supported by Cooperative Extension, USDA-Natural Resources Conservation Service (NRCS), or farmer associations, such as no-till alliances.

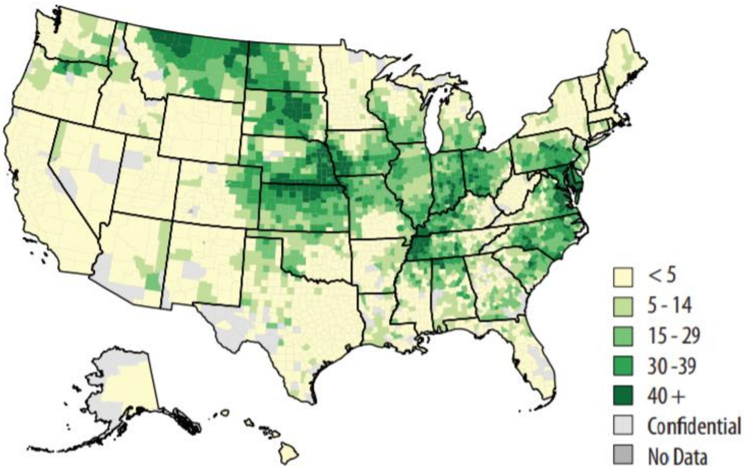

Figure 4. No-till acres as percent of total cropland acres in a county in 2017. Data from USDA-NASS (2021).

Extent of integrated crop-livestock-forestry systems in North America

Official statistics are not available as to the extent and distribution of integrated farming systems. In general, the current state of the majority of agricultural production in North America can be characterized as highly specialized with large land areas devoted to cereal grain production of a few crops, e.g. corn in the Midwest USA and Ontario, wheat in the Great Plains of the USA and Canada, and rice in the Central Valley of California and the Lower Mississippi River Valley. Although wheat and rice are mostly for human consumption, corn is for both human and livestock consumption. In addition, use of corn has grown rapidly since 1980 in the ethanol energy sector, e.g. <1% of corn was used for ethanol production in 1980 and 44% of corn was used for ethanol production in 2015 (USDA-ERS, 2015). Oilseed production with soybean co-exists as an outstanding crop rotation companion throughout the Corn Belt of the Midwest USA and canola is an attractive oilseed crop in the Prairie Provinces of Canada.

As outlined elsewhere, there are a number of integrated crop-livestock strategies that have been and continue to be used with sparse distribution throughout North America (Franzluebbers et al., 2011; Sulc and Franzluebbers, 2014). These include sod-based rotations, grazing cover crops, dual-purpose grain crops, grazing crop residues, and agroforestry or silvopasture systems. None of these approaches are used widely in any particular region, except for the relatively common dual-purpose wheat system practiced in the prairie region of Texas, Oklahoma, and Kansas (Redmon et al., 1995). Wheat is the dominant crop in the region and in close proximity to many of the cattle feedlots. Stocker cattle are often purchased and graze young wheat plantings in the winter and spring, and depending on grain and cattle prices, cattle may be removed to allow grain to mature or cattle may be retained on wheat to graze throughout the life of the wheat crop.

Sod-based rotations are practiced to a minor extent in different parts of the country, especially during periods of sharp increases in crop prices that attract the interest of farmland operators that otherwise opt for low-input livestock grazing systems. Climate change with warming temperature in the Northern Great Plains may have led to some expansion of corn and soybean cropping on rangeland sites at the border between humid and semi-arid regions. Expiration of Conservation Reserve Program (CRP) contracts that promoted land healing following extensive erosion has led to some conversion of grasslands to cropping. This land conversion can take advantage of the accumulation of soil organic matter during the CRP period and bring benefit to subsequent cropping (DELATE et al., 2002), although the environmental benefit appears to be dependent on the type of tillage management during conversion (FOLLETT et al., 2009; RUAN AND ROBERTSON, 2013). Additionally, to the extent that small dairies are still operating, pasture-crop rotations are practiced to rejuvenate alfalfa stands with periodic planting of corn for grain or silage prior to replanting forages (WALKER et al., 2017). There is also a growing interest in small-scale organic farming throughout North America and pasture-crop rotations can be a vital management option to build soil fertility and promote diversity on the farm (JARECKI et al., 2018). Both productivity and environmental improvements with a variety of pasture-crop rotations have been shown and summarized before (FRANZLUEBBERS, 2007; FRANZLUEBBERS et al., 2014; FRANZLUEBBERS; GASTAL, 2019).

There has been growing interest in soil health management in North America with a focus on four principles promoted by the USDA-NRCS, i.e. minimizing soil disturbance, maximizing soil cover, keeping living roots in soil, and promoting diversity (USDA-NRCS, 2013). One of the outgrowths of this promotion has been growing interest by cropland growers of diversifying further with grazing of cover crops. Although sufficient cover crop biomass return to the soil is still a concern, many growers see the potential to get economic return from the cost of cover crop establishment. Some examples of popular press articles describing the practices on working farms are available (STEIERT, 2017; SCHILLING, 2020). Research on the impacts of grazing winter cover crops has focused on potential benefits to cattle production (FRANZLUEBBERS; STUEDEMANN, 2007), the best types of cover crop mixtures to utilize (FARNEY et al., 2018), how to utilize cover crops efficiently for economic return (SCHOMBERG et al., 2014; MARCILLO et al., 2019), and the impacts of cover crops on soil health and potential water quality (FAUST et al., 2020; DHALIWAL; KUMAR, 2021; KELLY et al., 2021). Much research remains to describe the potential production, economic, and environmental effects of grazing of cover crops under the diversity of environments in North

America. Certainly, there will be benefits and issues of concern, and these multifunctional responses are needed for development of improved agricultural systems.

Farmer interest is growing for developing silvopastures in North America. This may be a result of the on-going outreach efforts of the National Agroforestry Center of the USDA-Forest Service in Lincoln, Nebraska (https://www.fs.usda.gov/nac/) and the Center for Agroforestry at the University of Missouri (http://www.centerforagroforestry.org/). The National Agroforestry Center has developed a wide-ranging library of information resources, including a synthesis on agroforestry as a mechanism to mitigate and adapt to climate change (PATEL-WAYNAND et al., 2017). The Center for Agroforestry has online teaching modules available, as well as newsletters, videos, podcasts, and an archive of webinars. They also hold an annual agroforestry symposium.

Various research and extension programs with a focus on agroforestry and silvopasure have been established in different parts of the USA. Some of these include the University of Minnesota (https://extension.umn.edu/forestry/agroforestry), Tuskegeee University (https://www.tuskegee.edu/programs-courses/colleges-schools/caens/cooperative-extension-program/agroforestry), the Center for Environmental Farming Systems in North Carolina (https://cefs.ncsu.edu/field-research/additional-research/agroforestry/), Virginia Tech (https://agroforestry.frec.vt.edu/), and Cornell Small Farms Program (https://smallfarms.cornell.edu/projects/agroforestry/). The silvopasture research project in North Carolina found that nitrous oxide emission under trees may be reduced, mostly as a function of avoidance of N fertilizer (FRANZLUEBBERS et al., 2017), and carbon dioxide emission under trees may be reduced, partly due to lower soil water content and reduced temperature during much of the year, but also likely from surface accumulation of tree litter early in the development of the timber species. Other research found that microclimate can be significantly modified under trees, but this may have negative impacts on warm-season forage growth near trees (CASTILLO et al., 2020).

CONCLUSIONS

Integrated crop-livestock-forestry systems are not the norm in North America, but there are plenty of examples of farmers using various forms of a wide diversity of options of integration. This review suggests there is further research needed to identify the limiting factors for adoption of these practices, but there is also a need for demonstration farms where farmers can view these approaches working and how they might be modified further to fit into specific farm operations in a region. Given the many possibilities for integrated crop-livestock systems to balance production and environmental quality issues facing agriculture (LEMAIRE et al., 2014; 2015), research and extension activities will need to continue in North America to reconcile towards a sustainable future with sound agricultural approaches. Greater focus on the environmental aspects of agriculture are needed to achieve both production and environmental challenges in the future (FRANZLUEBBERS et al., 2020).

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LIVESTOCK-FOREST INTEGRATION IN AUSTRALIA

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ABSTRACT

The Australian government's Carbon Farming Initiative provides incentives for farmers in establishing or managing trees on agricultural and grazing lands. Carbon offset methods have been developed for reforestation, assisted natural regeneration or avoided land clearing, with 8, 54 and 29 Mt CO2e awarded as Australian Carbon Credit Units (ACCUs) to landholders since 2012? against the three methods respectively. Even though the number of ACCUs issued is significant, broad adoption of these offset methods by farmers remains a challenge in Australia. This is due to a combination of high upfront costs for the development, administration and establishment of offset projects and the cost of maintaining, monitoring and auditing carbon obligations. The carbon income from the establishment of trees on agricultural land does not always compensate for the forgone agricultural productivity. However, the co-benefits of trees on agricultural land are poorly quantified and limited research suggests these may be much greater than the carbon income. These co-benefits include improved animal welfare, through reduced heat and cold stress in livestock, and improved water quality, soil organic matter, biodiversity and capital value, as well as contributing to carbon neutral production. Further research is needed to capture the true value of co-benefits as a means of promoting greater integration of forestry and livestock under future climate scenarios in Australia.

Key words: greenhouse gas, carbon farming, sequestration

AMBIENCE AND ANIMAL WELFARE UNDER ICLF SYSTEMS

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ABSTRACT
Goal was to quantify benefits of ambience and animal welfare promoted by the ICLF system over Zebu dairy cows. Evaluations were carried out using completely randomized design at an experimental area of Embrapa Cerrados, during 33 months with dairy cows under rotational grazing of Mombaça grass, under full sun and under ICLF shade. The treatment with the presence of trees in the ICLF system positively influenced animal physiology and milk production. The average surface temperature was reduced by up to 1.1oC and the rumination time was 32% longer for cows under shade. Dairy Gir cows increased individual milk production by 24%. Gir and Girolando cows from the ICLF system increased individual production in the dry season by 17% and in the first third of lactation by 18%. The average milk yield per hectare was 5.3% lower in the ICLF system. The average stocking rate was 3.7% lower in the ICLF system. A greater number of ovarian follicles, of total and viable oocytes and blastocysts were observed in Gir cows under the shade of ICLF when compared to those cows under full sun in the dry season. Adoption of ICLF for grazing dairy production is an alternative to promote animal welfare and to intensify production.
Key words: Thermal comfort - Zebu Dairy Cow - Shade -Silvopastoral System

INTRODUCTION

Dairy production in the Cerrado biome of Brazil is predominantly on pasture. The climate in this region has a high potential for grazing forage production, having seasonal interference, with greater production in the rainy season. However, high temperatures, humidity and intense solar radiation do not favor ambience and animal welfare.

Heat stress occurs in situations where the amount of heat absorbed from the environment and produced by dairy cows by their own metabolism is greater than their ability to lose or dissipate body heat. Heat loss in cattle occurs through both, the surface of the skin and the respiratory tract. Perceptible physiological changes are panting, increased respiratory rate, body temperature, water intake, salivation and sweating. Under heat stress, dairy cows can reduce dry matter intake, milk production, reproductive rates and rumination (Figure 1).

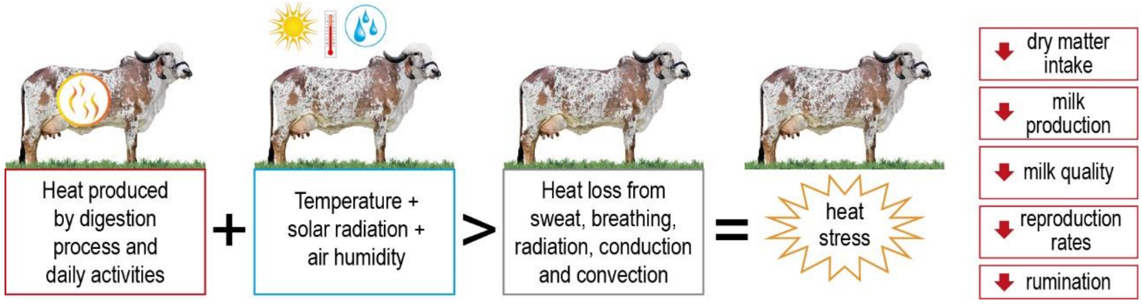


Figure 1. Conditions for the occurrence of heat stress and its consequences on dairy cows' performance. Illustration: Wellington Cavalcanti

The Integration Crop, Livestock and Forestry (ICLF Systems) is a strategy that aims at sustainable production, integrating crop, livestock and/or forestry activities carried out in the same area, in intercropping, in succession or rotated, and seeks synergistic effects among the components of the agroecosystem, encompassing environmental compliance, the valorization of man and the economic viability (BALBINO et al., 2011).

Integrating crops, livestock and/or forestry systems are important alternatives to promote the ambience and well-being of grazing dairy cows. Furthermore, the forestry component can generate income in the medium term, depending on the region's wood market. Trees reduce temperature, increase air humidity and block solar radiation. Cows' welfare can be enhanced using genetic groups better adapted to the tropical environment, in the presence of natural shade in the pastures.

ICLF systems promote animal welfare because they are alternatives for forage production in quality and quantity, both in the rainy season with pasture, and in the dry season through forage conservation. In this way, they support one of the pillars of animal welfare, which is: the animal must be free from hunger and thirst. They also provide an environment with good shelter, with lower temperature, favorable ambience and the possibility of resting in comfort, in addition to allowing for grazing, which is a basic expression of the species' natural behavior, without fear and stress.

Goal of this long-term study was to quantify the benefits of ambience and animal welfare promoted by ICLF systems compared to grazing systems under full sun, regarding production, reproduction and rumination of dairy cows of Zebu genetic groups, adapted to the tropical environment.

MATERIALS AND METHODS

The trial was carried out from January 2017 to September 2019, at Embrapa Cerrados, in area of the Technology Center for Dairy Zebu breeds (CTZL), Brasília-DF, (15 57'09" S, and 48 08'12" W) . This experimental farm is located in the central region of Brazil, in the Cerrado biome, under tropical climate, with an average maximum temperature of 28.1°C and average rainfall of 1,201.5 mm distributed predominantly from November to April and with dry winter between May to October (SILVA et al., 2017).

Treatments evaluated were two environments for pasture milk production, one using ICL (animals kept in pastures under full sun) and another using ICLF (animals kept in pastures under shade of the clone GG100 of Eucaliptus urograndis). The total area of 16 hectares was divided in half, so that each treatment uses an area of eight hectares with pastures of *Megathyrsus maximus* (syn. *Panicum maximum*) cv. Mombaça, divided into 12 paddocks of 0.66 ha each. In full sun environment, pasture was established after soybean cultivation, in an ICL system, and kept as monoculture. In the shaded environment, eucalyptus trees were arranged under single rows having 1.5 meters between trees and 25 m between rows, arranged approximately in the east-west direction, totaling 267 trees ha-1 with 8% tree occupation area (Figure 2).

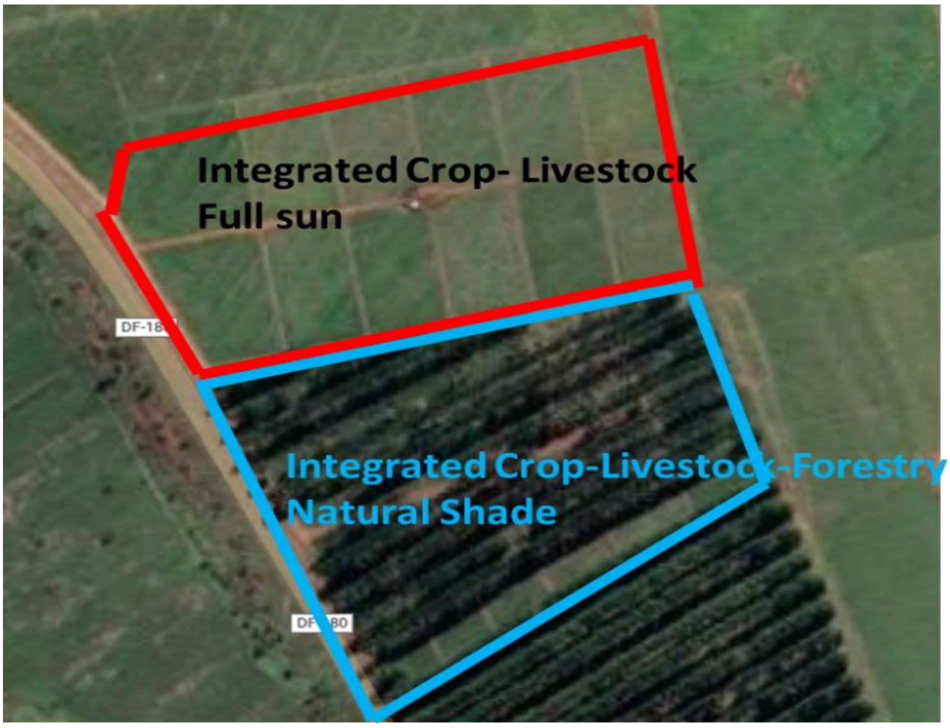
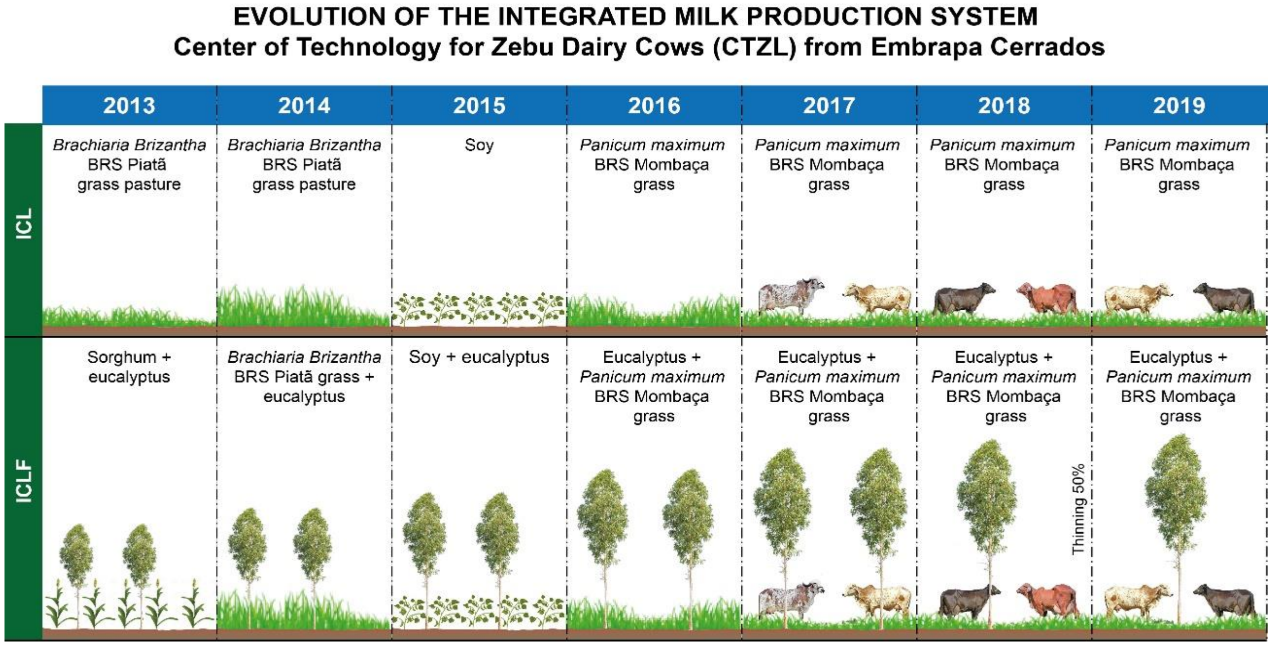


Figure 2. Experimental area (16 ha) divided between the treatments ICL (Integration Crop-Livestock – full sun pasture) and ICLF (Integration Crop-Livestock-Forestry – shaded pasture). Technology Center for Dairy Zebu Breeds (CTZL), Embrapa Cerrados, Brasília, DF. Source: Google Earth image from 12/04/2020.

Land use records for this area (Figure 3) indicate the succession and intercropping of crops over time in both systems, as well as the time of thinning in the ICLF system, when half of the trees were harvested every other in the row, it resulted in an average distance of 3 m between trees and shifting the average forest density to 130 trees.ha-1.



	2013	2014	2015	2016	2017	2018	2019
ICL	*Brachiaria Brizantha* BRS Piatã grass pasture	*Brachiaria Brizantha* BRS Piatã grass pasture	Soy	*Panicum maximum* BRS Mombaça grass	*Panicum maximum* BRS Mombaça grass	*Panicum maximum* BRS Mombaça grass	*Panicum maximum* BRS Mombaça grass
ICLF	Sorghum + eucalyptus	*Brachiaria Brizantha* BRS Piatã grass + eucalyptus	Soy + eucalyptus	Eucalyptus + *Panicum maximum* BRS Mombaça grass	Eucalyptus + *Panicum maximum* BRS Mombaça grass	Eucalyptus + *Panicum maximum* BRS Mombaça grass	Eucalyptus + *Panicum maximum* BRS Mombaça grass

Figure 3. Records of crops and mixes in the experimental areas of Crop-Livestock Integration (ICL - full sun) and Crop Integration- Livestock- Forest (ICLF-shaded). Technology Center for Dairy Zebu Breeds (CTZL), Embrapa Cerrados, Brasília, DF. Illustration: Wellington Cavalcanti.

At the beginning of the evaluations for this experiment, in 2017, the trees had an average height of 20 meters in the ICLF system. Climate data were obtained from the meteorological station of the National Institute of Meteorology (INMET) at Ponte Alta-Gama DF, three kilometers far from the experiment (Figure 4). The months of September and October were the ones with maximum temperatures above 34theC. The highest values of global solar radiation under the sun occurred in September and ranged from 1765.8 to 1864.9 KJ.mA-2, and the lowest value occurred in November 1126.3 KJ.mA-2. The average values obtained throughout the period were 1499.6 KJ.mA-2. The presence of trees reduces solar radiation by 44% in the annual average, values obtained with specific sensors coupled to automatic data loggers for reading data under the ICLF shadow.

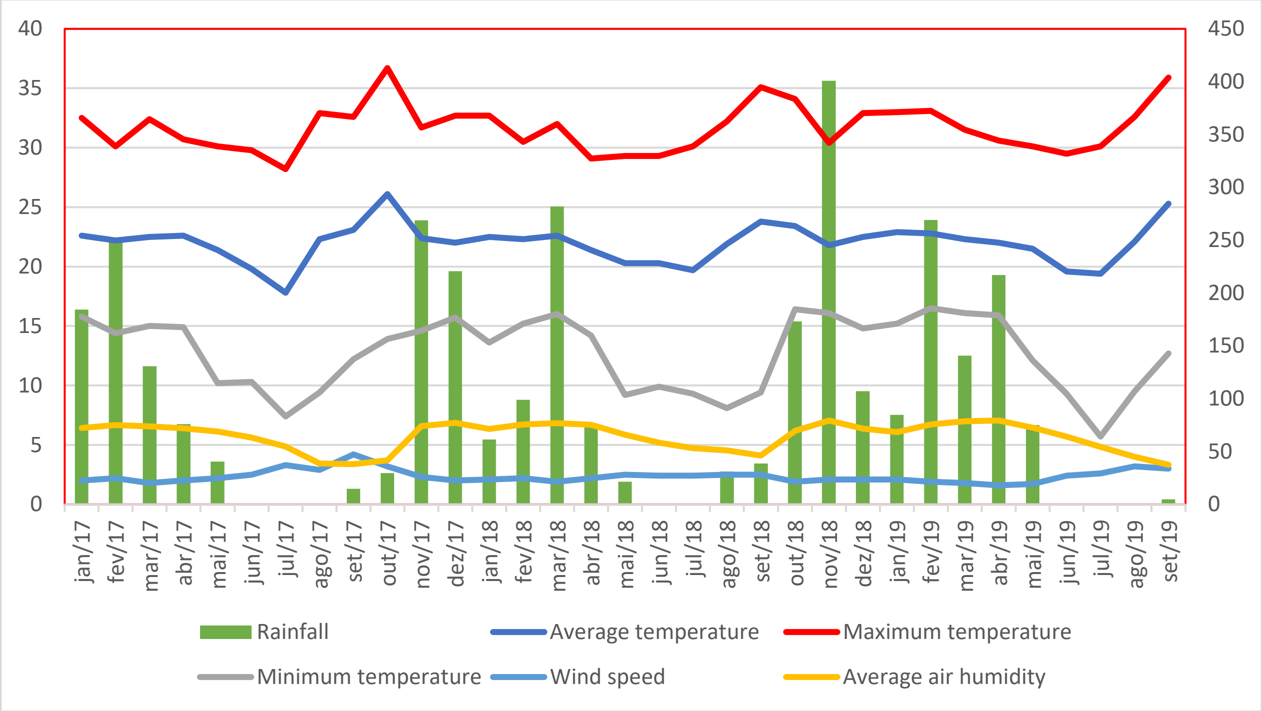


Figure 4. Climatic data from the meteorological station of INMET in Ponte Alta, Gama-DF, from January 2017 to September 2019. Temperatures and wind speed are shown on the X-axis. Rainfall and average relative humidity are shown on the Z-axis.

Experimental Animals

The experiment was in a completely randomized design. The Gir and Girolando cows were milked for an average of 273 and 311 days, respectively. The proportions of cows in the Girolando group were: 51% ½ Gir x ½ Holstein, 30% 5/8 Holstein x 3/8 Gir, 10% ¾ Holstein ¼ Gir, 6% ¼ Holstein x ¾ Gir and 3% 7/8 Holstein x 1/8 Gir. As for the calving groups, 20% of the cows were 1st group, 35%, 24%, 18% and 4% 2nd, 3rd, 4th and 5th groups, respectively. The average lactation days of cows under full sun were 213±5 and under ICLF shade were 200±5.

