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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