Cows were milked twice a day at 7 and 4 pm with calf at the foot and without any drugs to release milk. The waiting room had no shade or air conditioning. The waiting time for milking ranged around 20 to 30 minutes and the milking time of the batch from 30 to 50 minutes depending on the batch size (number of regulator animals). After milking, the animals stayed under a shed covered with tiles until they returned to the paddocks. Drinking troughs were available in the central area of the paddocks, before and after milking.

Milk production was obtained by weighing individual milk using a milk meter coupled to mechanical milking and calf consumption estimated at 25% (one teat), which totaled 1,498 measurements, in 119 cows, being 48 of which Gir and 71 of the Girolando breed, with an average number of 17 cows in each environment, during 33 months of the study (January 2017 to September 2019), on 43 different dates.

The milk yield data per hectare were processed by descriptive analysis, which considered the production of 119 cows testers and 32 regulators during the years 2017 to 2019, being six months on pasture under full sun of the ICL system (8 ha) and under the shade of the ICLF system (8 ha). The latter considered the area occupied by trees. In the six months of the dry period, with conserved forage source, an area of 2 ha for corn silage production was estimated for each treatment. Therefore, the total area of both systems was estimated at 10 ha.year-1.

The average number of animals that comprised the area in the rainy season was calculated and described in each year.

The animals were kept in rotational grazing, in the rainy and dry seasons, they received corn silage ad libitum. The water and dry minerals troughs were located in the central feeding area and with free access by the animals to the paddocks under grazing. The concentrate was supplied daily, only at milking, in the proportion of 1 kg of concentrate for every 3 kg of milk produced.

Rumination time was observed in 16 cows, 8 from each treatment (4 Gir and 4 Girolando) on 11 different dates in the spring-summer and autumn seasons over 2 years. The surface temperature by thermography of 55 cows was obtained in the animals in the morning and in the afternoon, periodically on 17 dates of different seasons. To obtain the surface temperatures of the animals and of the ground, thermographic images obtained through an infrared camera using the Quickreport® software were used to collect data from thermographic photographs at different points of the animals.

Reproductive parameters were obtained according to Martins et al. (2021).

Statistical analyzes were performed using mixed models and evaluation dates as repeated measure over time. The comparison between means with significant interactions was done according to Tukey Kramer (5%).

RESULTS

Results of this study will be published in Ferreira et al (2021, in press). The average environmental temperature for most of the period evaluated did not exceed 25oC. The maximum environment temperature was more challenging in the period from August to October, dry period in the Cerrado (Figure 4). In this environment, it was observed that the mean values of surface temperature by thermography in different parts of the animals under the ICLF shade reduced between 0.4 to 1.1 OC when compared to full sun (Figure 5). The rumination time of cows under shade was 32% longer than under full sun (Figure 6). This parameter is an indicator of animal welfare and favors greater milk production (Figure 7).

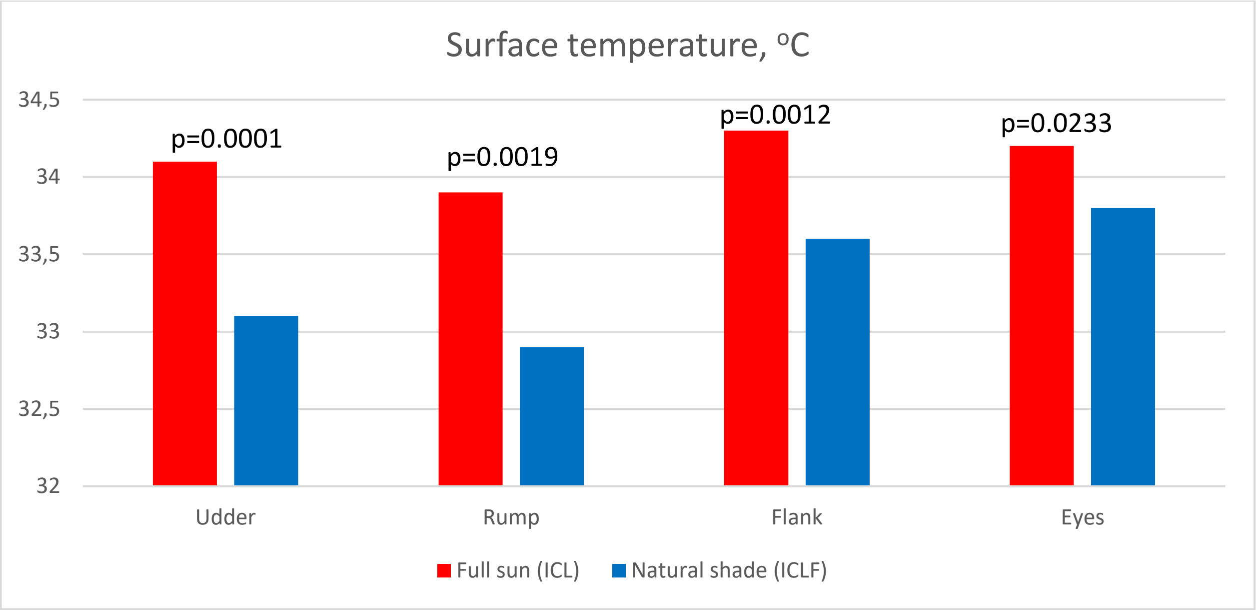


Figure 5. Surface temperature from Gir and Girolando dairy cows in grazing under full sun and natural shade treatments during the rainy and dry season.

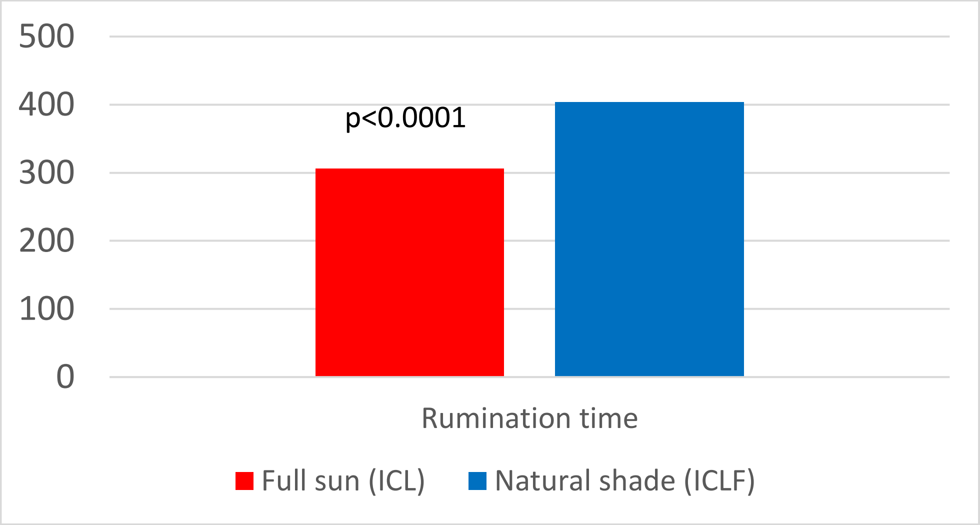


Figure 6. Rumination time, minutes, of lactating cows under grazing in full sun and natural shade treatments in rainy seasons

The presence of trees and ICLF shade influenced individual milk yield of Gir cows, being 24% higher than that of Gir cows under full sun (Figure 7). This shows the importance of providing thermal comfort, through shade, even for Zebu animals better adapted to the tropical environment.

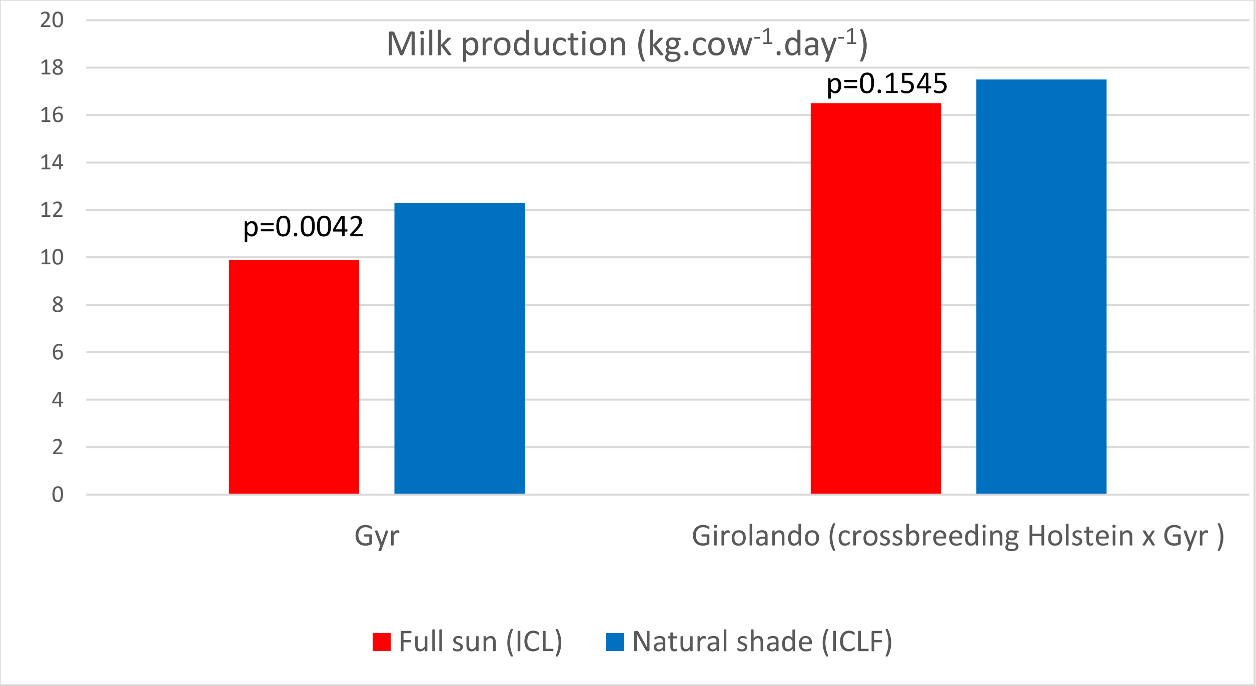


Figure 7. Average individual milk production (Kg.cow-1.day-1), of Gir and Girolando cows under full sun (Integrated Crop-Livestock ICL) and shade (Integrated Crop-Livestock-Forestry – ICLF) from January 2017 to September 2019 in the Cerrado Biome, in Brasília-DF

The effect of shade from trees of ICLF during the lactation phases can be observed at the beginning of lactation. From 01 to 75 days, milk production was 18% higher in shaded cows (Figure 8).

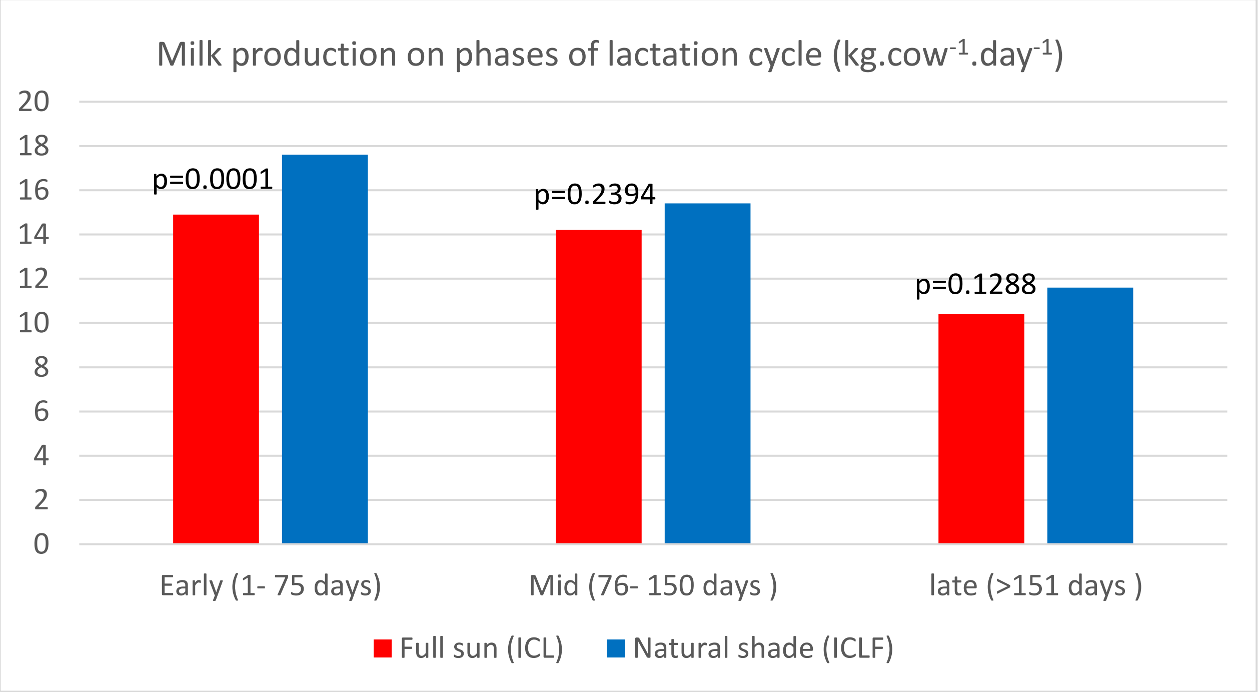


Figure 8. Average individual milk production (Kg.cow-1.day-1), of Gir and Girolando cows in the different lactation phases (initial, middle, final) under full sun (Integrated Crop-Livestock ICL) and shade (Integrated Crop-Livestock-Forestry – ICLF) from January 2017 to September 2019 in the Cerrado biome, in Brasília-DF

In the dry and rainy season, the presence of trees and shade provided by the ICLF system positively affected the milk production of individual Gir and Girolando cows. The 8% increase in the rainy season and 17% in the dry season can be attributed to the thermal comfort provided by shading (Figure 9).

This percentage represented in 180 days of the dry period, 378 kg of milk more for each cow in the ICLF system. Since the dry period has greater climatic challenge (high temperatures and low humidity in the Federal District region). This effect can only be attributed to the environment because the diet fed to the animals in both environments (ICL and ICLF) was corn silage with the same chemical composition. In the rainy season, in 180 days, the increase represents 216 kg more milk for each cow individually in the ICLF system.

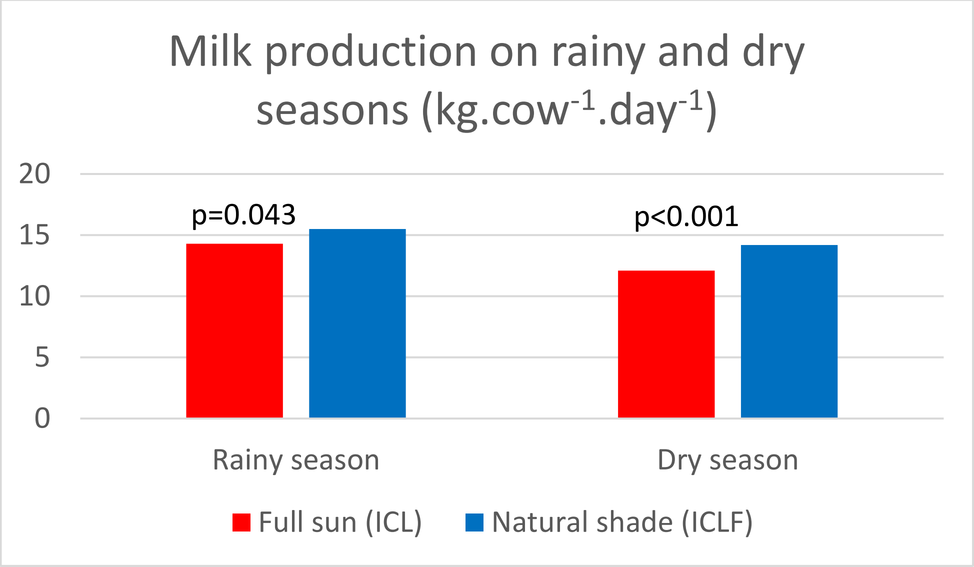


Figure 9. Individual milk production of Gir and Girolando cows (Kg.cow-1.day-1), in the rainy and dry season under full sun (ICL) and under shade (ICLF), in the period of January 2017 to September 2019 in the Cerrado Biome, in Brasília-DF

In 2018, the higher productivity observed in the ICLF area was probably associated with the thinning action of trees that allowed greater light incidence and, consequently, greater production of forage mass and, consequently, higher animal stocking rate in the area (Figure 10 and 11).

When comparing the total area used, including the occupation of trees and two hectares of production and roughage used in the dry season, the ICLF system loses in an average of three years 476 kg of milk.ha-1year-1. This loss of milk productivity can be offset by the potential income from wood production.

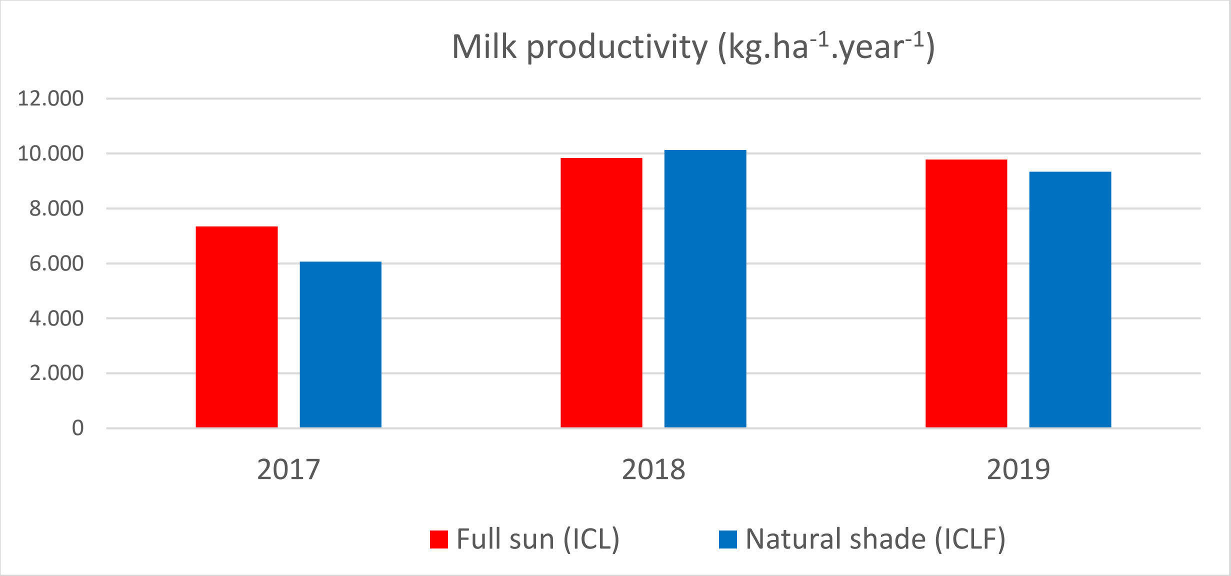


Figure 10. Annual milk yield (kg.ha-1.year-1) under full sun in the ICL system (in a total area of 10 ha) and under shade in the ICLF system considering the presence of trees (in an area of 10 ha) from 2017 to 2019 in the Cerrado biome, in Brasília-DF.

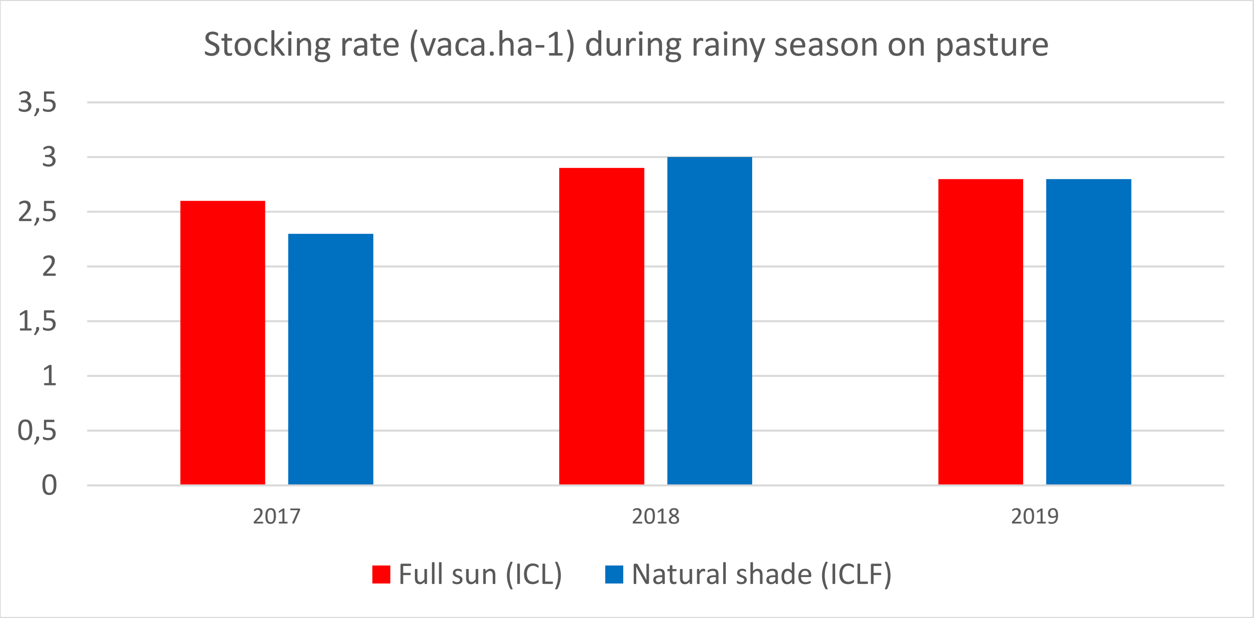


Figure 11. Animal stocking, in the rainy season from 2017 to 2019, under full sun and shade areas of the ICLF, in the Cerrado biome, Brasília-DF

The results of the reproductive performance'Gir cows (MARTINS et al., 2021) demonstrate the benefit of the presence of trees in the dry period (Figure 12). It was observed in Gir cows under ICLF shade, in the dry season, a greater number of ovarian follicles, total and viable oocytes and blastocysts when compared to those under full sun. Indicating a greater number of structures capable of being fertilized individually and enhancing reproductive indicators in cows under ambient conditions.

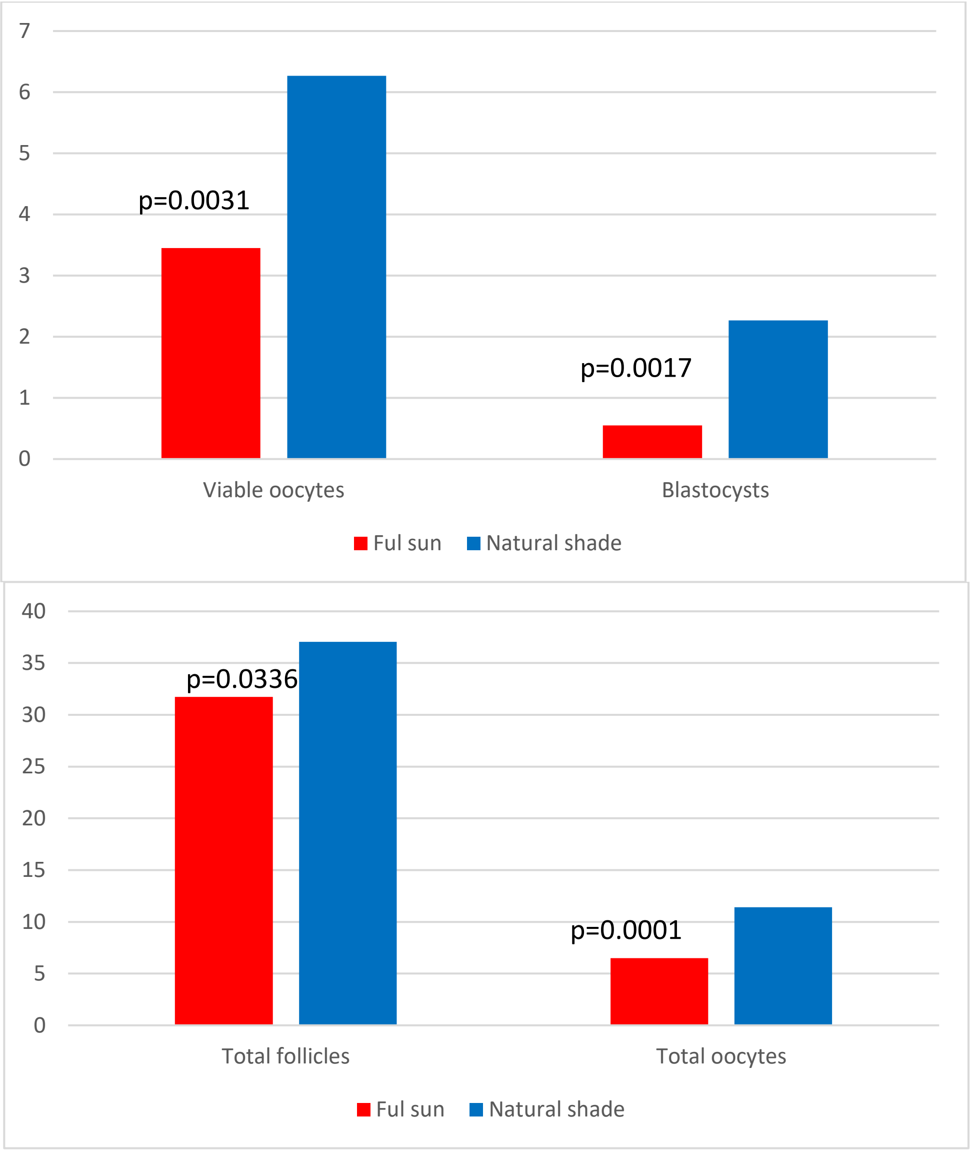


Figure 12. Average number of ovarian follicles, total and viable oocytes and blastocysts recovered by ovum pick up from grazing cows maintained in the areas with and without shade in dry seasons.

CONCLUSIONS

Under the conditions of the study for the Cerrado Biome, it was was proven the positive effect of tree shade provided by the ICLF system, for grazing dairy Gir cows on reproduction and on animal welfare during the dry period. Likewise, the importance of shade in the ICLF for Gir and Girolando cows on milk production was verified, mainly in the initial phase of lactation and in the dry period.

Adoption of ICLF for grazing dairy production is an alternative to intensify production and to promotes animal welfare.

ACKNOWLEDGMENTS

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ENTREPRENEURSHIP IN ILPF - SIPA

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ABSTRACT

The SIPA (in Portuguese called "Sistemas Integrados de Produção Agropecuária" here translated as Integrated Agricultural Production Systems, represent the state of the art on scientific knowledge for sustainable crop and livestock production in Brazil and in the world. The SIA (in Portuguese called "Serviço de Inteligência em Agronegócios") here translated as Agribusiness Intelligence Service, represents a case of entrepreneurship in SIPA for being specifically dedicated to the process of transferring this knowledge to the field, adapting language and providing opportunities for practical application by farmers of technical-scientific pillars consolidated in experimental protocols. Concepts such as "Pastoreio Rotatínuo" and Farm Design are examples of scientific content transformed into tools for implementing work in production environments. The knowledge is absorbed by the team of consultants and delivered to farmers in the most varied formats such as technical and business solutions: consulting, training, dissemination, technical assistance, coaching, project and business models. Transforming ideas and concepts into good business and rural life projects is SIA's mission, having sustainability and innovation at SIPA as transversal elements to all proposed solutions. Over 5 thousand farms have already received intervention from the company in the last 10 years.
Key words: integrated agricultural production systems; sustainability; business models; innovation

INTRODUCTION

Research on Integrated Agricultural Production Systems (SIPA) has increased exponentially in the last decade around the world. Much of these advances are attributed to the global guidelines published by FAO (2011), where the SIPA were considered one of the few food production models for the future capable of promoting sustainable intensification. As they are complex production systems, technical consultants need to know in depth the philosophy of these systems for the correct application of conceptual bases and tools. From this, SIA has been undertaking and innovating every year the way to transfer and apply knowledge in SIPA in the Brazilian agribusiness sector.

Entrepreneurship in ICLF - SIPA

SIA – Agribusiness Intelligence Service, which was founded in 2010, is a company specialized in promoting the sustainable development of Brazilian agribusiness. Its mission is to transform ideas into good business and life projects. In its portfolio of operations, it proposes corporate and technological solutions for the agribusiness in the form of technical consultancy, training, projects and business, having sustainability and innovation as a transversal assumption to any solution.

The technical team has a multidisciplinary background, consisting of more than 70 professionals from agronomy, animal sciences, veterinary medicine and forestry engineering. It operates continuously through technical consultancy in 1,027 farms, covering 167 municipalities. The largest concentration is in the states of Rio Grande do Sul and Santa Catarina and expanding to the states of Paraná, Mato Grosso, Rondônia and Piauí, in addition to Uruguay.

The SIA team aims to promote sustainable intensification in the countryside, so that more farmers can adopt these technologies, making their lands not only more productive, but also more profitable, sustainable and with respect for people. The focus of activity is the business itself and, therefore, everything that is most modern in research from around the world is transformed into a simple and easy way to be put into practice, so that the best decisions are made and the results year after year increase.

To work in consulting, technicians need to know, in depth, the philosophy of integrated systems so that they can correctly apply the conceptual bases and tools. They keep a systemic and holistic view of the processes, respecting farmers and their families. This requires in-depth training to enable the conversions of explicit and tacit knowledge into applied realities. This requires experience, understanding and a lot of technical and interpersonal knowledge, which cannot be acquired in short-term or just theoretical training. It does require a process of continuous training for the technical team, so that it also remains capable of promoting the ongoing training of farmers assisted.

The base methodology for knowledge transfer and application of SIPA concepts has been customized according to the target audience assisted in the different regions, farmer profile and productive segments in southern Brazil. In Rio Grande do Sul and Santa Catarina, the “PISA Projects” are focused on serving small farmers whose main economic activity is milk production. Medium-size farms having crops and beef cattle as the basis of their income are assisted in the so-called “ICL Projects” (Integrated Crop-Livestock). As a company providing specialized technical service for rural extension programs such as JPC (Together to Compete – SEBRAE/SENAR/FARSUL); ATeG (Technical and Management Assistance (SENAR) and other institutional arrangements that make the projects viable, SIA represents one of the main interfaces between the generation of knowledge on SIPA at universities and its direct transfer to farmers and their families. This dynamic and continuous process of knowledge feedback has provided great advances in the customization of delivery of techniques to each field situation, while validating concepts and contributing to adjustments in the scientific sphere.

As a way of validating the evolution of production systems, some farms that received technical advice from SIA received a sustainability diagnosis through the SAFA (Sustainability Assessment of Food and Agriculture Systems), a tool developed by FAO to assess sustainability in food chains. This tool involves the four dimensions of sustainability – economic resilience, environmental integrity, governance and social inclusion and is coordinated by the Federal Universities of Rio Grande do Sul and Paraná.

In the consultancies, several tools are used that have already been proven by science as tools that enhance farm's productive and economic results, as well as reduce environmental impacts. Among them, "Pastoreio Rotatínuo" and Farm Desing are noteworthy and can be considered the main levers for the transformation of production environments from productivist models to effectively sustainable models.

The pasture management through Pastoreio Rotatínuo (CARVALHO et al., 2013) allows for the reduction of work in animal management, as well as the activation of the acceleration of forage growth; animal welfare, as it has a choice of ingestion, minimizing losses and increasing weight gain or milk production. It is not a grazing method such as rotational or continuous. Pastoreio Rotatínuo represents a concept of management of pastoral environments capable of being conducted both, with rotation of animals in paddocks as well as in continuous areas without subdivision. It has no fixed relationship between animal stock and grazing area, but the necessary continued observation of grazing for maintenance of pastures in the optimal condition of individual production of animals and subsequent regrowth of used forages. As a result, the relationship between greenhouse gas emissions and other environmental or economic costs becomes more favorable to the pursue of sustainability for the planet. For each unit of animal product obtained less gas is emitted and less nutrients are used, that is, the production process is more efficient and sustainable.

Research shows that under SIPA, the relationship among soil-plant-animal-atmosphere components are extremely complex, but when properly managed these systems are capable of significantly improving productive, economic, environmental and social efficiency, such as: production efficiency of meat and grains in the same area, increase in soil microbiological activity (nutrient cycling), optimizing the use of nutrients (reduction in fertilizer in the medium and long term), store carbon in the soil (increase in soil organic matter), increase soil water retention (less impact from water stress), reduce the incidence of pests and diseases (less need for agrochemicals), reduce greenhouse gas emissions, increase economic resilience (diversification of activities), increase family income, helping to keep farmers on their holdings.

More recently, some authors have stated that these benefits can be even greater when pasture rotation and grain crops are planned, organized in space and time, so that crops can benefit each other, and the evolution of the whole system is enhanced. The concept of Farm Design has been attributed to this holistic and systemic planning. This tool represents the identity of SIA, since holistic thinking is present in each step of the projects, in each technical-financial projection, in each decision-making in the field together with the farmer. The “farm architecture” is a trademark of the company and the sum of this is the contribution we will leave for a better planet.

Despite all these benefits that SIPA can potentially promote on production systems, their complexity of understanding the processes involved requires technical knowledge in several areas, such as soil science, pasture management, animal and plant nutrition and many others. For such, lack of knowledge or adequate management of processes can compromise system's results, such as land degradation, with a reduction in production, economic capacity and environmental integrity.

In this sense, it is very important that knowledge and benefits from SIPA go beyond the walls of Universities and other Research Institutions, so that farmers are prone to apply them in the field, respecting principles and work philosophy held by the academy. For this, we believe that the presence of an extensionist is essential to fulfill this role of knowledge transfer to farmers. This technician is close to knowledge-building institutions, with specialized knowledge in SIPA, such as the SIPA Alliance. This professional needs a holistic and transdisciplinary view of the production environment and needs to be able to transform the results published in scientific journals into simple, convincing and applicable language, customizing it to farms.

Undoubtedly, the diffusion and transfer of technology and adoption of SIPA by farmers is extremely important and a huge challenge, especially due to the Brazilian diversity of climate, soils, productive arrangements, colonization and cultural influences.

Based on the work tools and scientific foundation already mentioned, over the years SIA has been formatting different solutions for farms, according to the status of the production system. At the farm level, SIA Diagnostics, SIA AgroCenários and SIA Tempo Integral stand out.

SIA Diagnostics is a specific solution aimed at farms that already have a defined production system, such as cattle breeding and rearing, or grain farming and crop-livestock integration, and need to better organize actions and boost technical and financial results. It is a consultancy specializing in the complete characterization of the current production system, with short-term recommendations, a delivery document with the technical-financial diagnosis of the current production system and projections of results when carried out in its excellence, in the technical vision of SIA. The document also contains notes on the strengths and limitations of the current business model and proposals for improvement for the medium and long term.

SIA AgroCenários is also a specific solution, but aimed at production systems in progress and for farmers who are not fully satisfied with the results and want to confront other potential business models and their financial and operational viability. It also applies to farms that do not yet have a defined production system and want to analyze business model options to guide their actions. SIA's technical team will visit production areas, tabulate current business data and build different alternative technical-financial scenarios, conducted in their excellence, with the SIA vision, for high profitability with sustainability of the production environment.

SIA Tempo Integral is a continuous technical and business consulting solution for the productive, operational and economic development of meat and milk production systems and crop-livestock integration. It is a customized solution in flexible formats of frequency and intensity of on-site technical visits in order to guide, implement and monitor technical actions related to the technical project developed, as well as other forms of communication that meet the needs and interests of each farm, its particularities, profile and preferences of its managers and work team. This solution is the most solid way to obtain the results projected at SIA Diagnosis or SIA AgroCenários.

In addition to these solutions, there are two other in an innovative format and done collectively, Farm Coaching and Agribusiness Mosaic. These two collective solutions are clear examples of entrepreneurship in SIPA, as they are different approaches, with an innovative format, to carry out the transfer of knowledge in integrated systems for farmers and agribusiness clients.

Farm Coaching is an innovative solution aimed at personal and professional development in agribusiness topics, using coaching techniques. It is an immersion designed for farmers and other agro professionals, who want to enhance their performance in their business. In this event, coaching tools are worked on and developed, allied to the technical theme of crop-livestock integration. Contents such as assertive communication, neurolinguistic programming, entrepreneurial attitude, time management, soil use and management, nutrient cycling, efficiency in integrated agricultural production systems, crop rotation, strategies for system management are covered. Immersion is closed with elaboration of an Action Plan, so that everything that was learned, absorbed, reflected and discovered during the immersion is put into practice.

The Agribusiness Mosaic is a biannual forum created by SIA that, together with partner companies and institutions, proposes an intelligent and dynamic meeting to promote the sustainable intensification of agricultural systems in Brazil. In 2022, the fourth edition of this event will take place, with thematic focus on the integration between farming and livestock and the digital world, with an expectation of 800 participants. In each edition, SIA has the premise of innovating and delivering to participants and partners the most current information about SIPA in the field of research, governance and companies.

The performance mainly in the field, applying sustainability through the tools mentioned among others, achieved a differentiated knowledge to SIA. This experience of more than ten years allowed the perception that the company also needs to act more expressively in the business sphere, building projects and new business models. As a result, this year the Sustainable Business and Projects Division was created, with the objective of working on the theme of sustainability (economic, social, environmental and governance), with a multidisciplinary vision and a focus on competitiveness and innovation in business.

CONCLUSION

The correct application of the SIPA concepts can be considered a virtuous proposition of a Business Model for farms in Brazil and around the world, an intelligent alternative in the search for economic, environmental and social sustainability in the countryside, because it concurrently considers "Production and Conservation". When applied in a holistic and systemic view, it is also capable of providing opportunities for the well-being, health and happiness of farmers and their families. A model that works for family farming, for medium and large producers. An evolving sustainability concept that is synergistic with global transformations and compliance needs.

However, consolidating this model as the way to produce food, nourish people, generate wealth and live in harmony with nature is a long, arduous path that requires persistence from its actors. It requires, above all, the evolution and establishment of a broader educational process, which seeks to build and transfer knowledge from the basis of people's education, in elementary and secondary education, in society's public forums, in cities, in the awareness of users of the planet, and not just in the vicinity of academies and scientific research institutions. As we are far from this, it seems, we must have the patience and determination to continue. Without radicalism, with intelligence and a dissemination strategy. That is how SIPA concepts are, and that is how we must continue to evolve.

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SOCIOECONOMIC ISSUES OF INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS

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ABSTRACT

The integrated crop-livestock and crop-livestock-forest are alternative agricultural system to promote sustainable intensification on agriculture, particularly, in Amazon and Cerrado regions. However, the adoption rate of integrated systems is still low. To contribute to increase adoption of integrated systems, our results illustrate the high and balance economic and environmental performance of integrated system in Mato Grosso, Brazil. Also, our results evidence that the economic barrier for widespread adoption of integrated system is the high commodity price.

Key words: Economic Performance; Sustainability; Cerrado; Amazon

INTRODUCTION

The negative impacts arising from the increasing complexity of interactions among society, the economic sector, and the environmental resources use such as increase of poverty, income concentration, and climate change suggest that the global society needs to settle a different development trajectory (IPCC, 2013; STEFFEN et al., 2015). A fundamental issue is to implement a development process based on a balanced interrelationship between economic growth and environmental resources use having as main goal to improve society well-being (BRUNDTLAND, 1987; DASGUPTA, 2010; PURVIS et al., 2019).

In this context, agriculture assumes an essential function on a global scale in the solution to the crucial social problem of increasing food production to meet an increasing demand and, simultaneously, promoting the preservation of natural resources (DAVIS et al., 2012; FOLEY et al., 2011; GODFRAY et al., 2010). Thus, over the last years, sustainable agricultural systems have been receiving special attention from policy and decision makers. Sustainable agricultural systems must be capable of maintaining its productivity using farming practices that conserve resources, protect the environment, produce efficiently, compete commercially, and enhance the quality of life for farmers and society overall (HANSEN, 1996; IKERD, 1993; SCHALLER, 1993).

Brazilian public policies have increasingly shown interest in promoting research and dissemination of on-farm practices that enhance economic results in agriculture and, at the same time, contribute to the reduction of its social and environmental negative impacts, notably in the Cerrado and Amazon regions, as indicated in international commitments assumed at COP-15, as well as in the Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Economy in Agriculture (ABC Plan) and in the ratification of the Paris Agreement in 2016 (BRASIL, 2016, 2012, 2010).

As a common issue in these initiatives, especially regarding the significant contribution of the agricultural sector to Brazilian CO_2 emissions, responsible for 31.3% of direct emissions in 2015 (SIRENE, 2017), it is the commitment to increase the areas of integrated crop-livestock (ICL) and crop-livestock-forest systems (ICLF), particularly in the Amazon and Cerrado regions. These agricultural systems aim to improve the sustainability through the integration of various production activities (i.e. crops, livestock and forestry) in the same area, via intercropping and rotations, as to obtain synergies among agroecosystem components (BALBINO et al., 2011; MACEDO, 2009; NAIR, 1991).

However, the adoption rate of the integrated systems in Brazil is low, around 11.5 million hectares in 2015/2016 (EMBRAPA; REDE ILPF, 2017), which represents 3.2% of agriculture area in the country (IBGE, 2017). We can list several social, cultural, structural, technological and economical barriers for widespread adoption of integrated systems in Brazil (CORTNER et al., 2019). From an economic perspective, farmers usually highlight as important barriers: i) high initial investment to implement integrated systems; ii) high production cost in comparison with exclusive crop or exclusive livestock systems; doubt about economic viability of integrated systems and; iv) difficulties to assess economic results of integrated systems.

Taking into account these perceived economic barriers, we will present some results to illustrate the economic performance of integrated systems in comparison with large-scale crop rotation soybean-corn and traditional livestock in Mato Grosso, Brazil (DOS REIS et al., 2021, 2020). Mato Grosso is one of the largest and most productive agricultural frontiers in the world (IBGE, 2020; IMEA, 2021; MAPA, 2020). It produces 28% of the soybeans, 33% of the corn, and 71% of the cotton cultivated in Brazil, an area of 11 million hectares (IMEA, 2021). Furthermore, it contains 15% of Brazilian beef cattle herd, 30.1 million heads, on an area of 23 million hectares (IBGE, 2020; IMEA, 2021). However, these economic results present, as counterpart, considerable negative environmental impacts, particularly deforestation (ANDERSEN et al., 2002; BARONA et al., 2010; HARGRAVE; KIS-KATOS, 2013; MALHI et al., 2008). Mato Grosso state figures as one of the main contributors for deforestation in the Amazon region, with 1,685 Km^2 cleared in 2019, representing 18% of deforestation in the Brazilian Amazon that year (INPE, 2021). These economic and environmental issues evidence the global relevance of assess agricultural performance in this region.

RESULTS

2.1 Economic viability of integrated systems[1]

We used an economic viability analysis approach to compare the economic performance of three agricultural systems: an integrated crop-livestock system versus a typical continuous crop (soybean-corn rotation) traditional livestock farm in the state of Mato Grosso. This method is established in the economic literature as an instrument to evaluate the economic potential of any investment decision (GITMAN; ZUTTER, 2014; LAPPONI, 2013). We used data from IMEA to generate typical crop and livestock farm and survey data to generate the iCL farm.

The iCL system showed the largest investment costs, but also showed the largest positive cash flows throughout the remainder of the study period, achieving a positive result of USD 654.04/ha in 2012 compared to USD 460.85/ha for continuous cropping and UDS 27.59/ha for continuous livestock (Figure 1). Macroeconomic fluctuations explain most of the changes in cash flows over the study period. In particular, soybean and beef prices increased considerably during the study period. The economic fragility of traditional livestock is evidenced by the smaller cash flow throughout the study period (on average USD 23,131.62 versus USD 109,164.24 for continuous cropping and USD 204,318.97 for the integrated system).

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[1] A complete economic analysis of integrated systems can find in: dos Reis, J.C., Kamoi, M.Y.T., Latorraca, D., Chen, R.F.F., Michetti, M., Wruck, F.J., Garrett, R.D., Valentim, J.F., Rodrigues, R. de A.R., Rodrigues-Filho, S., 2020. Assessing the economic viability of integrated crop−livestock systems in Mato Grosso, Brazil. Renew. Agric. Food Syst. 35, 631–642. https://doi.org/10.1017/S1742170519000280

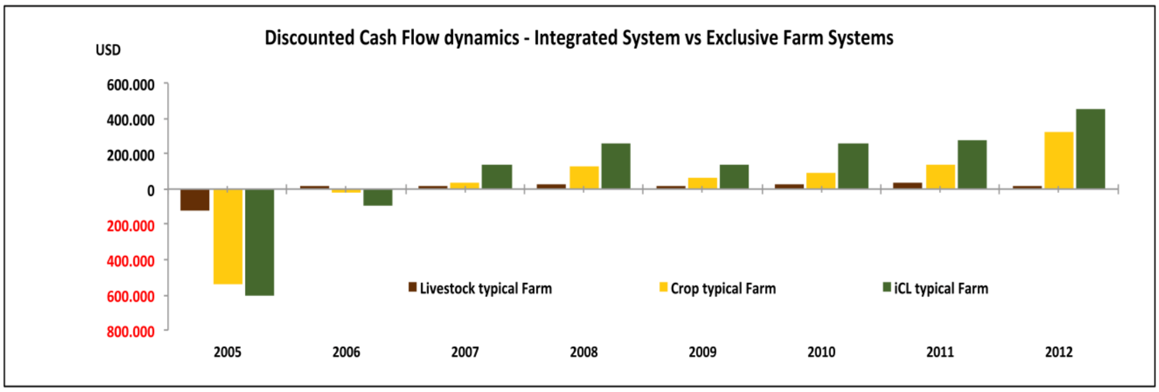

Figure 1. Cash Flow: integrated systems vs exclusive farms systems in Mato Grosso, Brazil

Another economic indicator widely used in the economic project analysis approach is the recovery period of the investment, known in the literature as the payback period (GITMAN; ZUTTER, 2014; LAPPONI, 2013). The iCL farm recovered the investment after 4 years (Figure 2), while the continuous crop did not recover their investment until year 6. The livestock system recovered the investment after 5 years. In the end of seventh year, the continuous crop and livestock farms had an accumulated cash flow of USD 228,207.46 and USD 40,313.76, respectively. However, the iCL farm had accumulated USD 825,868.81.

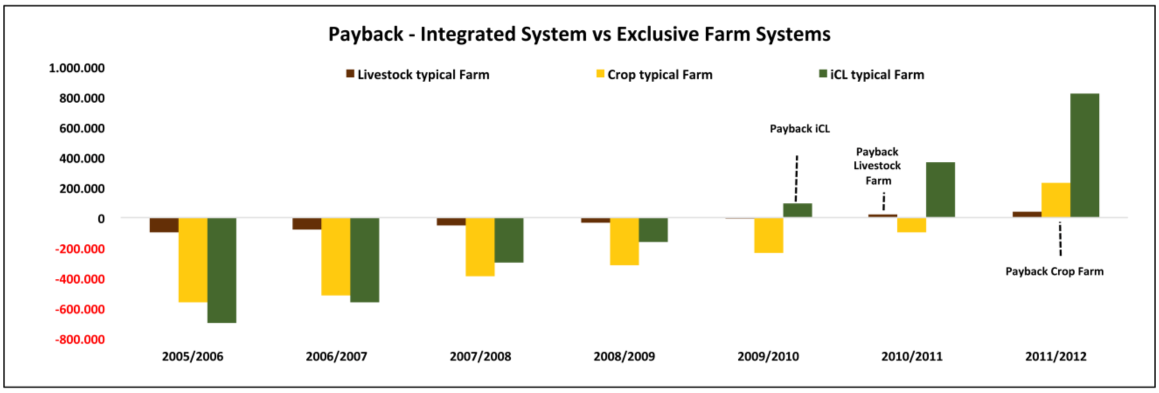

Figure 2. Payback: integrated systems vs exclusive farm systems in Mato Grosso, Brazil

2.2 Economic and Environmental performances – the emergy synthesis analysis[2]

The emergy accounting approach proposed by Howard T. Odum (ODUM, 1996) is an evaluation framework grounded in the hierarchical organization systems and following the irreversible thermodynamics in which the large-scale environmental support for the economy is quantified by computing the values of natural and economic resources on a common basis of energy flow, allowing comparison across different productive systems (BROWN, 2004; BROWN; ULGIATI, 2004, 1997; ODUM, 1996, 1988; ULGIATI et al., 2011). It is particularly useful for evaluating agricultural systems since they rely on the interrelationships between natural and economic inputs to produce goods and services (BARROS et al., 2009; ODUM, 1984; RÓTOLO et al., 2007). Emergy is defined as the available energy (exergy) of one kind, usually the equivalent solar energy (expressed in solar emjoules - sej), required directly or indirectly to make a product or service (ODUM, 1996).

The emergy analysis presented focused on comparison between typical crop and livestock farms from two different regions - Mid-North and Southeast - of the state of Mato Grosso in Brazil, elaborated

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[2] A complete emergy analysis of integrated systems in comparison with large-scale crop and traditional livestock can be find in: dos Reis, J.C., Rodrigues, G.S., de Barros, I., Ribeiro Rodrigues, R. de A., Garrett, R.D., Valentim, J.F., Kamoi, M.Y.T., Michetti, M., Wruck, F.J., Rodrigues-Filho, S., Pimentel, P.E.O., Smukler, S., 2021. Integrated crop-livestock systems: A sustainable land-use alternative for food production in the Brazilian Cerrado and Amazon. J. Clean. Prod. 283, 124580. https://doi.org/10.1016/j.jclepro.2020.124580

using survey data from Mato Grosso Institute of Agricultural Economics (IMEA) (IMEA, 2021), and a case study data from an integrated crop-livestock farm located in the municipality of Santa Carmen, in the Mid-North region of Mato Grosso for 2017/2018 season. To provide comparable results, the inputs and the outputs were normalized for ha^{-1}.year^{-1}. The baseline used was 12.1 E+24 sej.year^{-1} (BROWN et al., 2016).

The results for the set of indicators (Table 1) show a striking contrast between the crop system, heavily dependent on purchased external inputs (a renewable resource use of 25%), and the cattle system, based largely on free local resources (a renewable resource use of 66%). The integrated system is in between, using quite a few external inputs, but also capitalizing on free renewable resources (a renewable resource use of 31%).

Table 1. Emergy indices

Index	Formulas	ICL	Crop	Livestock
% Renewable	**R/(R+N+F)**	0.31	0.25	0.66
Environmental Loading Ratio	**(F+N)/R**	2.21	2.97	0.52
Emergy Sustainability Index	**EYR/ELR**	0.67	0.46	5.62
EmF (factor m)		3.21	3.97	1.52
Carbon-emergy output intensity (CemI)	**tonCO$_{2eq}$/Y(J)**	-2.71E-11	3.70E-11	7.98E-09

The small portion of renewable resources used explains the higher Environmental Load Ratio (ELR) for the crop system: 2.97. The ELR for the integrated system was 2.21, and for the livestock system 0.52. These results indicate that the crop system poses higher ecosystem stress than the other productive activities. The Environmental Sustainable Index (ESI) illustrates as the crop system presents an unbalanced performance, considering the economic and the ecological sub-systems. The value of 0.46 emphasizes the importance of external inputs for the crop system and the smaller relation R/(F+N) for this productive system. An opposite result is shown by the livestock system, with an ESI of 5.62. The ESI for the integrated system was 0.67.

The emergy footprint values highlight the heaviest environmental load for the crop system. If local renewable resources provided all emergy used in this activity, the farm area would need to be almost four times larger than its real size. In contrast, the emergy footprint for the livestock system indicated that an area 52% larger would be sufficient to provide all emergy used in this activity. For the integrated system, the area needed to provide all emergy used would be 3.2 times larger than its real size.

Lastly, the carbon-emergy indices show the potential of the iCL system to mitigate emissions of greenhouse gases from agriculture. The integrated systems displayed an emission factor of -2.71 E-11 tonCO$_{2eq}$ for each joule produced. In contrast, the crop system released 3.70 E-11 tonCO$_{2eq}$ for each joule produced. The traditional livestock demonstrated the worst performance. This system shows a positive emission of 7.98 E-09 tonCO$_{2eq}$ for each joule produced.

The economic results observed for the three agricultural systems (Table 2) highlight that the traditional economic evaluation provides incomplete results about the potential of activities to generate real wealth (BROWN; ULGIATI, 2004; ODUM, 1996). Even with the highest production costs (977.77 USD.ha^{-1}), the net profit for the crop system (295 USD.ha^{-1}) was 25% higher than the profit of the integrated system and incomparably higher than the livestock system, which show a net loss of 0.58 USD.ha^{-1}. These results would suggest that the crop system is the best alternative for farmers to invest their money. The economic results for the crop system are due to its high productivity and the high prices for corn and, mainly, soybean in the 2017/18 season (IMEA, 2021).

Table 2. Economic results.

ICL		**Crop**		**Livestock**	
Cultivated area (ha)	**2648**	**Cultivated area (ha)**	**1200**	**Cultivated area (ha)**	**2200**
	USD		**USD**		**USD**
Net Revenue (A)	812.70	**Net Revenue (A)**	1,456.83	**Net Revenue (A)**	186.08
Total Cost (B)	503.19	**Total Cost (B)**	997.77	**Total Cost (B)**	165.93
Gross Profit (A-B)	309.51	**Gross Profit (A-B)**	459.06	**Gross Profit (A-B)**	20.15
EBITDA	284.66	**EBITDA**	373.99	**EBITDA**	12.04
Net Profit	235.69	**Net Profit**	295.00	**Net Profit**	-0.58

Nonetheless, the economic results contradict the observed outcomes provided by the emergy synthesis approach (Table 1) once the economic analysis does not take into account the contribution from environmental resources (Odum, 1996). The crop system uses a considerable amount of external purchased inputs to capture environmental resources services. The high efficiency of external inputs and the large-scale production explain the positive performance of the economic subsystem. However, this pattern is unsustainable. The emergy results highlighted the environmental stress caused by crop system and its contribution to deteriorate environmental conditions, as indicated by the ELR, ESI and Emf indices.

FINAL REMARKS

Finding alternatives to deal with the global social problem of the increasing demand for food and, simultaneously, preserving the environmental resources is crucial for the agricultural sector. The negative environmental impacts of large-scale agriculture and traditional livestock husbandry compromise the continuity of these productive systems in the long run. Our results indicate that integrated crop-livestock systems can be a viable alternative to current agricultural activities. The mainly findings:

- ✓ Integrated systems are economically competitive, particularly in the long run.
- ✓ Even with higher investment, the integrated systems showed lowest payback.
- ✓ Large-scale crop systems display better economic performance on high commodities price scenario.
- ✓ The emergy indicators set showed that the social cost of large-scale continuous crop system is higher than its social benefits.
- ✓ The extensive beef cattle system is shown to be unsustainable in even more dimensions - low productivity, low profits, and high emissions.
- ✓ The integrated system displays balance economic and environmental performances achieving high profitability, while dramatically reducing environmental impacts.
- ✓ The real economic barrier for widespread adoption of integrated system is the high commodity price.

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POTENTIAL LAND-SAVING EFFECTS FROM INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

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ABSTRACT

A bold sustainable intensification strategy involves a multiple approach combining increased yields, cropping intensity, and resource-use efficiency. Well-designed and implemented integrated crop-livestock-forestry systems (ICLS) can achieve those goals. In this paper I discuss the potential land-saving effects arising from the recovery of low-productive pastures through ICLS and the potential land-saving effects from productive livestock systems already in rotation with high-yielding soybean crops. The recovery of low productive pastures offers an impressive way of sparing land from cultivation. Land-saving effects resulting from turning low productivity pastures into productive ones through ICLS may reach 11 ha spared/ha recovered but figures around 3 to 5 ha spared/ha recovered would probably be more realistic. The potential for generating land-saving effects in high-productive ICLS is lower (up 1.40 ha spared/ha) because land-productivity is close to or is already at the attainable yield level. However, productive ICLS have a higher potential to deliver environmental benefits and their already high levels of land-productivity indicate that associated rebound effects are unlikely. Thus, productive ICLS will likely promote land-sparing effects with no leakage.

Key words: agricultural R&D; Jevons' paradox; land-use change; sustainable intensification

INTRODUCTION

Population and per capita income are the two most important shifters of agricultural demand curve. In the past decades (1960-2006), population growth explained around 80% of the variation in global agricultural demand. In the horizon up to 2050, the increase in world's population, whilst at decreasing rates, will still be quite relevant (55% of the variation in agricultural demand). Per capita income is projected to gain relevance, and for the 2006-2050 period it will account for 45% of the agricultural demand growth (HERTEL; BALDOS, 2016).

On the one hand, population and per capita income growth, combined with changes in eating habits resulting from the expansion of the world middle class and the growing rate of urbanization, will keep the demand for agricultural products with higher income-elasticities, such as animal protein, fruits, and legumes, at high growth rates over the next decade. On the other hand, the progressive aging of population associated with possible changes in consumers' preferences, motivated by health and environmental issues, could reduce that potential rate of increase in animal protein demand. Structural and large-scale transformations, however, are complex processes, and generally encompass several decades to be more fully observed.

Brazil is a major player in feed and animal protein production, and it is projected to supply a substantial share of these products to meet global demand over the next decade (OECD-FAO, 2020). Despite such positive prospects, maintaining and/or expanding that market share is not trivial. In addition to inherent challenges of expanding production (biophysical, market, infrastructure, and institutional related issues), Brazilian agriculture will face increasing scrutiny by consumers and other governments who will require more detailed information about the agricultural production processes and their potential impacts on the environmental and social dimensions of sustainability. It is of

Brazil's agriculture interest to critically analyze sound-based recommendations and to pursue alternatives for improvement whenever necessary. The country must also invest in better communicating scientific evidence, allowing for different stakeholders in Brazil and abroad to clearly understand the facts that are really known and those that are not yet well established.

Brazilian agriculture has proven to being following a science-based approach over the past decades (MARTHA JR.; ALVES, 2018). In spite of localized problems, the most noted one is the deforestation pressure at the borders of Cerrado and Amazon biomes, it is worth of noting that two-thirds of Brazil's immense territory is still covered with native vegetation (MAPBIOMAS, 2021). A successful past history, however, is no guarantee for grand achievements in the future. Brazil must clearly intensify its efforts into the sustainability path. Such approach requires increasing agricultural production with low pressure on natural resources and biodiversity, and with minimal land area expansion (e.g. leakage) to other regions.

A bold sustainable intensification strategy would involve a multiple approach combining increased yields, cropping intensity, and resource-use efficiency. Well-designed and implemented integrated crop-livestock-forestry systems (ICLS) in Brazil can achieve those goals.

Consider, for example, ICLS with a focus on soybean, corn and beef production. Depending on the agroecological region considered it is possible to have a cropping intensity as high as three crops per year under rainfed conditions. In such systems, during the rainy season, a short-cycle soybean crop is followed by a second-season corn crop, known as "safrinha", in which corn is established together with the grass pasture. For both crop seasons, a no-till planting approach is used. Once the second-season corn is harvested, the already established pasture allows for a third "cattle crop" during the dry season. In the next growing season, the farmer is well positioned to choose between another crop-livestock cycle or depending on farmer's objectives and prevailing relative prices (crops, livestock, inputs), the farmer may decide to keep the pasture for a few more months (or even years).

In well-managed ICLS it has been observed the disruption of pest and disease cycles, and over the medium to long-run those systems operate with greater nutrient-use efficiencies (CORDEIRO et al., 2015). The ICLS with the greatest potential from a technological and economic perspective, with expected positive impacts on social and environmental dimensions, are those managing their "crop" and "livestock" components with a focus on high productivity (coupled with high resource-use efficiency) (MARTHA JR. et al., 2011).

But, what determines land-productivity? In a given agroecological region, the potential yield of a crop is defined primarily by climate parameters (radiation, temperature, etc.), considering an environment under no water or nutrient constraint. For rainfed conditions, the water-limited yield potential, a situation in which soil water capture and storage is optimal and nutrient constraints are eliminated, is generally preferred. "Achievable (or attainable) yields" are generally lower than that potential because plant growth is frequently limited by lack of water and/or nutrients relative to its needs during the growth cycle. In practice, other reducing factors, such as pests, diseases, weeds, and other management limitations additionally constrain crop growth so "actual yields" are usually lower than "attainable yields" (TITTONELL; GILLER, 2013; DIJK et al., 2017).

Actual yields, even if they are at a point of technical efficiency (e.g. when the maximum amount of output is produced for a given amount of inputs), may or may not be at an economic optimum point. For that to occur, it is necessary to additionally meet a condition of allocative efficiency, observed when inputs and outputs are combined to achieve their highest possible net value (HEADY, 1960; BEDDOW et al., 2014; DIJK et al., 2017). At such allocative efficient condition, the price ratio (price of factor/price of product) must equal the transformation ratio (marginal productivity of the resource). Thus, as relative prices changes, so does the economic optimum yield level. As the price of the factor becomes smaller relative to the price of the product, the price ratio line becomes flatter and the use of a higher level of the factor is advantageous (HEADY, 1960). Needless to say, that increasing the level of inputs use to achieve higher yields must also consider resource-use efficiency and best-practice recommendations to avoid negative externalities such as pollution to soil, water, and air.

Land productivity gain complexity in pastoral systems under both a technological and an economic perspective. In addition to forage production, two additional partial efficiencies are relevant to grazing systems: the grazing efficiency (e.g. the proportion of herbage dry mass (DM) that is actually consumed by the grazing animals); and the conversion efficiency (e.g. the portion of consumed herbage DM that is converted into animal product, such as kg DM/kg live weight gain (LWG)). In pasture-based systems, productivity (kg LWG/ha) is therefore given by the product between animal performance (kg LWG/head) and stocking rates (head/hectare). Animal production (kg LWG) is then the product between area (ha) and productivity (kg LWG/ha) (MARTHA JR. et al., 2012).

Considering only one of the productivity's components (e.g. animal performance or stocking rates) and ignoring the other in the estimation of productivity in pastoral systems might lead to misleading conclusions. If stocking rates increase to a level that significantly reduce animal performance, animal productivity and economic performance are jeopardized (besides, with a lower animal performance the intensity of methane emissions increases). Likewise, if a higher level of animal performance is associated with a very low stocking rate, again, technical and economic performances are compromised. Therefore, from an economic viewpoint, there is no rule of thumb, e.g. increasing stocking rates (head/ha) or animal performance (kg LWG/head) might be – or might be not – profitable. Each situation must be evaluated carefully and the allocative efficiency in pastoral systems must take into account price and transformation ratios for both productivity components, stocking rates and animal performance, including the possibility of using supplements for the grazing animals.

Agronomic and economic decisions regarding land productivity levels also have implications to land use. For a given output level, the higher the land productivity (output per unit area) – the intensive margin – the lower is the demand for agricultural land expansion – the extensive margin. Such reasoning provides the basis for the so called "land-saving effect", that is, the area of land left uncultivated due to technological progress increasing agricultural output per unit of area (e.g. yields) instead (MARTHA JR.; ALVES, 2018).

Following this extended introduction, in the remainder of this article I consider the potential land-saving effects for ICLS in the Brazilian Cerrado, with a focus on soybean (crop phase) and, especially, on beef production (livestock phase). In a final section, I bring to attention some of the policy challenges to increase land-productivity and, hence, to further expanding the potential land-saving effects.

MATERIAL AND METHODS

In this article I discuss the potential land-saving effects arising from the recovery of low-productive pastures through ICLS. I also present the potential land-saving effects from productive livestock systems already in rotation with a high-yielding soybean crop. For the two cases, the impact of varying the proportion of cropland and pastureland on land-savings is discussed. Details about land-saving calculations were presented by Martha Jr. et al. (2012).

Typical productivity ranges for soybean and beef production in ICLS were considered. For soybean, an average yield of 3000 kg/ha was assumed for an "exclusive-soybean" production system. For its counterpart in ICLS, I considered an average yield of 3500 kg/ha. That yield difference (e.g. 500 kg/ha) between the two systems is compatible with the results presented by Reis et al. (2019). Land-saving effects arising from the recovery of low-productive pastures considered an initial animal productivity of 54 kg LWG/ha/year (e.g. 90 kg LWG/head/year * 0,60 head/ha/year). Then, I estimated the land-saving effects when animal performance and stocking rates are improved up to 180 kg/head/year and 3,6 head/ha/year, respectively. It is worth of noting that an annual stocking rate of 3,6 head/ha/year is compatible with 1,8 head/ha during the dry season (120 days), and 4,5 head/ha during the rainy season (245 days). For the productive system scenario, animal performance and stocking rates ranged from 150 to 180 kg/head/year, and from 2,5 to 5 head/ha/year, respectively. An annual stocking rate of 5 head/ha/year is compatible with 2,2 head/ha during the dry season (120 days), and 6,4 head/ha during the rainy season (245 days). For the exercise with varying proportions of cropland and pastureland I considered an animal productivity of 450 kg LWG/ha/year (e.g. 150 kg LWG/head/year * 3 head/ha/year) for both the low-productivity and the productive scenarios. It is assumed in these calculations that supplementation of grazing animals, if it occurs, has no significant effect neither on animal performance nor on stocking rates.

RESULTS AND DISCUSSIONS

The land-saving effect arising from productivity gains in ICLS-soybeans, as compared to "exclusive-soybean" production systems (3,5 t/ha vs. 3,0 t/ha), is small, approximately 0,14 ha spared/ha. That reduced effect reflects the already relatively high yield level in "exclusive-soybean" systems, meaning that the opportunities for closing the yield gap between the two systems is narrow. Nonetheless, if achieving the highest possible net value for a given level of resource-use is focused, that "narrow yield gap" between the two soybean systems might be quite relevant from an economic perspective. Considering current soybean prices and the exchange rates in Brazil (e.g. R$ 165,00/60-kg sac; R$ 5,6456/US$ 1; 07/April/2021) an extra revenue of US$ 243,55/ha would be gained in the ICLS-soybean. That figure approaches a net value gain, since costs of production are not expected to vary significantly between the two soybean production systems.

The recovery of low productive pastures offers an impressive way of sparing land from cultivation. The information presented in Table 1 shows that improving both animal performance and stocking rates play a very important role, but the latter, as expected, provides a greater land-saving potential. It is worth of noting that an interacting effect occurs, which reflects the combined results of animal performance and stocking rates on productivity levels. The land-saving effect arising from animal performance increases from 1 to 6 ha spared/ha recovered as stocking rates increase from 0,60 to 3,6 head/ha/year. The land-saving effect arising from stocking rates increases from 5 to 10 ha spared/ha recovered as animal performance rises from 90 to 180 kg LWG/head/year. Combined, land-saving effects resulting from turning low productivity pastures into productive ones through ICLS may reach 11 ha spared/ha recovered but figures around 3 to 5 ha spared/ha recovered would probably be more realistic.

Table 1. Potential land-saving effects resulting from the recovery of low productivity pastures through ICLS.

Liveweight gain (kg/hd/yr)	Average stocking rate (head/ha/year)					
	0,60	1,20	1,80	2,40	3,00	3,60
	ha spared/ha recovered					
90	0,00	1,00	2,00	3,00	4,00	5,00
120	0,33	1,67	3,00	4,33	5,67	7,00
150	0,67	2,33	4,00	5,67	7,33	9,00
180	1,00	3,00	5,00	7,00	9,00	11,00

Source: Author's calculation and elaboration.

As the pasture proportion in ICLS declines so does the land-saving potential (Table 2), as a higher area of productive soybean implies in a lower opportunity to closing the yield gaps. However, even in a situation in which 75% of the area is allocated to high-yielding soybeans (e.g. 25% of pasture in the area), a land-saving effect of around 1,5 to 2 ha spared/ha recovered would probably be observed in those ICLS.

Table 2. Potential land-saving effects resulting from different proportions of pastureland to cropland in ICLS.

%pasture in the area	Average stocking rate (head/ha/year)					
	0,60	1,20	1,80	2,40	3,00	3,60
	ha spared/ha recovered					
100%	0,67	2,33	4,00	5,67	7,33	9,00
75%	0,53	1,78	3,03	4,28	5,53	6,78
50%	0,40	1,24	2,07	2,90	3,74	4,57
25%	0,27	0,69	1,10	1,52	1,94	2,35

Source: Author's calculation and elaboration. For the livestock phase it is considered a stocking rate of 3 head/ha/year and an animal performance of 150 kg LWG/hd/year.

As productive pastures sustaining high animal performances and stocking rates enter into the rotation with productive crops, both phases in ICLS now operate with smaller yield gaps. Therefore, the potential for generating land-saving effects substantially decreases (Table 3). For a starting productivity condition of 375 kg LWG/ha/year (e.g. 150 kg LWG/head/year * 2,5 head/ha/year) in the livestock phase, a land-saving effect of up 1,4 ha spared/ha would be observed, but a figure of less than 1,0 ha spared/ha would reflect a more common situation. As the pasture proportion in ICLS declines, the resulting land saving-effects decline even further (not shown).

Table 3. Potential land-saving effects resulting from high productive ICLS.

Liveweight gain (kg/hd/yr)	Average stocking rate (head/ha/year)					
	2,50	3,00	3,50	4,00	4,50	5,00
	ha spared/ha					
150	0,00	0,20	0,40	0,60	0,80	1,00
160	0,07	0,28	0,49	0,71	0,92	1,13
170	0,13	0,36	0,59	0,81	1,04	1,27
180	0,20	0,44	0,68	0,92	1,16	1,40

Source: Author's calculation and elaboration.

The potential for generating land-saving effects in high-productive ICLS is low because land-productivity is close to or is already at the attainable yield level. The high cost of production in those systems (MARTHA JR. et al., 2011) reinforce the need for farmers to manage their resources according to technical and allocative efficiencies. The chosen yield level will vary as farmers respond to changes in relative prices in order to meet the allocative efficiency condition.

In well-managed ICLS it is possible to observe a more resilient condition for crop and livestock production over time, given the progressive improvements in soil quality (CORDEIRO et al., 2015). Such condition contributes for reducing farmers' risk perception and, hence, their selected discount rates for future benefits. A lower discount rate favors the adoption of sustainable practices with a longer-term pay-off. From a society's perspective, in addition to the increase in the potential flow of environmental benefits, a greater and more resilient crop and livestock output contributes to the industry and service sectors through multiplier effects in the economy.

An important consideration relates to the possible existence of a rebound effect (also referred to as "Jevons' Paradox"), in which an increase in agricultural productivity will be accompanied by an expansion in land area. Hertel et al. (2014) and Hertel (2016) comprehensively reviewed that matter and found that the direction of land use change in an innovating region, in response to an improvement in agricultural technology, will be related to the absolute value of the price elasticity of excess demand facing producers in that region. The elasticity of excess demand is determined by three factors, (a) the responsiveness of consumer demand around the world to changes in the product price; (b) the potential for producers in the rest of the world to respond to price changes; and c) the share of global supply provided by the innovating region. When the price elasticity of excess demand is higher than 1, increasing productivity will lead to agricultural land expansion in the innovating region, and when it is lower than 1, the price depressing effect of output expansion will restrain expansion (HERTEL et al., 2014; HERTEL, 2016). The authors additionally found that Jevons' Paradox is most likely to happen when global food demand is price responsive and land-productivity in the innovating region is far lower than the world average. From that reasoning it is reasonable to say that rebound effects are likely to occur when the "innovating region" has very low relative crop and livestock land-productivities. In contrast, when high-productive ICLS are considered, the observed high land-productivity levels, close to or already at achievable yields, will likely promote land-sparing effects with no leakage.

Looking ahead, a preliminary exercise reveals the potential of expanding productive ICLS in the Brazilian Cerrado. Considering the additional increase in corn (+ 25.256 kt), soybean (+ 21.846 kt), and beef (+ 678 kt cwe) production in Brazil for the 2020-2029 horizon (OECD, 2020), implementing productive ICLS in 9 Mha (~ 15% of the pasture area in the Cerrado) would contribute with 126%, 81%, and 400% of that projected increase in production (Table 4).

Table 4. Potential impact of expanding productive ICLS in the Brazilian Cerrado.*

	Avg. productivity		Additional increase in output (2029)		
	2020	2029	OECD-FAO (1)	+ 9 Mha ICLS (2)	Contribution (2)/(1)
	kg/ha/year		kt or kt cwe		% increase
corn	-	3.905	25.256	31.838	126%
soybean	-	7.040	21.846	17.660	81%
beef	188	788	678	2.713	400%

Source: Author's calculation and elaboration.

*Yields for ICLS-corn and ICLS-soybean are 10% higher than the values projected by OECD-FAO (2020). Initial beef productivity considered a stocking rate of 1,5 hd/ha and an animal performance of 125 kg LWG/hd. For the 2029 projection, ICLS-beef productivity considered 4,5 hd/ha and an animal performance of 175 kg LWG/hd.

At last, but certainly not least, agricultural R&D is a crucial determinant of agricultural productivity and production. Hence, strengthening the sustainability and competitiveness of Brazilian agriculture involves a sustained, solid base of agricultural R&D expenditures. Strategically, R&D expenditures in the country should be equivalent to the main international players. Developed countries invested, on average, 3% of agricultural gross domestic product (GDP) in public agricultural R&D over the 2009 – 2013 period (HEISEY; FUGLIE, 2018). Brazil invested approximately 1,8% of agricultural GDP in research, mostly public, in the 1990s up to 2013 (MARTHA JR.; ALVES, 2018). The gap in research intensity between Brazil and developed countries has probably increased in the recent past. The fiscal policy space in Brazil, necessary to boost (or at least to sustain) public agricultural R&D

expenditures was squeezed by the 2014-2016 recession and the weak economic recovery in the following years. That scenario has been additionally aggravated by the Covid-19 pandemic (2020-2021) and the need for a large fiscal stimulus to cope with the resulting health and economic crisis. A slowdown in Brazilian agricultural R&D will negatively impact future productivity growth, leading to a reduced agricultural output level in the country and increased food prices in Brazil and the world (LIMA et al., 2021). Such combination is a "perfect storm" to inflationary and food insecurity pressures. Therefore, it is of Brazil's interest to find ways to keep up with agricultural R&D investments. In addition to strengthening public agricultural R&D, a successful strategy should encourage an increased private sector engagement in order to expand agricultural R&D intensity in Brazil to the levels observed in developed countries.

CONCLUSIONS

Observed land productivity levels reflect choices made by farmers (technology, inputs, management) conditioned by uncontrolled elements in the natural environment (BEDDOW et al., 2014). Those choices are unique to a given farmer-farm combination because the quantity and quality of resources and inputs available (land, labor, physical and human capital), their relative prices, and farmers' individual values vary on a case-by-case basis so, thus, farmers' opportunity costs and perceived risks (MARTHA JR., 2020).

Brazilian farmers are exposed to market forces. The level of incentives ("producer support estimate") they receive is low and averaged only 1,6% of gross revenue at farm level for the 1995-2017 period (OECD, 2018). Consequently, Brazilian farmers will consider adopting new technologies or recommended practices if they recognize them as having potential to delivering positive benefit/cost ratios. Under favorable relative prices (and/or incentives), conducive to technology adoption, several technological approaches for closing the land-productivity gap in ICLS might be considered. Those strategies are quite diverse as they involve different biological components (crops, livestock, forest) and their multiple interactions to each other and to the surrounding production environment. Improvements in plant and animal genetics (advanced biology), as well as on input- and resource-use efficiency, through new products and/or techniques, should be pursued. Farmers will increasingly benefit from proven digital solutions that can increase overall efficiency gains, improve resource- and input- use efficiency, and lower costs of production in agriculture (MARTHA JR., 2020).

Furthermore, closing each one of those gaps – e.g from actual yields to allocative efficient and/or technically feasible yields, and from that yield level to the (water-limited) yield potential – requires different policy strategies (BEDDOW et al., 2014). Farmers with actual yield levels lower than those achieved by farmers implementing best practices in their most productive fields in a given region may benefit from policies that promote technical and allocative efficiency improvements, such as educational extension programs and dissemination of market information to aid decisions (TITTONELL; GILLER, 2013; BEDDOW et al., 2014).

There is also scope for closing the gap between the allocative efficient yield level and the technically feasible yield level (given the best available technology). That gap is expected to be larger in less developed regions, within a country or across countries, because of market imperfections (DIJK et al., 2017; MARTHA JR.; ALVES, 2018). As emphasized by Martha Jr. & Alves (2018), *"... one of the greatest barriers to ensure modern technology will be more broadly and effectively adopted is market imperfection, which alters relative prices and the returns to investment in technologies. Reducing market imperfections is a necessary condition for expanding production in a more inclusive way, and to increase the effectiveness of policies targeting technology adoption by farmers*". Policies resulting in more favorable relative prices to technology adoption, e.g. reduced unit costs of inputs or increased unit value of outputs, might be considered to close that gap. However, such policies need to be carefully evaluated and might only be justified if they are targeted to correct some form of market distortion (BEDDOW et al., 2014).

Closing the yield gap from technically feasible yield levels to (water-limited) yield potential involves shifting the production possibility frontier upward, meaning that advanced technologies need to be successfully implemented (BELLOW et al., 2014; DIJK et al., 2017). Such transformations encompass broader institutional, technological, economic and social factors (DIJK et al., 2017). A key cornerstone for such strategy involves strengthening agricultural R&D to provide knowledge and problem-solving technologies to sustain total factor productivity gains at high levels over the medium- to long-run (MARTHA JR.; ALVES, 2018). A R&D intensity goal of 3% is often recommended (CARVALHO, 2018).

Those already challenging relationships will gain further complexity in face of climate change, that will inevitably lead to a less predictable and a riskier production environment, making yields – and associated land-saving effects – more difficult to anticipate. Agriculture in the tropics may be severely jeopardized if technological progress does not keep pace with such changes in the production environment, reinforcing the critical role of R&D for a sustainable and resilient agriculture in the future. Embrapa has been putting a high priority to adapt, develop and promote products, practices, and systems that aid in both mitigation purposes and adaptation strategies, such as the continuous development and improvement of ICLS.

As a final remark, under a political-economic perspective, protection of the environment and climate change actions are not costless. Those measures have an opportunity cost, since scarce resources used for environmental protection or for mitigation/adaptation actions could have been alternatively used in other ways. Governments, thus, "*... play the essential role in putting into place policies that ensure that resources contribute to the long-term economic development and not only to short-term revenue generation*" (OECD, 2011).

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ADDING VALUE AND ILPF CERTIFICATION

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ABSTRACT

The world needs to feed billions of people. Producing more is the order. Clearing new areas is the easiest path, but this world is already experiencing significant climate changes. Another path has to exist, sustainable agriculture allows for increased productivity, optimizing land use, without the need to open new areas, mitigating greenhouse gas emissions and increasing climate resilience. Systems and methods are known, but today only 5% of farmers adopt sustainable practices; technical assistance and financial resources are lacking to promote this change. Wrong practices have damaged the image of our agriculture overseas. Bringing back outside investors will be a construction that needs to be based on trust. Trust that will not be self-declared information, but rather monitored, reported and verified information.

Key words: Sustainability, MRV Platform, TrustScore, Green Financing

INTRODUCTION

By 2050, the world will need to feed nearly 10 billion people. Sustainable agriculture brings greater productivity without the need to clear new areas, creates income for farmers, mitigates greenhouse gas emissions and increases climate resilience. While Brazilian agriculture has seen a significant increase in yields in recent decades, there are still vast areas of low productivity. Private companies and governments need to work with farmers to scale up the implementation of sustainable agriculture with significant socio-economic and environmental outcomes.

As we can see in the executive summary of the ABC Observatory (Low Carbon Emission Agriculture), “the mitigation potential of greenhouse gas (GHG) emissions from Brazilian agriculture is more than ten times greater than the target stipulated by the ABC Plan. Between 2012 and 2023, it is possible to reach 1.8 billion tons of CO2 equivalent (tCO2 eq.), adding avoided emissions and carbon stored in the soil, just by adopting three of the technologies recommended by the ABC (pasture recovery (RDP), crop-livestock integration (ILP) and crop-livestock-forest integration - ILPF) in 52 million hectares of degraded pastures” (RODRIGUES, et al., 2015).

Large agricultural exporter, Brazil still maintains 66% of its territory covered by native vegetation (TERRITORIAL, 2019). On the other hand, Agriculture, Forestry and Other Land Uses (AFOLU) is responsible for 44% of Brazil's emissions (ROVERE et al., 2018).

Intensification of integrated agriculture can ensure sustainable growth, maintaining this important economic activity. ILPF is a technology in which different production systems are applied in the same area, generating mutual benefits. ILPF is based on sustainable principles, increasing productivity with less environmental impact. ILPF and RPD are the technologies mentioned in the NDC (Nationally Determined Contribution) of Brazil (NDC, 2015), with a goal of reaching 35 million hectares by 2030. The NDC also includes the goal of complying with the Forest Code and zero illegal deforestation in the Amazon.

During the strategic planning of the ILPF Network, two bottlenecks were registered. The scarcity of specialized technical assistance and the lack of funding for this change in Brazilian agriculture. The federal government created the ABC plan, but the private sector also needs to do its part. One way is through the creation of programs that attract investment from large national and international companies. It so happens that the current certification models and others, based on self-declaration, are no longer sufficient to convince the external investor. A new way of selecting and monitoring farmers needs to be implemented to rebuild lost trust.

In this sense, TrustScore®, a technology platform for Measurment, Reporting and Verification created by Ceptis Agro to Measure the Adherence between the Producer's Production Process and a Sustainable Agriculture Protocol, was part of a proposal submitted to the competition called The Lab in early 2020. This proposal called SAFF (Sustainable Agriculture Financing Facility (PUGAS et al., 2020) or Financial Instrument for Sustainable Agriculture) aims to provide long-term, low-cost and flexible financial and technical resources for small and medium-sized farmers to implement sustainable agricultural technologies (TAS), such as Integrated Crop-Livestock-Forestry systems (ILPF), increasing the area with the adoption of technology and creating socioeconomic and environmental results.

The implementation of TAS generates socioeconomic and environmental benefits, but it involves large initial costs and requires qualified technical assistance. SAFF is a framework composed of: a) a fund to receive resources and a management company selected for financing and technical assistance to farmers; and b) a non-profit association (Rede ILPF) to standardize the protocol and provide certification (using TrustScore® technology). The program's objective is to select sustainable farms, so that they have access to resources with especial interest rates, and it can also monitor the production process, ensuring that the commitment to sustainability is maintained.

How will the financing work

Farmers sign a contractual agreement with the management. To qualify for credit, the farmer must have started the Sustainable Agriculture Certification process, ensuring the best environmental and social practices and quality, including compliance with environmental legislation. Loans allow for a flexible repayment schedule. Technical assistance is then provided as part of the agreement to reduce risks and increase profitability of investments in sustainable technology.

The credit operated through the SAFF is intermediated by a partner entity that assigns the receivables arising from transactions with certified farmers to theinvestment fund in form of credit rights. Discount rates for discounting receivables are lower compared to those in the market, benefiting farmers with more favorable conditions for guarantees, interest rates and amortization and grace periods. The final interest rate parameterization follows the TrustScore, with variations in the interest rates owed by the certified producer to the SAFF being proportional to their average scores in the scoring system during the credit granting period until the time of the amortized portion. This linking allows lower rates to be achieved by getting better scores on TrustScore and vice versa.

Overcoming obstacles with SAFF

Although there are subsidized credit lines for the implementation of sustainable technologies, acceptance is insufficient to catalyze transformation on the necessary scale, especially among small and medium farmers. The main barrier is a general lack of knowledge. In the banking system, there is not enough experience in evaluating credit applications for TAS. Technical assistants lack training to support implementation. Farmers may be unable to navigate bureaucratic processes. Available financing is not linked to the technical assistance needed to ensure productive returns within the expected timeframes. Also, credit lines often do not allow for repayment flexibility.

An additional barrier to the access of small and medium farmers to these lines of credit is the difficulty in meeting the required levels of guarantees to support credit applications, since financial institutions do not have prices adjusted for TAS which tend to have risks lower when implemented with the right technical support.

To overcome these barriers, SAFF intends to provide experience in evaluating loan applications for TAS. Loans would be low-cost, with simple and less bureaucratic procedures to facilitate applications. Technical assistance then becomes part of the farmer's installation agreement to ensure correct implementation and expected financial and environmental returns.

To be eligible, technical assistants must have passed the ILPF Network Training program, ensuring adequate knowledge and quality service. In addition, RedeILPF's Farm Certification Program generates a TrustScore®, a label of trust that will be used by SAFF as a complement to traditional credit assessment processes. The mechanism will also allow small and medium farmers better access to international markets. By aggregating high quality producers, it will generate economies of scale so that they can participate more competitively in the market for agricultural inputs (generally imported and bid in international currencies) and in international trade chains.

MATERIALS AND METHODS

TrustScore® consists of 5 scores: Checklist Score, Environmental Score, Social Score, Score on Compliance with the Management Plan and Score on Productive Potential.

The Checklist Score is calculated based on a checklist with approximately 70 questions, divided into pillars of crop farming, livestock, forestry, integration and farming. In addition to the pillars, the questions are divided into categories. Each question can have 4 possible answers: not applicable, insufficient (0), improvement (50) or sufficient (100). Each question also has weight, which will be used to calculate the Checklist Score. After sending the first version, the producer will receive as points of attention any questions that are not sufficiently answered. Throughout the year, the farmer will be able to implement action plans to increase his Checklist Grade.

The Environmental Note aims to measure compliance with the forest code and with what has been requested by authorities. It is calculated based on satellite analysis, consultations with government bases and document analysis. The goal is to verify the farmer's adherence to the monitorable articles of the forest code. It will be verified if the farm:

- did illegal deforestation, if so, in what proportion and if there is TAC in force;
- had zero deforestation;
- it is located in the Amazon, Cerrado or Campos Gerais areas;
- it intersects with Indigenous Lands, Conservation Units, Restricted Use Areas, embargoed area polygons;
- made changes to the CAR Limit;
- has sufficiency Legal Reserve and Riparian Forest;
- has fines or embargoes;

- etc.

The Social Score is calculated based on consultations on the websites of the judiciary, in search for the number of convictions in the first instance, to be cross-referenced with the maximum number of employees, added to a score extracted from the checklist regarding working conditions. The Social Score also takes into account the presence on the "dirty list", in addition to other factors.

The Score on Compliance to the Management Plan is an inverted S curve and demonstrates how closely the producer's plan was followed. The more planned the producer is, the more he follows the management plan, the higher his grade will be. It is believed that by monitoring the management plan, we can verify whether the farmer's production process is indeed sustainable, and, also take the carbon balance calculation to scope 3, taking into account the farm's input suppliers.

The Productive Potential Score is calculated based on the productive potential of the soil, the climatic conditions and the farmer's efficiency. The more efficient, the closer to the best reference productivity for the biome, the higher the score. The greater the probability of success of the selected crops, the higher the score.

Over the scores, it may incur penalties and bonuses. The occurrence of a suppression (deforestation) generates a very severe penalty in the environmental score. On the other hand, the presence of the Forestry component allows for a bonus to the farmer.

TrustScore® has a current measure monthly calculated, but its value is published in a 12-month rolling average. TrustScore® will be used as eligibility criteria for green finance instruments. The higher the TrustScore®, the better conditions: lower level of guarantee, longer term to pay, better interest rate. Each month a new TrustScore® will be issued, through continuous farm monitoring. With deviations identified and verified, the TrustScore® may fall to levels below those acceptable by financial instruments, and depending on the fund's policy, rate changes or even early maturity can be expected.

Right before the publication of this article, we had the announcement that the European Union (EU) will direct investments and acquisitions towards sustainable agriculture (Matthias Berninger, 2021). Adding value to the ILPF Farm Certification Program involves reducing the financial cost of financing, increasing productivity, and consequently revenue, maintaining the forest stock (native or recomposed), encouraging the forestry component, increasing availability of technical assistance, for the recovery of the confidence and image of Brazilian agribusiness.

The first instance of SAFF should go into operation in June/21, and we will be happy to share the results at the next event.

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II WORLD CONGRESS ON INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEMS

May 4th and 5th, 2021 - 100% Digital

"INNOVABILITY" IN BRAZILIAN AGRIBUSINESS

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ABSTRACT

The implementation of the crop-livestock-forest (ILPF) integration system at Fazenda Boa Vereda arose from the motivation to combine innovation and sustainability, which gave rise to the neologism "innovability". Until then, the farm had beef cattle ranching as its main activity, but it had low economic profitability, in addition to large extensions of areas with degraded pastures. Thus, support was requested to the Brazilian Agricultural Research Corporation (Embrapa) looking for an alternative form of innovability to change this scenario, that is, the ILPF system. The implementation of the ILPF system was carried out in stages on the farm, and various configurations of the system were evaluated, as a way to obtain greater synergy among the components and achieve improvements, especially in terms of economic and environmental aspects. Because of the success obtained with the ILPF system at Fazenda Boa Vereda, it became a Technological Reference Unit (URT) of Embrapa. In this context, in partnership with different institutions, efforts were made to carry out numerous Research, Development and Innovation (RD&I) and Technology Transfer (TT) actions, favoring the dissemination of ILPF systems in Brazil and in several countries. Over 12 years, 79 technical-scientific publications and 153 TT actions were computed, which has contributed to the expansion of the adoption of the ILPF system in several Brazilian farms.

Keywords: Agrosilvopastoral system; income diversification; research and innovation; technology transfer.

INTRODUCTION

The expansion of agricultural production, through crop-livestock-forest integration systems (ICLF), has been quite significant over the years in Brazil, with 10 million ha between the years 2005 and 2015. The integrated systems constitute a versatile production model that makes it possible to combine agricultural, arboreal, forage and animal components, simultaneously or sequentially in time and space, on a temporary or permanent basis, with economic, environmental and social benefits. These systems are recognized for allowing the diversification of activities on the farm, reducing risks and increasing agricultural production.

In this sense, in 2007, the motivation for implementing the ICLF system at Fazenda Boa Vereda (total area of 270 ha), located in the municipality of Cachoeira Dourada, southwest region of the state of Goiás, Brazil, emerged. At that time, beef cattle ranching was the main activity on the farm. The farm had a low economic profitability, in addition to the presence of degraded pastures. A more profitable alternative, at the time, would be the lease of land for the cultivation of sugarcane, as a means of supplying the sugarcane complex plants in the southwest region of Goiás. However, there was a lack of interest on the part of the farmer in this type of lease, having been sought from the Brazilian Agricultural Research Corporation (Embrapa), an alternative form of innovation in the agricultural production system, that is, the ICLF system, to increase profitability and sustainability of the farm.

The ICLF system was implemented in stages or consecutive harvests, on different plots of degraded pastures on the farm. This choice was made in order to better equate the producer's financial expenses over time, facilitating the implementation of the system. This factor is also important because, due to the greater complexity of the ICLF system in relation to traditional monocultures, every year the operational procedures are improved, minimizing risks. After prospecting the demands of the regional market, it was decided to use soybeans and maize as crop components, eucalyptus as forest component, in addition to continuing with the tradition of beef cattle raising and pasture on the farm.

In the 2008/2009 harvest, the first stage of implementation of the system was established in an area of 47 ha. The ICLF system was implemented in a spatial arrangement of rows of three eucalyptus lines (clones AEC 144 and AEC 244), spaced 3 m apart and 3 m between plants, between rows of 14 m for planting the crop (totaling 500 trees /ha) and, later, the pasture. The system followed the following sequence: in the first year (Year 0) the following were planted: soybean (cultivar BRS-GO 8360) and eucalyptus in intercropping; 2) in the following year (Year 1) maize was planted (in the area previously occupied by soybeans) (cultivars BRS 1030 and BRS 1035), intercropped with brachiaria (*Urochloa brizantha* cv. Marandu). After maize harvesting, the pasture was already established and, as brachiaria presents rapid regrowth, the pasture can be used for silage approximately one month after corn harvesting. At 18 months after planting, the eucalyptus trees were, on average, 8 m high and 10 cm in diameter at breast height (DBH), a result of the use of high productivity clones, which allowed the animals to enter the system without risk of damaging trees. Since its implementation, the pasture has annually rceived fertilizers according to soil analysis and crop recommendations, to maintain its carrying capacity. From Year 2 onwards, this pasture area is used for rearing and fattening beef cattle, which is repeated annually.

In the following harvests, the implementation of the ICLF system was carried out in the other plots with degraded pastures. Over the years, several configurations of the system arrangements were tested, in particular, regarding the spatial arrangement and planting density of trees, in order to improve the system and alleviate the low productivity of the pasture between eucalyptus rows. In addition, over the years, different eucalyptus, soybean, maize and forage cultivars have been used as a way to ensure productivity gains, reduce risks and also as a way of valuing the diversity within the system.

After making several adjustments in the arrangement over time, the beginning of the system implementation occurs with no-till soybean seeding (early cycle cultivation), in the total area of the plot, at the beginning of the rainy season in the Brazilian Cerrado, i.e. in November. After the soybean harvest, eucalyptus is planted, still in the same rainy season (February), in rows of one line, with a spacing of 2.5 m between plants, with a distance between rows of 15 m, simultaneously, followed by sowing of millet among the rows. The cultivation of millet favors the protection of the soil, due to its cultural remains and straw, even after its harvest. In November, the second grain crop begins, again with soybeans. In this second harvest, soybean cultivation is carried out between rows of eucalyptus. After the soybean harvest, the forage planting is carried out and, after 60 days, the introduction of the animal component begins. This initial grazing is temporary (10-15 days) and carried out at a higher stocking rate in order to carry out the sprouting and favor the tillering of the forage. Depending on the occurrence of rain and the growth rate of the pasture, after 30-40 days, the animals return to the field permanently under a normal stocking rate.

This strategy allowed the achievement of productivity rates above the national average (monocultures) in all components implemented, in addition to favoring the full recovery of pastures and the return of animals to the area, permanently, in approximately 18 months after the start of the system. Since then, this arrangement has been adopted on this farm.

With the success achieved with the ICLF system at Boa Vereda farm, the area was expanded to a second farm, called Fazenda Varjão (total area of 350 ha), located in the municipality of Inaciolândia, southwest of the state of Goiás. The ICLF system cited above was replicated. Currently, approximately 50% of Fazenda Varjão's pasture area is already under the ICLF system, and the rest of the degraded pastures will be converted, in stages, to the same system in the next few years.

As these are successful cases, the Boa Vereda and Varjão farms have been used to conduct numerous actions related to Research, Development and Innovation (RD&I) and Technology Transfer (TT), being considered as Technological Reference Units (URTs) of Embrapa. The performance of these actions and the diffusion of this technology have allowed the expansion of ICLF systems in farms in Goiás, together with farmers and in cooperation established with the A'gência Goiana de Assistência Técnica, Extensão Rural e Pesquisa Agropecuária" (EMATER-GO), in addition to other public institutions such as the "Instituto Federal Goiano – Campus de Morrinhos" and the Federal University of Goiás. There are also joint actions developed with the Associação Rede ICLF and, more recently, Fazenda Boa Vereda was selected as a demonstration unit of the "Instituto Brasileiro de Desenvolvimento e Sustentabilidade (IABS) - Rural Sustentável.".

It is observed that these RD&I and TT actions of the Boa Vereda and Varjão farms are perfectly aligned with the concept of "innovanility", disseminated by the companies EDP Brasil and Suzano, being based on the capacity that people, and naturally organizations, have to develop to innovate and reinvent themselves constantly, and also based on the convergence of the concepts of innovation and sustainability applied to agricultural production systems. In this context, this document aims to contemplate not only the progress achieved, especially in the URT of Fazenda Boa Vereda, which already has 100% of the arable areas converted into ICLF, but also to bring the entire history of actions and results in the scope of RD&I and TT carried out by Embrapa and partner institutions in the 12 years of implementation of the URT on this farm.

Main results achieved by the URT on Fazenda Boa Vereda

- The average yield of soybeans in the ICLF system is equal to 3600 kg/ha, which is considered a good result since the average Brazilian productivity of soybeans in monoculture is estimated at 3330 kg/ha.

- The average yield of maize in the ICLF system is 6000 kg/ha, which is also satisfactory considering that the average yield of inter-season maize in monoculture in the Brazilian territory is 5460 kg/ha.

- The average yield of beef cattle in the ICLF system is 540 kg live weight/ha/year. Since yield, prior to the implementation of the ICLF system, was 120 kg live weight/ha.year, there was an increase of 350%. The average yield of traditional beef cattle in Brazil is estimated, at best, at 210 kg live weight/ha.year.

- The average yield of eucalyptus in the ICLF system is estimated at 45m^3/ha/year, which is higher than the average productivity of eucalyptus monoculture in Brazil (1,666 trees/ha = 35 m^3/ha.year), with approximately one third of this density of trees in ICLF. Besides, of course, trees in ICLF suffer less competition due to the smaller number of trees/ha. In the first years of eucalyptus cultivation, pruning management takes place up to a height of 6 m following the silvicultural protocol for the genus in order to obtain high quality stems and, also to allow greater light entry in the ICLF system. Wood production has been mainly destined for energy use, to meet the demands of agribusiness in the Southwest region of Goiás, but there was also the sale of poles for construction/supporting high voltage lines and, there is already the possibility of future supply of wood for wood preservation plants (generation of treated solid products). The eucalyptus cutting cycle has taken approximately 6 years to obtain all these products.

- The forage component has shown good productivity and quality, allowing good feed for cattle, except under rows of three and four rows of trees. For this reason, the arrangement of rows with a sole row of trees was adopted, eliminating the problem of shading and poor pasture formation within rows. It is noteworthy that the annual fertilizer application on the pasture has brought significant benefits in terms of greater productivity for the pasture and, indirectly, also for the eucalyptus trees.

- The income obtained from the farming component has allowed to fully paying the costs of implementing the ICLF system. Thus, the financial benefits generated by income diversification are clearly observed.

- With the use of the ICLF system, there has been a stimulus and consolidation of better training of farm employees.

- The legal reserve and permanent preservation areas of the farm are, according to current legislation, correctly registered at the "Cadastro Ambiental Rural da República Federativa do Brasil", being properly protected and conserved, contributing to the maintenance of the biodiversity of the Cerrado in Goiás and its consequent benefits.

- The spatial distribution and diversity of the components of the ICLF system, together with the preservation of areas of native forest remnants have contributed to greater sustainability as well as to enhance the scenic beauty of the landscape.

- It can be noted an increase in the presence of wild fauna on the farm after the adoption of the ICLF system, which is also used as a shelter, refuge and/or food source for a great diversity of birds, monkeys, anteaters, armadillos, jaguars, deer, among others .

- The ICLF system has contributed to improving the image of agricultural production, as it reconciles productive activity and environmental sustainability.

- Research, Development and Innovation Actions (RD&I):

In a survey conducted in April 2021, 79 publications were prospected, mostly developed at Fazenda Boa Vereda, through a partnership led by Embrapa and several institutions, especially the Federal University of Goiás, in the last 12 years (Figure 1). The following topics were addressed in these publications: 1) production system: from ICLF planning to the end of the cycle of all components; 2) production and nutrient stock in annual, arboreal and forage components; 3) ambience and animal productivity; 4) soil fertility (physical, chemical and biological attributes), plant nutrition and nutrient cycling; 5) bacterial inoculation and biological nitrogen fixation; 6) estimates of greenhouse gas emissions and carbon sequestration; 7) economic evaluation of the ICLF system and 8) technological properties of the eucalyptus wood used as a tree component in the ICLF systems of the Boa Vereda and Varjão farms, and also of the teak used as a hedge around the perimeter of the Varjão Farm..

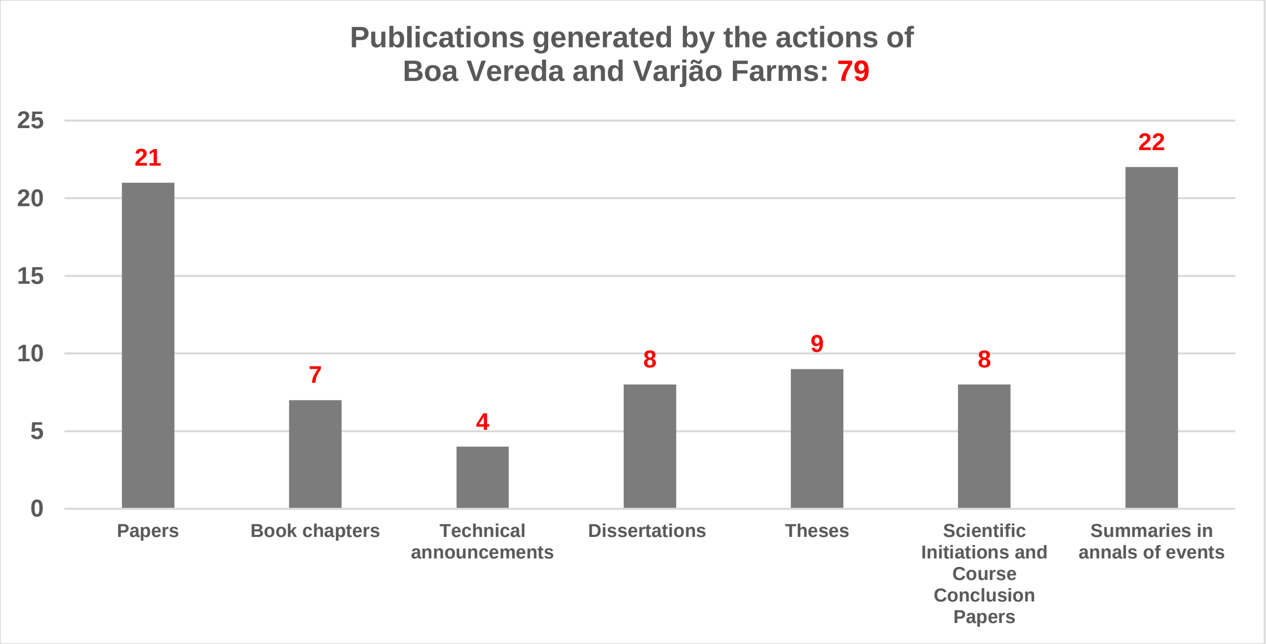

Figure 1. Publications generated by technological reference units (URTs) in crop-livestock-forest integration systems (ICLF), mostly on the Boa Vereda farms, in the municipality of Cachoeira Dourada and Varjão, in the municipality of Inaciolândia, Goiás.

Some of the main results obtained in RD&I actions are listed below. The complete list of publications, generated by Embrapa and partners, is presented in sequence in order to allow the reader to see the results generated in more detail.

- As for the improvement of the chemical attributes of the soil, comparing soil analyzes conducted in 2009 and 2017 (0-40 cm), it was observed: increase of 17.70% in the cation exchange capacity (CTC), 40% in calcium (Ca), 80% in magnesium (Mg), 9.70% in H+Al, 54.30% in phosphorus (P), 95% in organic matter (MO) and 5.60% in pH. The nutrient reduction was only observed in potassium (K), with 54.30%. In recent analyses, through Embrapa's Soil Bioanalysis (BioAS) technology, satisfactory results are observed regarding the biological attributes of the soil.

- There was an increase in litterfall levels. The litterfall deposited in the soil is estimated at 3,600 kg/ha.year, being incorporated into the soil: 98 kg/ha.year of macronutrients + 3.50 kg/ha.year of micronutrients in the cycling process.

- There was a clear reduction in soil compaction and erosion, due to the high amount of straw in the system and crop rotation, with progressive attenuation of the impact of rainfall.

- With regard to research on the mitigation of greenhouse gas emissions, it is estimated approximately 13 tons/ha.year of fixed carbon. Consequently, the meat produced by cattle in the ICLF system is in line with the designation of Carbon Neutral Beef, a concept trademark for adding value to this product, launched by Embrapa.

- There is an increase in animal welfare, as the animal component benefits from the improvement of environmental conditions provided by the trees (protection against high temperatures, storms, wind and hail). The cooler environment has contributed to reduce water consumption by animals between 20-30% when compared to consumption prior to the implementation of the ICLF. Thermal comfort is also revealed by the average temperature reduction of up to 3º C in the shaded area of the ICLF system. A more docile behavior of animals is also noticed.

- Information generated by Embrapa's Ambitec-Agro software, composed of 27 multicriteria system and 148 indicators:
- Even with its intensification effect, economies in the use of natural resources (by unit of product) balanced increases in use of inputs (but not energy). The general performance of the establishment since adoption of ICLF resulted from highly positive. Important improvements in environmental quality (especially soils) and customer respect (especially social capital and animal welfare) resulted in a positive integrated index for the Ecological impact dimension. Highly positive indices were observed for the economic (especially income and patrimonial value) and the social (especially food security, social equity, quality of employment) Dimensions of Sustainability, Attesting to Contributions of ICLF for the General Performance of the Farm. These results confirm the intensification and diversification effects of ICLF as contributions for local development and farm sustainability.
- Technology Transfer Actions (TT):

Figure 2 shows a survey of TT actions carried out over the past 12 years, focusing on training and/or updating of consultants, entrepreneurs, students, extension workers, employees of research and rural credit development agencies, researchers, farmers, teachers, professors and teachers, among other professionals in the agricultural sector. These activities were divided into six categories: courses, field days and technical visits, journalistic articles, lectures, awards and institutional videos, totaling 153 activities.

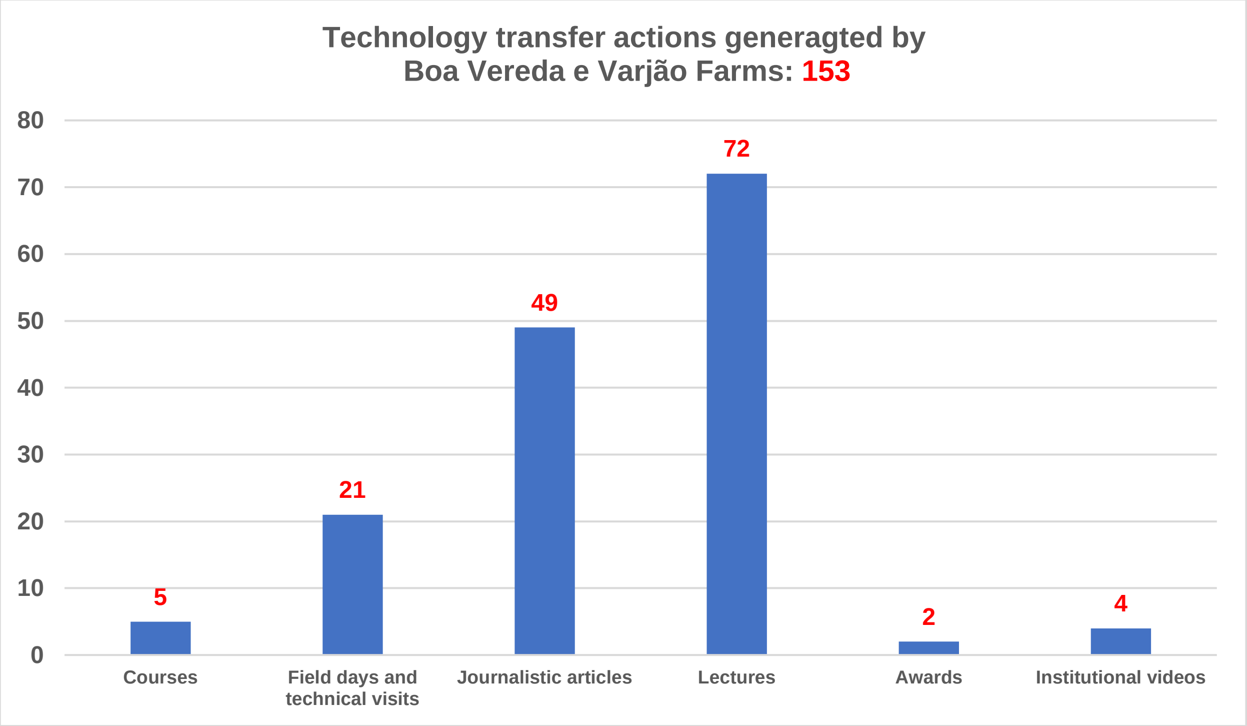

Figure 2. Technology transfer and communication actions generated by technological reference units (URTs) in crop-livestock-forest integration systems (ICLF), mostly in the Boa Vereda Farms, in the municipality of Cachoeira Dourada and Varjão, in the municipality of Inaciolândia, Goiás.

Hosting various events, *in situ* and *ex situ*, has met the demands of interested parties both nationally and internationally. Visitors from Asia, Africa, North America and Europe, as well as various Brazilian regions, made up of government representatives, researchers, producers, professors, entrepreneurs, undergraduate and graduate students have come to know in situ the actions developed in these URTs.

In the *ex situ* modality, it has been possible to represent Embrapa in several national events and, also in international missions. Goal was to present the ICLF systems technology in several events and countries such as: Conference for American Investors in New York (New York, USA - 2016), International Consortium on Applied Bioeconomy Research - ICABR (Washington, USA - 2018), United Nations Climate Change Conference - COP 24 (Katowice, Poland - 2018), Green Business Forum Paraguay (Assuncion, Paraguay - 2018) and Dialogue on Sustainable Food and Agriculture: Building a Resilient Farming Through International Trade (Brussels, Belgium - 2019).

These actions and the diffusion of technology have also allowed for the expansion of the adoption of the ICLF system in farms. In addition to that, other URTs located in strategic regions of Goiás were implemented in: Nova Crixás/GO and Quirinópolis/GO, together with farmers and, in Morrinhos/GO, in partnership with the "Instituto Federal Goiano – Campus de Morrinhos" and also in cooperation with the "Agência Goiana de Assistência Técnica, Extensão Rural e Pesquisa Agropecuária" (EMATER-GO), in addition to other public and private institutions. Over the years, as a result of this partnership, approximately 80 farmers in Goiás have adhered to this system, especially in the region of the municipality of Quirinópolis/GO.

The technological development obtained in recent decades has maximized the speed with which information and novelties emerge and, with the very change in social habits, further enhanced by the coronavirus pandemic, virtual communication actions and the use of digital tools tend to be expanded. In this scenario, some TT actions of these URTs have also followed this trend of popularizing the results obtained via Embrapa and partners' social networks.

In this regard, so far, two videos have been produced for the institutional dissemination of Fazenda Boa Vereda, one of which is available in Portuguese (https://youtu.be/eHMRO03jpOw) and in English (https://youtu.be/Bo_xsw0RXZs). The second video of this farm is presented in the virtual lecture of the present event. The URT for the silvopastoral system, located in the municipality of Quirinópolis, Goiás, implemented in partnership with a farmer and EMATER-GO, can be seen in two other videos (https://www.youtube.com/watch/watch?v=M5V50Sk-opc and https://www.youtube.com/watch?v=J4MJe8Y_Cw0).

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ATTACHMENTS

The details of all the RD&I and TT actions carried out as a result of the implementation of the aforementioned URTs in the last 12 years are presented below..

Research, development and innovation actions (RD&I)

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Technology transfer actions (TT)

Courses

1. PACHECO, A. R. Da viabilidade econômica à sustentabilidade ambiental. Associação Rede de Fomento ILPF, 2021, evento virtual.

2. PACHECO, A. R. Sistemas de integração lavoura-pecuária-floresta: Diversificação da renda na propriedade rural em Goiânia. Serviço Brasileiro de Apoio às Micro e Pequenas Empresas (SEBRAE-GO), 2019, Goiânia.
3. PACHECO, A. R. Técnicas de poda de árvores em ILPF. Sede da Agência Goiana de Assistência Técnica, Extensão Rural e Pesquisa Agropecuária (EMATER-GO), 2019, Quirinópolis.
4. PACHECO, A. R. Viabilidade econômica e sustentabilidade do sistema integração lavoura-pecuária- floresta (ILPF). In: CONGRESSO DE ENGENHARIA, ARQUITETURA E CONSTRUÇÃO, Faculdade Araguaia, 2017, Goiânia.
5. PACHECO, A. R. Sistemas ILPF. In: ENCONTRO NACIONAL DE PLANTIO DIRETO NA PALHA – PALHA, AMBIENTE E RENDA, 2016, UFG – Campus Samambaia, Goiânia.

Field days and technical visits

1. VISITA TÉCNICA DE ALUNOS DO CURSO DE AGRONOMIA, 2019, Fazenda Varjão, Inaciolândia.
2. VISITA TÉCNICA INTERNACIONAL - GOVERNO DE ANGOLA, 2019, Fazenda Varjão, Inaciolândia.
3. ENCONTRO DO PRODUTOR COM A CIÊNCIA, 2019, Fazenda Varjão, Inaciolândia.
4. DIA DE CAMPO SOBRE SISTEMA DE INTEGRAÇÃO LAVOURA-PECUÁRIA-FLORESTA: ILPF, 2018, Sede da Prefeitura de Quirinópolis, Quirinópolis.
5. DIA DE CAMPO SOBRE TRANSFERÊNCIA DE TECNOLOGIA EM INTEGRAÇÃO LAVOURA-PECUÁRIA-FLORESTA NO BIOMA CERRADO, 2018, Fazenda Boa Vereda, Cachoeira Dourada.
6. DIA DE CAMPO DO WORKSHOP EMBRAPA & AGRICULTURE AND AGRI-FOOD CANADA, 2018, Fazenda Boa Vereda, Cachoeira Dourada.
7. VISITA TÉCNICA DE PRODUTORES RURAIS DE MORRINHOS/GO SELECIONADOS PELO PROGRAMA ABC CERRADO, 2016, Fazenda Boa Vereda, Cachoeira Dourada.
8. VISITA TÉCNICA DE PRODUTORES RURAIS DE CROMÍNIA/GO SELECIONADOS PELO PROGRAMA ABC CERRADO, 2016, Fazenda Boa Vereda, Cachoeira Dourada.
9. VISITA TÉCNICA DE TÉCNICOS DA EMATER-DF, 2016, Fazenda Boa Vereda, Cachoeira Dourada.
10. VISITA TÉCNICA DE CAPACITAÇÃO DOS TÉCNICOS DO PROJETO ABC CERRADO, 2016, Fazenda Boa Vereda, Cachoeira Dourada. Available at: <https://www.youtube.com/watch?v=w7QdfMKO1p8 >. Accessed on: April 15, 2021.
11. VISITA TÉCNICA DE COMITIVA DE NORTE-AMERICANOS DA EMPRESA APPLIED GEOSOLUTIONS, 2015, Fazenda Boa Vereda, Cachoeira Dourada.
12. VISITA TÉCNICA DE TÉCNICOS E CLIENTES DA EMPRESA PLANALTO TRATORES, 2014, Fazenda Boa Vereda, Cachoeira Dourada.
13. VISITA TÉCNICA DA COMITIVA DO PRESIDENTE DA EMBRAPA DR. MAURÍCIO ANTÔNIO LOPES, 2013, Fazenda Boa Vereda, Cachoeira Dourada.

14. VISITA TÉCNICA DO WORKSHOP DO PROJETO FLORESTAS ENERGÉTICAS, 2013, Fazenda Boa Vereda, Cachoeira Dourada.

15. VISITA TÉCNICA DA COMITIVA DA DIRETORA ADMINISTRATIVA DA EMBRAPA VÂNIA BEATRIZ RODRIGUES CASTIGLIONI, 2012, Fazenda Boa Vereda, Cachoeira Dourada.

16. VISITA TÉCNICA DO CONGRESSO INTERNACIONAL DA CARNE, 2013, Fazenda Boa Vereda, Cachoeira Dourada.

17. DIA DE CAMPO SOBRE INTEGRAÇÃO LAVOURA-PECUÁRIA-FLORESTA, 2012, Fazenda Boa Vereda, Cachoeira Dourada.

18. VISITA TÉCNICA DO VIII WORKSHOP EMBRAPA E UNIPASTO, 2011, Fazenda Boa Vereda, Cachoeira Dourada.

19. DIA DE CAMPO SOBRE INTEGRAÇÃO LAVOURA-PECUÁRIA-FLORESTA, 2011, Fazenda Boa Vereda, Cachoeira Dourada.

20. MOSTRA DE TECNOLOGIAS: INTEGRAÇÃO LAVOURA-PECUÁRIA- FLORESTA, 2010, Fazenda Boa Vereda, Cachoeira Dourada.

21. DIA DE CAMPO SOBRE INTEGRAÇÃO LAVOURA-PECUÁRIA-FLORESTA, 2009. Fazenda Boa Vereda, Cachoeira Dourada.

Journalistic articles

1. TV BRASIL. Programa de financiamento de agricultura sustentável cresce 16%. **Programa Brasil em Dia**, 12 abr. 2021. Available at: <https://www.youtube.com/watch?v=IEsQ8JxQNGs>. Accessed on: April 15, 2021.

2. REVISTA DO CONSELHO FEDERAL DE MEDICINA VETERINÁRIA (CFMV). Agronegócio brasileiro foca na sustentabilidade para conquistar resultados. **Revista CFMV**, ano 26, n. 83, p. 8-12, 2020. Available at: <https://certidao.cfmv.gov.br/revistas/edicao83.pdf>. Accessed on: April 15, 2021.

3. BERGAMIM, M.; PICHELLI, R. Agrotins 2020 aborda temática florestal. **Notícias - Portal da Embrapa**, 25 set. 2020. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/52651344/agrotins-2020-aborda-tematica-florestal>**.** Accessed on: April 15, 2021.

4. MAGALHÃES, H. Adoção de ILPF aumenta renda e sustentabilidade em propriedade de Goiás. **Notícias - Portal da Embrapa**, 8 jun. 2020. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/53171817/adocao-de-ilpf-aumenta-renda-e-sustentabilidade-em-propriedade-de-goias#:~:text=Ado%C3%A7%C3%A3o%20de%20ILPF%20aumenta%20renda%20e%20sustentabilidade%20em%20propriedade%20de%20Goi%C3%A1s,-Share&text=O%20Sistema%20Integra%C3%A7%C3%A3o%20Lavoura%2DPecu%C3%A1ria,econ%C3%B4mica%2C%20social%20e%20ambientalmente%20sustent%C3%A1vel.. Accessed on: April 15, 2021.

5. LOBATO, B. Dia de campo no DF mostra integração lavoura-pecuária-floresta na pecuária leiteira. **Notícias - Portal da Embrapa**, 6 mar. 2020. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/50587741/dia-de-campo-no-df-mostra-integracao-lavoura-pecuaria-floresta-na-pecuaria-leiteira>. Accessed on: April 14, 2021.

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7. COELHO, S. Alagoas é palco de debates sobre integração lavoura-pecuária-floresta. **Notícias - Portal da Embrapa**, 27 ago. 2019. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/46047645/alagoas-e-palco-de-debates-sobre-integracao-lavoura---pecuaria---floresta>. Accessed on: April 14, 2021.

8. MAGALHÃES, H. Encontro na Fazenda Varjão, em Goiás, destaca componente florestal no sistema ILPF. **Notícias - Portal da Embrapa**, 03 jul. 2019. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/44661525/encontro-na-fazenda-varjao-em-goias-destaca-componente-florestal-no-sistema-ilpf#:~:text=07%2F19%20%7C%20ILPF-,Encontro%20na%20Fazenda%20Varj%C3%A3o%2C%20em%20Goi%C3%A1s%2C%20destaca,componente%20florestal%20no%20Sistema%20ILPF&text=Coordenado%20pela%20Embrapa%20Arroz%20e,o%20componente%20arb%C3%B3reo%20em%20ILPF.>. Accessed on: April 14, 2021.

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10. MAGALHÃES, H. Embrapa e Universidade de Nottingham-Inglaterra iniciam diálogos para parceria em pesquisa na área de alimentos. **Notícias - Portal da Embrapa**, 22 mar. 2019. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/42155315/embrapa-e-universidade-de-nottingham-inglaterra-iniciam-dialogos--para-parceria-em-pesquisa-na-area-de-alimentos>. Accessed on: April 14, 2021.

11. ALVES, B. Unidade de Referência Tecnológica da EMATER-GO, em parceria com Embrapa, recebe visita de universidade inglesa**. Notícias da Secretaria de Agricultura, Pecuária e Abastecimento do Estado de Goiás**, 22 mar. 2019. Available at: <https://www.agricultura.go.gov.br/noticias/2808-unidade-de-refer%C3%AAncia-tecnol%C3%B3gica-da-emater,-em-parceria-com-embrapa,-recebe-visita-de-universidade-inglesa.html>. Accessed on: April 14, 2021.

12. LOBATO, B. Dia de campo e reunião técnica em Goiás destacam oportunidades e inovações do sistema ILPF. **Notícias - Portal da Embrapa**, 14 abr. 2018. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/33321781/dia-de-campo-e-reuniao-tecnica-em-goias-destacam-oportunidades-e-inovacoes-do-sistema-ilpf>. Accessed on: April 14, 2021.

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14. COORDENAÇÃO GERAL DE COMUNICAÇÃO SOCIAL E EVENTOS. IF Goiano faz balanço sobre implantação das UEPEs. **Instituto Federal Goiano**, 21 mar. 2018. Available at: <https://www.ifgoiano.edu.br/home/index.php/component/content/article/160-noticias-anteriores/8344-if-goiano-faz-balanco-sobre-implantacao-das-uepes.html>. Accessed on: April 15, 2021.

15. ASSESSORIA DE COMUNICAÇÃO SOCIAL - CAMPUS MORRINHOS. Campus Morrinhos implanta Unidade de Ensino, Pesquisa e Extensão em ILPF. **Instituto Federal Goiano**, 28 fev. 2018. Available at: <https://www.ifgoiano.edu.br/home/index.php/ultimas-noticias-morrinhos/8114-campus-morrinhos-implanta-unidade-de-ensino-pesquisa-e-extensao-em-integracao-lavoura-pecuaria-floresta.html>. Accessed on: April 15, 2021.

16. PROGRAMA REVISTA DO CAMPO. Produtores de Goiás aderem ao sistema ILPF. **Programa Revista do Campo**, 21 fev. 2018. Available at: <https://www.youtube.com/watch?v=xA5bw5kcsbo>. Accessed on: April 15, 2021.

17. SENAR SANTA CATARINA. Conferência internacional dedica espaço para pesquisa brasileira que desenvolveu ILPF. **Senar Santa Catarina**, 2018. Available at: <http://www2.senar.com.br/Noticias/Detalhe/9844>. Accessed on: April 15, 2021.

18. OLIVEIRA, H. de. TecnoShow: estandes das unidades e palestras lotam a Casa da Embrapa. **Notícias - Portal da Embrapa**, 6 abr. 2017. Available at: <https://www.embrapa.br/busca-de-noticias/-/noticia/21537168/tecnoshow-estandes-das-unidades-e-palestras-lotam-a-casa-da-embrapa>. Accessed on: April 14, 2021.

19. RODRIGUES, D. Municípios de MG, GO e MA recebem seminários do ABC Cerrado. **Notícias – Portal da Embrapa.** Available at: <https://www.embrapa.br/en/noticias?p_p_id=101&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&_101_urlTitle=municipios-de-mg-go-e-ma-recebem-seminarios-do-abc-cerrado&_101_groupId=2343075&_101_struts_action=%2Fasset_publisher%2Fview_content&_101_type=content&_101_assetEntryId=5453766 >. Accessed on: April 15, 2021.

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21. Brasil inova em boas práticas agrícolas. **Revista A Lavoura**, n. 718, p. 10-19, 2017. Available at: <https://issuu.com/sociedadenacionaldeagricultura/docs/a_lavoura_718?ff >. Accessed on: April 15, 2021.

22. OLIVEIRA, F. As orientações sobre o uso da ILPF. **Programa Sucesso no Campo**, 17 jul. 2017. Available at: <https://www.youtube.com/watch?v=xyBM1k6Qyjw>. Acessed on: April 14, 2021.

23. CAMPO VIVO. Sistemas de integração podem contribuir para aumento de renda e diminuição da degradação do solo. **Revista Campo Vivo**, 7 mar. 2017. Available at: <https://campovivo.com.br/pecuaria/sistemas-de-integracao-lavoura-pecuaria-floresta-podem-contribuir-para-aumento-de-renda-e-diminuicao-da-degradacao-do-solo/>. Accessed on: April 14, 2021.

24. MONSANTO EM CAMPO. Integração lavoura-pecuária-floresta maximiza a produtividade nas propriedades agrícolas. **Monsanto em campo**. Available at: <http://monsantoemcampo.hospedagemdesites.ws/?p=1810>. Accessed on: April 14, 2021.

25. GOVERNO DE GOIÁS. Encontro mostra que ILPF é viável para pequenos produtores. **Governo de Goiás**, 20 set. 2016. Available at: <https://www.goias.gov.br/servico/80738-encontro-mostra-que-ilpf-e-viavel-para-pequenos-produtores.html>. Accessed on: April 15, 2021.

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FARMER'S VIEW: LIMITING FACTORS AND OPPORTUNITIES FOR ICLF SYSTEMS ADOPTION

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Key words: Sape Agro; diversification, integration; Ecological succession

INTRODUCTION

Currently, the company Sapé Agro operates in beef cattle with selection of Brangus breed animals. Besides, in agriculture works with production of soy, corn, sugar cane, milk, poultry, education and rural tourism. In order to maximize its results, it adopts the most modern technologies in its production system, and it permanently seeks productive sustainability with the integration between these activities. The valorization of knowledge and innovation by the leaders in this company makes it competitive and seeks a path to excellence in its management.

Sapé Agro is a synthesis of a dream that has going through many generations, over 130 years. It is a commitment to the land and to these people who dedicated themselves to it, in order to produce food and energy. Sapé Agro has a proud story with respect to its employees, its community, the surround environment, its partners and, especially, the future generations.

Mission

To develop and operate an integrated and efficient agricultural production system.

Vision

To be recognized as a model of excellence in agricultural management.

Values and Principles

1. COMMITMENT: taking responsibility; to be committed to work and to the colleagues.

2. INNOVATION: proposing, undertaking, inventing and generating new solutions.

3. SOCIAL AND ENVIRONMENTAL RESPONSIBILITY: valuing workers, the local community and the environment.

4. CREDIBILITY: meeting the proper terms and the pre-established conditions on the negotiations signed with customers and partners.

5. TRANSPARENCY: providing clear information and goals that facilitates the company's performance and the people's conduct.

6. VALUING PEOPLE: treating people with consideration, observing the rules, creating new opportunities, developing potentials and recognizing good performance.

The Story

In 1872, three families from *Goiás* and *Minas Gerais* State have arrived in *Maracaju* region. In the 1930s, the widow Maria Ozória Garcia Corrêa, a descendant of these colonizers, bought, wrote and donated to her youngest daughter Ozória Garcia Corrêa and her husband Sebastião Alves Corrêa, rough lands; where nothing existed other than native pasture. The challenge for the young couple was to transform the gross assets into a productive farm. Therefore, they did!

Among all the difficulties of that time, little by little it was outlined what the Sapé Farm would be. In there, they built fences, put winter pasture for cattle, the made the first thatch (sapé) ranch, which originated the property's name. In addition, they built the owners' shed, wooden house, and the water stream called *bica*.

It was established a basic structure for the development of the main productive activity of the farm: extensive beef cattle. At that time, Mr. Sebastião Alves Corrêa inherited another land located further away from his parents, Balbino Corrêa and Antonia Alves Corrêa, both descendants of the colonizers. They called it *Invernadinha* and *Volta Rica* Farm.

In the 1970s, migrants from the south cultivated rice and soybeans in the region. Some areas of these farms were leased, and a new cycle of production began, with formation of cultivated pastures and mastery of agricultural production technology in the region's fields.

In 1991, Sapé Agropastoril Ltda was established; a company formed by the properties of the couple Sebastião and Ozória, milestone of the professionalization of the production and economic activities. The family succession process began at that time, which climaxed today with the participation of the daughter and the 03 grandchildren of Sebastião and Ozória.

Governance

- Cultural aspects
- Risk management
- Specialization x Diversification
- Scale Economy x Scope Economy
- Average Cost Reduction Trend

Factors That Limit Diversification

The factors that limit Diversification are:

1. Market mechanisms as the only risk management tools;

2. Lack of mastery on project analysis tools and their feasibility;

3. Emotional connection to the activities, making even the mere consideration of another activity impossible for the rural company;

4. Difficulties in managing and or conducting current activities, making it impossible to consider new activities; and

5. Lack of practical examples and close to diversified systems that worked.

Challenges

General Organization

- Increase in the complexity of business management;
- Management team capable of handling different activities;

- Allocation of time resources in the management of each activity, making it possible to deliver what each one needs to perform within the established objectives, without losing the proportionality of each activity in the size of the company;

- Organize processes that allow different activities to be attended (which naturally have different timings), without harming one to the detriment of the other.

Cost and Cash Management

- The insertion of more than one business unit within the same production system requires:

- Creation of compatible cost centers, which allow the correct allocation of these costs;

- The mandatory creation of a stock of raw materials that are shared by different activities, so that they can be allocated correctly only in their application (and not in the purchase), thus respecting the factor that generates the cost and its allocation to the correct center.;

- Compatibility of activities with different cash flows in a single cash flow, making it possible to optimize the allocation of financial resources.

People Management

- Different activities within the same business demand people with different levels of technical training, with different skills and often with different behaviors. Therefore, the manager must have the ability to move through these different levels, adapting the language and even the leadership style;

- There is a need to consolidate remuneration models (including fixed and variable) that are able to promote unity between sectors and avoid attempts at comparison, normally existing in diversified companies.

Diversification Opportunities

- Optimization and specialization of the middle activity;

- Earned results by taking advantage of existing synergies in different systems;

- New business platform in production;

- Family succession.

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“In order to work with agribusiness, it is essential to dialogue with the new generations.”

Eduardo Riedel

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PUBLIC POLICIES TO PROMOTE THE ADOPTION OF ICLF SYSTEMS IN BRAZIL

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ABSTRACT

The world population is approaching 8 billion inhabitants, with the expectation of totaling 10 billion by 2050. According to FAO projections, the world will demand 70% more food and 40% more water. Not only is this already challenging, but there are also added threats arising from climate change, demanding accurate strategies that promote resilience and efficiency in agricultural systems. Countries committed to this sustainable development agenda are able to guarantee food security. In Brazil, the Ministry of Agriculture, Livestock, and Supply (MAPA) is one of the main institutions responsible for launching public policies that align food security, mitigation of greenhouse gases, and adaptation to climate change. Among the initiatives of the Secretariat for Innovation, Rural Development and Irrigation (SDI), the following will be presented as policies led by the Department of Sustainable Production and Irrigation (DEPROS), with emphasis on the ABC and ABC + Plan, Pronasolos, Águas do Agro, Agriculture Irrigation and value added products. These all incentivize the integration of Crop-Livestock-Forest systems in different ways. It is worth noting the support given by the MAPA to the expansion of certified programs such as the "low carbon" and "neutral carbon" certification, as a result of these systems.

Key words: sustentability, innovation, Carbon Neutral Brazilian Beef, ABC Plan, Ministry, Pronasolos

INTRODUCTION

With 851.57 million hectares, Brazil is one of the largest countries by area in the world. According to the Agricultural Census, rural establishments occupy an area of 351 million hectares, representing approximately 41% of the total territory (IBGE, 2017). Currently, the country faces the challenge of analyzing and validating data from the Rural Environmental Registry (CAR), in order to detail the use of land in rural areas.

The area occupied by agricultural production, as shown by different studies on land use in Brazil, is divided between pastures (native and cultivated), agriculture (permanent and temporary crops), and forestry.

The grazing area varies from 162 million hectares to 180 million hectares (IBGE, 2017; Embrapa, 2018; Lapig / UFG, 2020). Agriculture, including temporary and permanent crops, makes up an equivalent area of 61 to 66 million hectares, depending on the database. Of these, on more than 20 million hectares, there are two to three crops produced in the same year. About 10 million hectares are occupied by forestry, in which eucalyptus species are present in about 75% of the area (EMBRAPA, 2018; CONAB, 2020, IBGE, 2020).

This brief exploratory contextualization of the numbers indicates that, when considering the highest values of all the bases consulted, the productive area of Brazilian agriculture totals 256 million hectares, i.e., 30% of the national territory. Comparing these values with the data from the Agricultural Census, referring to the area occupied by rural establishments, there is a difference of 11%. A difference to be attributed to infrastructure (roads, warehouses, etc.) and, in a significant percentage, the Areas of Permanent Protection (APP) and Legal Reserve (RL).

Despite being the largest country in the southern hemisphere, Brazil imported essential foods from the basic basket in the 1970s and 80s. As investment in research, innovation, and logistics in the agricultural sector has turned the tide, Brazil now produces basic foods domestically.

It is imperative to mention the role of the Brazilian Agricultural Research Corporation (Embrapa), as well as the teaching and research institutions. Also worth noting is the role of technical assistance, public and private, whose rural extension actions provided producers with access to appropriate technologies and those adapted to tropical conditions, albeit a small portion relative to the size of the country.

It reinforces the idea that innovation was fundamental to the advances in productivity that Brazil has achieved in the last three decades. According to IBGE (2020), in the late 1970s, the area destined for grain production was 37 million hectares, with an approximate production of 37 million tons. A 1:1 ratio. In the previous crop year, 2019/2020, 241 million tons of grain were produced on 63 million hectares. That is a production of 3.8 million tons for each 1 million hectares harvested, i.e., 3.8: 1.

The strategies of Crop-Livestock-Forest Integration (ILPF) were fundamental in this advancement. In 2005, areas with some type of integrated system represented only 1.87 million hectares. In just over ten years, the area has multiplied almost ten times, reaching 15 million in 2016 (Rede ILPF, 2019). Staggering growth continues to be one of the major trends in food production on a sustainable basis in Brazil.

The "Integrated Landscape Approach", advocated by ABC + as the main land use strategy in the country for the next decade (2020-2030), ILPF-type systems in their different arrangements, guarantee greater efficiency, less risk and better use of natural resources to produce safer food.

In this work, the main public policies led by the Department of Sustainable Production and Irrigation (DEPROS), Secretariat of Innovation, Rural Development and Irrigation (SDI), of the Ministry of Agriculture, Livestock, and Supply of Brazil (MAPA) will be explained. These promote an increasingly sustainable and strategic agriculture for the social and economic development of Brazil, emphasizing their role in the growth of areas with ILPF in the country.

Sectorial Plan for Mitigation and Adaptation to Climate Change- Plano ABC e ABC+

Brazil was a pioneer in bringing together strategies to promote sustainable technologies in the Sectorial Plan for Mitigation and Adaptation to Climate Change, aiming at the consolidation of a low carbon economy in agriculture (ABC Plan), which was the basis for the construction of regional policies. This is one of the largest plans to promote sustainable production technologies in the world, which in 2020 completed 10 years of service.

The ABC Plan was established in the context of the National Policy on Climate Change (Law No. 12,187 / 09), whose basic premise is to encourage the adoption of systems, technologies, practices, and products with the capacity to promote sustainability in the field, conserve natural resources, such as soil and water, and mitigate greenhouse gas (GHG) emissions, to make the agricultural production process more resilient.

Considered one of the greatest public policies to promote sustainable and conservationist development of natural resources in the field, both nationally and internationally, it is unique in its genre and scope. In its first 10 years, it considered six technologies (crop-livestock-forest integration and Agroforestry Systems; recovery of degraded pastures; no-till system; biological nitrogen fixation; forestry and animal waste treatment) and a program (adaptation). Together, they ensured productive gains, resilience, and reduced greenhouse gas (GHG) emissions.

From 2010 to 2018, 52 million hectares adopted the six technologies promoted by the plan (Lapig, 2020 and Manzatto et al, 2020). The values, until 2020, are being updated in the process of reviewing the Plan. It is worth mentioning the study carried out by Lapig / UFG where it was possible to have geoinformation of the 26.8 million hectares of recovered pastures. In this same study, the authors point out that the recovered pasture areas are also those with growth in integration technologies.

The Lapig study also points out that, of the 171 million hectares of pasture in Brazil, 26% is in severe degradation, 31% in mild degradation, and 43% in good condition. The areas of light and severe degradation add up to 98 million hectares. Compared to what was already presented in the introduction to this chapter, there are 30 million hectares more than that, currently occupied by agriculture. For this reason, MAPA's strategy is that the areas with single pasture use decrease, giving space to agriculture and systems in integration, with an increase in the production of meat and milk.

This phenomenon is called “sustainable intensification”, by which Brazilian agricultural production can be multiplied in areas already anthropized. In this sense, the Pronasolos Program, which will be detailed later, is committed to identifying areas with agricultural suitability and for which crops where integration can grow strategically, within the 98 million hectares where there is agricultural suitability.

With a new proposal to meet the new cycle from 2020 to 2030, the Ministry of Agriculture, Livestock, and Supply launched in April 2021, the Sectorial Plan for the Adaptation of Agriculture to Climate Change and Low Carbon Emission in Agriculture, with Views Sustainable Development (ABC +). Among its updates, there are conceptual bases based on the integrated approach to the landscape and the promotion of adaptation, in addition to low carbon technologies and systems.

The systems of the type Integrated in Crop-Livestock-Forest (ILPF), and Agroforestry (SAF) are technological solutions considered to increase agricultural productivity, in addition to mitigating the emission of greenhouse gases (GHG). Notably recognized as mitigating the effects of climate change on the production of food, fibers, grains, and wood, they also reduce their vulnerability, reducing risk and increasing the income of rural producers.

Considered a strategy for sustainable intensification, the ILPF integrates agricultural, livestock, and forestry activities in the same physical area, but not necessarily over time. Various combinations, such as farming with livestock, forest with farming, or forest with farming and livestock, in intercropped cultivation and in the form of succession or rotation, provide synergistic effects between the components of the system (BALBINO et al. 2011).

Present with different crops, scopes, and edaphoclimatic conditions, the ILPF aims to promote a change in land use, based on the integration of the components present, aiming to reach higher levels of production and productivity, with the recovery of the physical and chemical quality of the land. For soil, with an increase in the quality of the agricultural product generated, and improvement of environmental quality in terms of the conservation of natural resources and recovery of biodiversity, will result in the generation of income and quality of life in the countryside. Thus, they become a classic and feasible example of mitigating and resilient production systems.

As the ABC Platform points out, in 2018, there were about 15 million hectares that used some type of ILPF system in Brazil. A value significantly higher than the 1.87 million hectares measured in 2005. The states that stand out the most in terms of adoption are Mato Grosso do Sul, Mato Grosso, Rio Grande do Sul, and Minas Gerais.

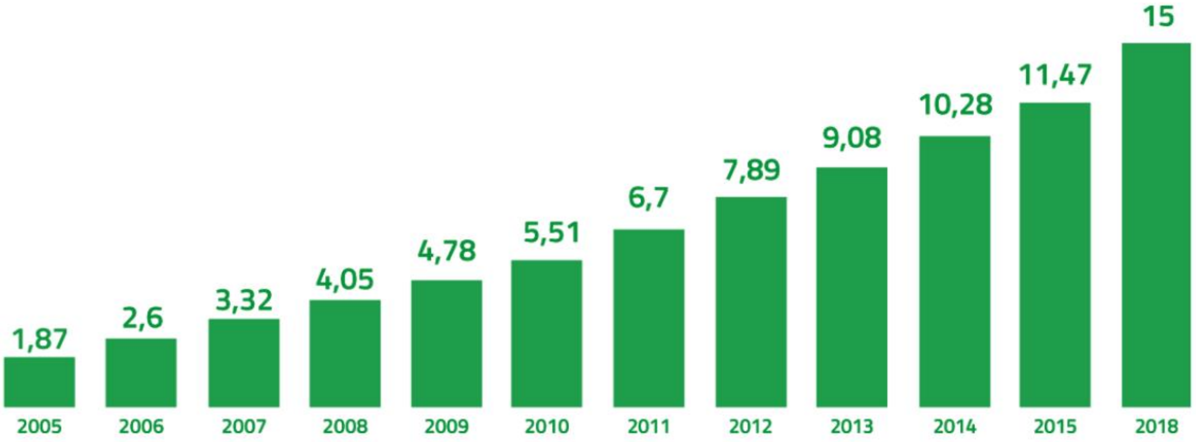

Figure 1. Evolution of the ILPF adoption area, in millions of hectares. Source: ABC Plataform.

Brazil has a lot to do in terms of innovation for the measurement of ILPF areas. MAPA, in partnership with the MCTI, has joined efforts in this regard, including improving the greenhouse gas (GHG) mitigation indicators considered in the National Inventory, linked to this technology. Currently, GHG mitigation resulting from the use of integrated systems is not accounted for in the National Inventory.

Even so, several publications support the results presented previously. Manzatto et al (2020) estimated the ILPF area to be 12.61 million hectares by 2018. Embrapa (2019) estimates it to be 15 million, with Andrade et al. (2020) assume that, in 2020, the value would reach 16.27 million hectares.

In its new 2020-2030 cycle, ABC + maintains the sustainable production systems already consolidated in the previous phase, incorporating other conservation practices, which, together with modern conceptual bases, such as the “Integrated Landscape Approach” (AIP), allow to align ABC + to the dimension of sustainability and governance strategies that gain prominence in the international scenario, and which enhance the effective conservation of natural resources, without prejudice to the producer's productivity and income.

The ILPF and its combinations will be further stimulated in this new phase, as the limitations of natural resources, especially water and soil, and the growing worldwide pressure for sustainability in its three aspects (social, economic, and environmental), will be the propellants for systems of more resilient and sustainable production.

Promoting Agricultural Irrigation

As previously presented, in its new phase, ABC + has a fundamental pillar which is adaptation and resilience to climate change. In this context, irrigated agriculture is a fundamental technology. It currently occupies 20% of the world's arable land and 40% of food production relies on irrigation technology. In the production of cereals, these figures are 40% of the harvested area and 60% of the production (FAO, 2012). FAO projects that by 2050 more than 50% of food will be produced in irrigated systems.

Brazil is one of the countries that least utilizes its water availability. The irrigated area in the country is only 8.2 million hectares, just 3% of the arable area. Far below international indicators. Even so, currently, irrigated foods show up on the Brazilian table. Typical foods of the national diet such as rice, beans, legumes, vegetables, and fruits are mostly produced through irrigation. This index exceeds 90% in the case of horticulture and rice production (ANA, 2021).

A recent study published by ESALQ, points out that there is water available to irrigate 55 million hectares, almost seven times more than the area currently irrigated. The potential area to be irrigated in Brazil is twice that of the United Kingdom.

In addition to water availability, other important aspects were considered for the development of irrigated agriculture such as medium / high fitness in terms of altitude, slope, drainage, agricultural fitness (edaphoclimatic conditions), soil (physical-water properties, management systems, and conservation, fertility), relief (slope), infrastructure (road and rail, appropriate electrical network, storage capacity), excluding environmentally protected areas.

With this data, it was possible to refine priority areas for the advancement of irrigated agriculture. It was identified that 8.1 million hectares are rain-fed agricultural areas and have the possibility of becoming irrigated areas due to the existence of water potential, irrigated areas already prevalent in these territories, and having high and medium infrastructure conditions (energy, transport, and storage). These are considered areas of intensification.

Expansion areas are those that have the possibility of converting the use of pasture land to irrigated agriculture and that have the same characteristics as the intensification areas. Currently there are about 7.5 million hectares that have the capacity to become intensification areas.

The interesting thing to note is that the additional irrigatable areas are anthropized areas, which carry out agricultural production, and there will be no need to open new areas. (Figure 2). Thus, in about 15.6 million hectares, it is easier to implement irrigated production in the country and boost productivity in these territories.

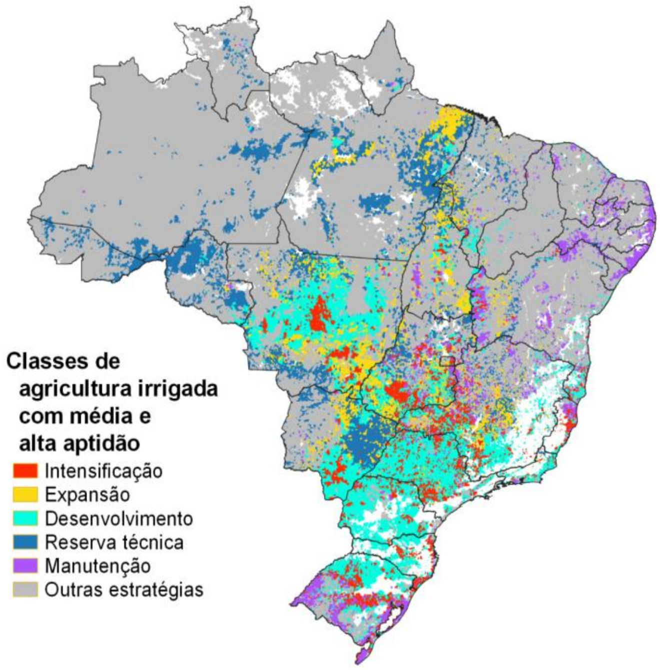

Figura 2. Mapeamento das regiões de média e alta aptidão para agricultura irrigada, por classe. Fonte: ESALQ

These classifications allow for better planning by the federal government and execution of its actions, to prioritize the areas that are closest to becoming irrigated. Despite the great potential that exists, the Brazilian State needs to prioritize the territories to be worked on so that there is no dispersion of efforts and few results.

In addition, for the growth of the irrigated area in Brazil to occur, with sustainability and efficiency in the use of natural resources, it is necessary to advance in some aspects such as improving its infrastructure, modernizing the management of water resources, improving its legislation and also investment in accelerating instruments, such as credit, research, technical and managerial assistance.

Thus, irrigation will be able to compose the productive systems of practically all cultures. It can be an inducer and a technology to enhance the growth of ILPF technology.

The National Program for Rural Development and Sustainable Management of Natural Resources in Watersheds - Águas do Agro

One of the main functions of land use planning is to make better use of rainwater, avoiding excessive losses through runoff, creating conditions for rainwater to infiltrate the soil.

The National Program for Rural Development and Sustainable Management of Natural Resources in Watersheds - Águas do Agro aims to promote sustainable economic development in rural areas through the adoption of soil and water conservation measures and practices, with efficient management of resources. Natural resources are used to maximize the productivity of agricultural land through an efficient, rational, and intensive exploitation system, which also ensures the continuity of the productive capacity of the soil, with the availability of water.

The principles of Águas do Agro are, therefore, guided by the logic of sustainable intensification of land use, with the maintenance and increase in food production associated with the generation of ecosystem services.

In this context, the Crop-Livestock-Forest Integration is an excellent strategy for the consolidation of the program, incorporating into the production systems technologies that produce a strong synergy between the components, with multiple socioeconomic and environmental benefits. Thus, the actions related to the Águas do Agro Program, from the main perspective of soil and water conservation, will be excellent drivers for the adoption and expansion of integrated production systems, such as the ILPF.

Based on the experiences acquired in models of programs and projects for the use and sustainable management of natural resources, especially soil, water, and biodiversity, Águas do Agro's actions will be carried out on two levels - considering the watershed and the agricultural property individual as planning units - in an integrated manner. At the micro-basin level, the Work Plan must be established by the micro-basin community together with the main partners. The planning of individual properties is the step immediately after the planning of the watershed.

Considering the huge contingent of micro-basins existing in Brazil, it was necessary to establish criteria for the selection of priority micro-basins that will constitute the first phase of the program's performance. The criteria used took into account: the criticality of water availability of the micro-basins (Figure 3) with critical and very critical levels; the presence of technical assistance and properties with the use of irrigation in the municipalities; in addition to the areas with a greater presence of uncovered soils and accentuated laminar erosion.

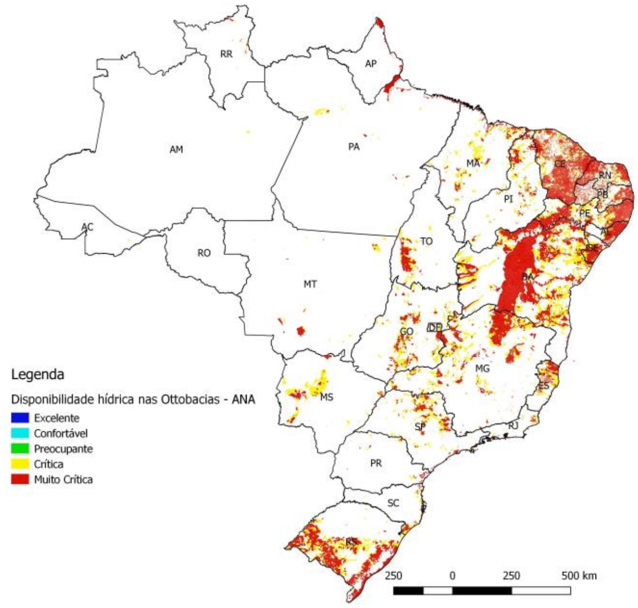

Figure 3. Distribution of critical and very critical Ottobacias considering water availability. A-N-A

The program's actions are based on four pillars, which are: implantation of technological reference units, technical and managerial assistance to rural producers, training in soil and water conservation technologies and practices, as well as the monitoring of adoption and regional impacts. There will be several soil and water conservation technologies addressed, such as terracing, level planting, no-tillage system, pasture management, improving of the side roads , among others, in addition to the recovery of the Permanent Preservation Area - APP and Reserve Legal - RL.

As a result of Águas do Agro, the adaptation of rural properties is expected through actions that promote an increase in the rate of water infiltration into the soil; the reduction of water erosion of agricultural soils in the micro-watersheds worked. Upon achieving these improvements, other direct benefits appear such as the improvement of quantity and quality and water in river basins; the increase in water availability in the basins; reducing the effects of droughts and the impacts of floods the increasing the useful life of reservoirs and dams. For farmers the benefits in terms of productivity are improving the productive capacity of soils; the increase in crop productivity and the capacity to support pastures.

Thus, the social, economic, and environmental benefits resulting from the adoption of the management and conservation practices of natural resources and the agricultural management instruments disseminated, will have a regional impact in the context of strengthening and sustaining agricultural activity.

PronaSolos - National Soil Program of Brazil

Another Program of great relevance and that deserves to be highlighted is PronaSolos - National Soil Program of Brazil. PronaSolos originated from an agreement in which the TCU identified that Brazil does not have sufficient information on its soil, and that this information was not available in an easy and accessible way by society.

In this way, PronaSolos' general objective is supplying the lack of soil information in Brazil, through soil surveys and interpretations of use in scales equal to or more detailed than 1: 100,000, compatible with state, municipal, and rural planning

Currently, approximately 9% of the Brazilian territory is covered by soil maps published between the scales 1: 100,000 and 1: 250,000, and only 1% of its territory is mapped in more detailed scales than 1: 100,000.

PronaSolos is putting Brazil at the forefront of knowledge, use, and conservation of the world's soil and water. With continental dimensions, the country embarks on the challenge of knowing to take care of its soils as the main natural heritage for the Brazilian citizen.

In general, PronaSolos aims to adapt a research structure in soils to increase the level of knowledge of Brazilian soils, enabling their governance by the public authorities, valuing the sustainable management of natural resources, with emphasis on soil, and enabling the country to have an orderly and long-term agricultural development.

Long-term actions refer to the expansion of soil survey and its interpretations on a 1: 100,000 scale, as well as more detailed mappings (scales 1: 50,000 and 1: 25,000). In this phase, the structure of PronaSolos will be consolidated, allowing its continuity to improve and detail the mapping and knowledge of Brazil's soils, which are essential to guarantee the country's sustainable development.

The main expected results from PronaSolos refer to the constitution of an integrated database of soil surveys (maps, reports, profiles) and interpretations of potentialities and limitations to agricultural use (agricultural aptitude, diverse zoning, etc.), in the level of detail and scales compatible with the needs of land use planning in rural areas, as well as for the guidance and definition of public policies throughout the national territory.

In December 2020, the PronaSolos Platform was delivered, which organizes all data and information already existing in Brazil on a modern technological platform, where any Brazilian citizen will have access and will be able to apply them in their daily lives. Specifically for agriculture, the results of the program may make it possible to know where the most suitable areas for the sustainable growth of agricultural and livestock production are in the national territory.

The main impact of PronaSolos will be to contribute to increasing the competitiveness, profitability, and sustainability of Brazilian Agribusiness through better use and conservation of soils, greater efficiency of imported fertilizers, increased productivity, and strengthening of cow Carbon agriculture in Brazil. It will be possible to measure the dynamics of changing stocks of carbon fractions and denitrogen in the soil.

As for Águas do Agro, the actions related to PronaSolos will support the adoption and expansion of integrated production systems, such as ILPF. This will make it possible to measure the dynamics of the change in stocks and fractions of carbon and nitrogen in the soil, which are related with the current use and suitability of the land.

In conclusion, it is noted that integration technologies bring more environmental sustainability, increase production by productivity, which will impact not only agriculture, but also the country's logistical infrastructure, and the planning of the use of natural resources. The impacts on the urban environment with the reduction of instability in the food supply, in addition to the scarcity of water and hydroelectric power will be mitigated, all while maintaining strong economic and social pillars.

CONCLUSIONS

The Ministry of Agriculture, Livestock, and Supply has in the Department of Sustainable Production and Irrigation a technical body focused on the conduct, formulation and dissemination of public policies aimed to improving the sustainability of Brazilian agriculture. The various programs and actions coordinated by the Department seek, whenever possible, to have correlation and complementarity. Sustainability is the link that unites the themes of conservationist agriculture, irrigation, water and soil conservation and added value.

The adoption of the Integrated Crop-Livestock-Forestry systems is an important tool that has been encouraged by Depros to leverage the sustainability of national agriculture. As it is a system that protects soils and water, it is based on conservation practices, enables carbon neutralization in the production system and can add value to production, reflects in a practical term, the general objectives of the Department.

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THE GLOBAL AGENDA FOR SUSTAINABLE LIVESTOCK AS A PUBLIC POLICY DRIVER FOR MIXED LIVESTOCK SYSTEMS IN THE WORLD

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INTRODUCTION

With the world's population expected to reach nine billion by 2050, increasing income per capita and a smaller proportion of people living in rural areas, an estimated 70% increase in food demand is expected. Due to this projected increased demand, livestock food systems, which represent an important economic sector in the world, will have to adapt to this new reality. Animal sourced food (ASF), which presents important nutritional values for the maintenance of good health status and growth of children, has the potential to contribute to this challenge considerably. It is expected that the world will demand up to 50% more ASF to nourish the global population. The increase in demand for nutritious food offers an opportunity to better incentivize sustainable livestock production, foster competitiveness and give access to the international market for less capacitated producers.

However, while the livestock sector can play a key role in improving the lives of millions, it also comes with several important and complex interactions that could have challenging repercussions on society. Growth of the livestock production, among other important public health concerns, also could create threats for the environment and climate if it occurs at the expense of natural ecosystems. The livestock sector is the largest user of natural resources, including an 80% of agricultural lands for grazing purposes and feed production, and another 8% of water use to irrigate feed crops. Moreover, it is estimated that it produces 14.5% of total anthropogenic emissions of greenhouse gases (GHG), primarily methane and nitrous dioxide.

To a great extent, these potential negative effects of livestock production when occurring are due to inadequate agricultural practices that focus on intensification and monoculture production. Therefore, to address global climate change, land degradation, deforestation and food security concerns, whilst improving the environment, solutions that conciliate socio-economic development need to address the growing competition for natural resources such as land, forests, water, and energy. Sustainable, land-intensive production can contribute to harmonizing these interests. In that regard, various studies from the international research community are increasingly promoting mixed livestock systems as forms of natural intensification that can produce positive environmental and economic effects, combining productivity growth and natural resource conservation when they are well designed.

Among the international community groups fostering mixed livestock systems, there is the Global Agenda for Sustainable Livestock (GASL), a multi-stakeholder partnership with 117 institutional partners, with nine technical groups (Action Networks) researching on different livestock sustainability dimensions, that has facilitated policy dialogue and action among diverse stakeholders during the past 10 years to make livestock systems more sustainable. GASL recognizes nine

Sustainable Development Goals (SDGs) with particular importance for the livestock sector (Figure 1).

Figure 1. SDGs with particular importance for the livestock sector.

GASL adopted also the following four sustainability domains to better focus its actions in support of achieving the SDGs: food and nutrition security, livelihoods and economic growth, animal health and animal welfare, and climate and natural resources use. In line with these domains of action, GASL considers mixed systems key to achieve its vision for sustainable livestock systems and closely works with the research community, private sector, public sector social movements, NGOs, intergovernmental organizations and a group of donors to foster the adoption of mixed systems on the ground a widespread reality.

This document is structured as follows: section 2 reviews literature on mixed systems attempting to grasp generalities and benefits that can arise from certain types of mixed systems as well as barriers for their adoption. Section 3 describes some cases of mixed systems around the world and tries to look at factors that are important to uptake when considering mixed systems. Section 4 lists key policy measures that can help farmers in the adoption of mixed systems. Section 5 builds on GASL's work and contribution for mixed systems. Finally, section 6 presents the conclusions.

MIXED SYSTEMS

Mixed systems take advantage of the positive synergies among crops, pasture and tress (or combinations of two of them) and can allow land use to be more economically profitable all year round at lower costs, whilst increasing product and environmental quality. Among mixed systems, silvopastoral systems (SPS) and intensive silvopastoral systems (ISPS) have been proposed to reduce the environmental impact of industrialized livestock and simultaneously increase production and economic performance. The systems, which include trees mixed with grasses, combine the advantages of the two products and naturally intensify agricultural practices. They can be less dependent on the use of external inputs and can generate a reduced carbon footprint of animal production, while improving farmers' economic returns.

The overall objective of mixed systems is to make use of fully optimized biological cycles of plants and animals, including inputs and their residues, to produce more diversified production systems.

Additionally, they can maintain and restore damaged ecosystems through the adoption of both traditional land use practice and innovation, while contributing to new employment opportunities and social welfare, especially in rural communities.

Mixed systems have been adopted in several countries, particularly in Latin America, Oceania, and several European, African and Asian regions and can be classified in seven categories: systems using natural forests; systems using planted wood trees; systems using orchards; systems using tree plantations for industrial purposes; systems using introduced trees and shrubs; systems using multipurpose trees; and systems for intensive cattle production.

Benefits of mixed systems

It is important to note that mixed systems' impacts vary in magnitude depending on the actual system implemented, and the geographical and policy environment of the region where applied. Therefore, mentioning generalities that apply universally to the systems would not be realistic. However, what emerges from different geographical cases and systems is that thanks to these mixed agricultural practices progress towards sustainability is enhanced. They significantly improve environmental protection, the provision of high-quality food, the rehabilitation of degraded ecosystems, and the mitigation of climate disruption, as well as to the increase of economic profitability and rural development for socio-economic and welfare promotion.

Concerning the contribution to sustainability, mixed systems may contribute to one or more of the following aspects depending on the context where they are applied:

Climate change mitigation and adaptation

In some instances, mixed systems can involve more biomass and improved use of natural resources and their inputs in agricultural practices; they can also contribute to climate change mitigation and reduction of net GHG emissions thanks to an improved absorption capacity of carbon through plants, and enhanced physical, chemical and biological properties of soils. In addition, trees and plants can prevent the risk of soil erosion due to wind and water, thus avoiding carbon losses in soils. It is reported that in some areas, mixed systems could also contribute to climate change adaptation by conserving hydric and edaphic resources, maintaining microclimate, providing shelter and shade to animals, reducing heat stress and reducing temperature fluctuations.

Soil fertility and quality

Mixed systems use crop rotations and grazing of forage crops and crop stubbles to improve soil quality. They may correct and restore soil organic matter and help bioremediation with its organisms, nutrients and dead organic materials. If we depart from situations of continuous cultivation, the move to rotation with pastures is a considerable improvement.

Biodiversity conservation

Some forms of mixed systems can support the protection of habitats and ecosystems for flora, fauna and insects, including for crop pollinating agents. The system can reduce the use of agrochemicals and incidence of weeds, pest and diseases through biological control. In addition, the importance posed on landscape aesthetics highlights that these systems can have also a value for cultural importance.

Animal welfare and health

Trees and thickets used in mixed systems can be beneficial to animal welfare and health providing shelters for harsh climate conditions and from predators and shades for the sun; in addition, these systems may encourage the natural behavior of animals, such as foraging and scratching, which is beneficial for both animal and soil wellbeing.

Moreover, mixed systems can benefit the economy of farmers, the private sector, and of rural communities' and society's welfare through:

Economic profitability

Generally, mixed systems are apt for large, medium, or small rural properties. The systems' economic benefits result in a greater supply of food, fibres, biofuel and biomass and animal products at lower production costs, because of more efficient use of resources and minimal reliance on external inputs that can increase agricultural productivity. In addition, these systems can provide more revenues as a range of diversified outputs are derived from integrated production over different periods of the year. It is estimated that combining multiple products can provide substantial cost reductions of 20%–70% when compared to specialized farms. The systems also present reduced risk in the event of shocks and are seen as more resilient due to improved production conditions, diversified commercial activities, and commodities production.

Rural communities' welfare

Mixed systems' diversification can stimulate the local economy, social insertion, population retention in rural areas through new job opportunities and better incomes. In addition, landscape recovery and conservation allow recreational opportunities and agritourism activities that provide additional income diversification for farmers, which also get an enhanced public image for environmental awareness and improved quality of life.

Benefits to society

Society at large benefits from a greater range of supply of food products and other commodities with safer and higher quality, improved environmental health and conservation of physical resources, including reduction of deforestation and degradation of landscapes.

Barriers of adoption for mixed systems

Barriers of adoption are also very context-dependent and vary across farming systems, markets, geographical locations and policies in a given region. However, technical constraints and administrative and social burdens for the successful implementation in a more generalized context are found in the literature.

Mixed systems, which integrate crops, livestock and trees (or two of them) in one unit of land, are seen as more difficult to manage and usually more complex and knowledge-intensive than conventional agriculture. The wider range of variables and the complex interactions between dynamic elements renders the systems particularly challenging and need careful design and more skills in several areas of work to be performed by certain farmers, who can take less advantage of economies of scale. Any inefficiency reducing production occurring in the system can drive farmers to leave integrated systems for product specialization. This could be due to lack of labour in a specific time of the year or specific management tasks and inability of farmers to manage technical complexities. For instance, in the European Union (EU) farmers perceive agroforestry is more labour-intensive than conventional agriculture due to tree management operations and difficulties in the use of large, mechanized machines in silvoarable systems.

Poor agribusiness infrastructures, lack of qualified labour and limited financial incentives, lack of insurance and land tenure are also cited by farmers as key barriers. From a financial point of view, establishing integrated systems may involve higher investments as well as additional management inputs compared to conventional farming. It is pointed out that, even though mixed systems, depending on the region, may give higher levels of productivity, profitability, return on investment, lower payback periods and economic risk, continuous cropping provides better economic results than the integrated system. This is often due to additional costs associated with external inputs and labour. For instance, in geographical regions where seasonal feed scarcities result in high feed costs like Australia, mixed systems have substantially lower costs than specialized operations.

Policies also have a key role in determining the adoption or rejection of mixed systems by farmers. Looser policies on regulation of carbon and nitrogen emissions, climate insurance, tariffs on imported feed, and food safety policies for animals in cropland areas, are likely to reduce the implementation of mixed systems, as conventional systems would result cheaper.

Farmers have also pointed to the administrative burden as a constraint for the implementation of mixed systems in some geographical areas. In the EU the Common Agricultural Policy (CAP) presents many different provisions with additional different sets of rules under its pillars. For example, agroforestry farmers in Spain mention that management of dehesa wood pastures requires more administrative work and more burdensome permissions than conventional arable agriculture.

Finally, culture and social prestige also influence preferences related to the adoption of the systems and information towards mixed systems. Farmers' traditions and norms of using continuous production systems may inhibit the will to explore other systems, while different forms of agriculture associated with prestige and personal experiences may also shape their behavior towards conventional production.

Key Features for Successful Cases of Mixed Systems Worldwide

Policies in major global food production regions that span across a range of socioeconomic and environmental contexts can incentivize the use of integrated crop and livestock and forestry practices. However, despite the environmental and economic benefits and governmental support, the level of dissemination of mixed systems among farmers is still low. In the present section we focus on key successful cases within policy environments and other factors that led to the adoption of mixed systems in different regions across the world.

Latin America

Brazil

In Brazil the natural regeneration of native trees was initiated in 1980 as a response to the practice of cutting trees and shrubs, or using herbicides, in conventional pasture management. Trees are necessary to enhance production, quality and sustainability of pastures and well as to contribute to animal welfare. Seemingly, the practice in the country successfully reduced weed control costs, improved animal comfort, enhanced forage quality and quantity, produced extra source of income for farmers, and promoted biodiversity, carbon sequestration, and erosion reduction.

After the natural regeneration of native trees, researchers and policymakers in the country are also increasingly promoting the Integrated Crop-Livestock-Forest Systems (ILCF). These systems focus on agricultural practices that integrate crop, livestock and trees with forest components, in rotation, combination or succession in different years, on the same land unit. Therefore, ILCF have numerous modalities, involving different forms of integration of resources in the same areas over the same or different periods of times. In the country, although the uptake of ILCF is still low in comparison to conventional production, government policies for recovering degraded grasslands support the dissemination of ILCF and have made crop and livestock production attractive for farmers and, in general, have favored wider adoption in comparison to other countries.

Policies have provided resources for research and development (R&D), training of extensionists, subsidized credits and high import taxes on fertilizers and livestock feed to foster these systems. In addition, the absence of insurance mechanisms for income losses, food safety restrictions on animal croplands and a recent restriction on deforestation further incentivized the uptake of sustainable intensification systems. Some studies highlight the important role played by farmers' human and physical resources when adopting these systems, including knowledge, scalable agricultural land and fixed capital, together with access to credit and extension services by the government, farmers' innovative capacity, and availability of local infrastructures.

Colombia

In Colombia, cattle farming occupies one-third of the country and could cause environmental impacts, including deforestation, degradation, loss of biodiversity, and GHG emissions. To increase the environmental sustainability of cattle ranching and enhance economic efficiency at the same time, ISPS that include a range of integrated livestock and forestry practices have been extensively promoted with mixed results. This is due to several barriers for farmers, including knowledge gaps and lack of assistance.

However, a joint project that involved several research institutes (the Colombian Cattle Ranching Federation, the Centre for Research on Sustainable Agricultural Production Systems – a GASL champion, the Action Fund, The Nature Conservancy, the Global Environmental Facility, and The World Bank – a GASL partner) was implemented in five agro-ecological regions in Colombia. The project demonstrated at small scale that key factors including technical assistance, training, environmental service payment schemes, and credit management, successfully favored the adoption of sustainable livestock systems.

Oceania

New Zealand

Research indicates that New Zealand has some of the most favorable policy environments for mixed systems and evidence shows that in recent years its farmers have undergone a transition toward mixed crop-livestock systems and especially beef and sheep mixed farms have grown. Key policies that allowed this transition were based on water pollution regulations, stringent biosecurity requirements on feed imports, and funding for research. In addition, policies that do not allow price and income supports and subsidies for crop or livestock insurance also incentivize farmers for the adoption of the systems.

Europe

In the Eropean Union (EU), policies and new technologies that promoted processes of specialization resulted in a decline of mixed farm methods, especially in the western part of the EU. In 2016, all types of mixed farms accounted for 10.4% of all farms in the EU-10, only 2.5% were mixed crop-livestock farms. Integrated systems such as agroforestry have traditionally been a key component of landscape management. However, they are both a traditional way to use land as well as a focus for innovation and sustainable solutions. For instance, the Portuguese "montado" is a traditional agrosilvopastoral system where livestock grazes extensively among oak trees where several commodities are obtained including acorns and cork, cereals, forage and ASF among others. Also, the "montado" system provides many ecological services, protection of biodiversity and contributes to the local rural economy. Other systems with similar features are the "dehesa" in Spain, the agroforestry system in Italy and Greece and the reindeer husbandry in Sweden, Norway and Finland, covering respectively 14, 16 and 11 million hectares of land. Farmers practicing silvopastoral systems are supported by pillars I and II of the Common Agricultural Policy (CAP) through direct payments and rural development support.

West Africa

In Africa, the ruminant component of the mixed crop-livestock systems is the dominant system in terms of household livelihoods. Integrated crop-small-ruminant production systems have been identified as one of the mechanisms to enhance food security and reduce poverty while being environmentally sustainable. A recent study, analyzing farmers' adoption of mixed systems in Gambia, Mali, Ghana and Benin constated the technical efficiencies of these systems in the region, where the performance was influenced by gender, household size, age and access to credits that varied among countries. These were key findings that highlighted the need for country-specific factors and targeted interventions when implementing policies.

South East and South Asia

Research highlights that crop–animal interactions in mixed farming systems are predominant in most low middle-income Asian countries. These systems are diverse, complex, and characterized by the physical environments of the different countries. In Southeast Asia, the main agro-ecological zones are characterized by humid/sub-humid climates, while in South Asia, arid/semi-arid areas are prevalent.

Several case studies on mixed farming systems among many countries in the regions have indicated the successful production rates of these systems, with a positive contribution for several sustainability domains, including environmental protection and socio-economic wellbeing of stallholders. However, the rising demand in quantity and quality for food products in the continent is shifting production towards intensive systems mechanisms, underestimating the important potential of mixed crop-ruminant systems in South East Asia.

The implementation of clear policy mechanisms that increase technological application, more intensive production systems and private sector participation will be key for sustaining mixed systems and safeguard environmental sustainability .

Policy Measures that Can Help Overcome the Barriers of Adoption of Mixed Systems

As shown also by the cases above, the adoption of mixed systems is strongly determined (and inhibited) by farmers' availability of resources, including human resources, land, fixed capital and knowledge on crop farming. Previous research suggests several policy options and changes that could increase incentives for farmers to uptake the systems.

As indicated, the adoption of these policies requires the implementation of climate-smart and environmental policies, to avoid the insurgence of free riders from conventional agriculture. Of importance are also the interlinkages with other cross-cutting policy fields such as food safety and energy and the political context of a region.

Policy options to support adoption of mixed systems include:

Agricultural policies

Targeted incentives to redirect agribusiness could help the uptake of sustainable intensification. For instance, subsidized credits and governmental extension service for intensification, or rewards and payments for the environmental services provided by sustainable agricultural practices based on an EU-like model. Also, farmer education by well-trained and independent extension service providers and simplification of bureaucracy; incentives that encourage identification and implementation of innovative crop rotations such as the Australian Grain and Graze program or the UK environmental stewardship subsidy schemes. Additionally, fostering of synergistic collaborations between arable and livestock sectors as well as tax credits to reduce dependence on imports for input providers such as feed and inorganic fertilizers; biofuels; and strengthening research and development for mixed systems.

Environmental policies to control emissions

Policies should encourage insurance programs for the adoption of agricultural practices that foster the reduction of climate risk and increased environmental health; strengthen enforcement of policies that reward nutrient recycling practices and punish nutrient runoff and that foster conservation restriction; also policies that aim at driving agribusiness to reduce deforestation under existing private conservation policies must be fixed to avoid rebound effects from intensification. Finally, price premiums or the creation of sustainable certifications associated with environmentally responsible management.

Financial support to animal health and welfare

The promotion of livestock sustainable intensification envisages technical and financial support for mixed systems, improved animal nutrition and welfare. In the long term, higher demand for alternative animal products and a change in diets can also be expected, therefore, policies that affect demand-side drivers, such as dietary choices, food waste and animal welfare could be used to promote integrated models into circular solutions. Finally, reducing food safety restrictions on the integration of animals and manure in cropland could be considered.

Work of Gasl Action Networks on Mixed Livestock Systems

GASL facilitates dialogue, generates and assembles scientific evidence and fosters sustainable practice and policy change in the livestock sector.

The GASL Action Networks (ANs) address different dimensions of livestock sustainability: resource efficiency, value of grasslands, bioeconomy, environmental assessment, dairy in Asia, silvopastoral systems, antimicrobial resistance, social development, and animal welfare.

Championed by well–known research organizations, some of the AN sustainable solutions relate to mixed systems, including a resource efficiency matrix, a multi-criteria grasslands value model, livestock environmental and performance guidelines, good animal welfare practices to enhance animal productivity and the contribution of SPS to the SDGs in Latin America.

In particular, three Action Networks are very active on the mixed systems thematic:

the Global Network on Silvopastoral Systems that provides information on the impact of silvopastoral models on productive, economic, and cultural options for supporting livelihoods and business activities with sustainable livestock farming. The Closing the Efficiency Gap Action Network which develops methodologies to measure resource use efficiency; and the Restoring Value to Grasslands Action Network that focuses on maintaining, restoring and enhancing the environmental and socio-economic values of grasslands and manages a database of pilot sites worldwide.

Specific countries and regions that have adopted appropriate policies and legislation in favour of sustainable livestock development are now using GASL’s principles and its Multi-Stakeholder Partnership (MSP) approach. The expected outcome of producing practice and policy change in favour of sustainable livestock development around the world can be seen in Mesoamerica (CODEGALAC resolutions) and Mongolia (Mongolian Agenda for Sustainable Livestock), and is rapidly developing in Eastern Europe and Central Asia (the Uman Conclusions) and South America (2018 Regional MSP Meeting in Sao Paulo, Brazil).

Finally, recent developments in the United Nations Climate Change Conference in Madrid (COP25) and the 10th and 11th Global Forum for Food and Agriculture in Berlin, recognized the GASL as an important platform to contribute to the solution of the sustainability challenges in the livestock sector.

CONCLUSIONS

The livestock sector is key for ensuring food security, economic prosperity and safeguard cultural aspects. However, some current production systems have to be adapted in order to improve their sustainability. Mixed systems, contextualized to specific geographical areas and political conditions, can be valid alternatives to increase productivity, contribute to the economy and livelihoods of many countries, and lower environmental burdens of livestock production, including protecting and restoring ecosystems in line with the SDGs. GASL provides an innovative multi-stakeholder platform for policy dialogue and joint action around the world, and fosters awareness, political will and capacity to generate and share a wide range of technical and policy solutions for sustainable livestock at international, national and local level.

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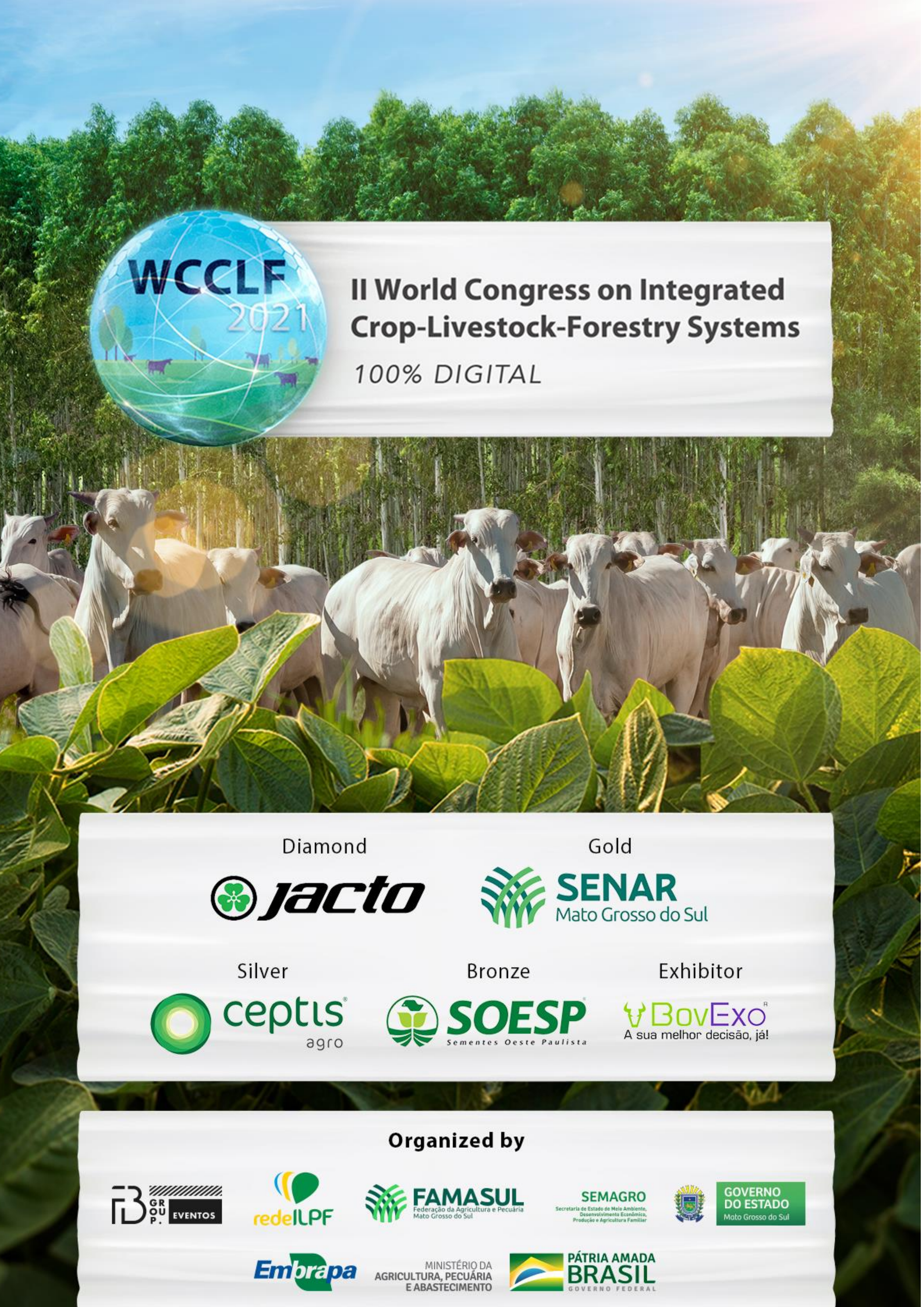

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