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6 e 7 de junho 2023
São Carlos , SP

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Presentation

The accumulation of greenhouse gases (GHG) in the atmosphere remains an important topic of scientific and public interest. The increase in these gases has been considered to be a major cause of global warming. In this context, agriculture, especially Brazilian livestock production, has been the target of numerous criticisms related to global warming. Appropriate agricultural practices can reduce GHG emissions and improve the sustainability of the cattle industry, being the manipulation of ruminal fermentation and the increase in the sequestration of C strategic technologies for Brazil. In this regard, this project has been implemented through the collaborative work of 4 institutions: 1) The Brazilian Agricultural Research Corporation - EMBRAPA (EMBRAPA Livestock Southeast, EMBRAPA Instrumentation and EMBRAPA Environment); 2) The University of São Paulo-USP (College of Veterinary Medicine and Animal Science, College of Animal Science and Food Engineering and Center of Nuclear Energy in Agriculture); 3) The Sao Paulo Agency for Agribusiness Technology-APTA (Institute of Animal Science), and 4) The University of California (Davis). The project itself consisted of an experimental component and a data processing component. The experimental component aimed to evaluate different GHG mitigation strategies within the following contexts: 1) characterization of pasture productive components, 2) rumen metabolism and metagenomics; 3) animal performance and dry matter intake; 4) meat quality; 5) ruminal methane and soil GHG flux, and 6) the dynamics of organic matter and carbon stock in soil. The experimental component consisted of four trials: 1) the effects of grazing intensification and integration (integrated crop-livestock-forestry); 2) the use of pigeon pea bean in degraded pastures; 3) grass and legume intercropping for biological nitrogen fixation (BNF) of the soil, and 4) deferred grazing as a strategy for GHG mitigation. After the development of these experiments, it was identified - from among the systems currently available - those that have the greatest potential for GHG mitigation increasing soil carbon stocks.

This project resulted in the training of 25 students (seven in technical training, eight in master's, seven in doctorate and three in post-doctorate degrees) and in the production of more than 60 technical-scientific publications, 12 of which are scientific articles, seven master's dissertations, seven doctoral theses, two book chapters and several abstracts in scientific events.

We gratefully acknowledge São Paulo Research Foundation (FAPESP), for funding this project (grant numbers #2017/20084-5)and EMBRAPA, USP, IZ and DAVIS University for the development of the study.

Sumary

Methane emission intensity of Nellore cattle during the rearing and finishing phases on intercropped Pigeon pea and *Urochloa* spp. pastures

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Abstract - This study evaluated the effects of intercropping pigeon pea (*Cajanus cajan* L. Millsp. cv. BRS Mandarim) with tropical pastures for feeding Nellore cattle in the rearing and finishing phases, considering animal performance and enteric CH_4 emissions. The intercropped system was compared with other pasture-based systems during the dry and rainy seasons of 2021 (rearing phase) and 2022 (finishing phase). Thirty-six Nellore steers (221 ± 7 kg of initial body weight and 15-16 months old) were randomly distributed in three treatments with three replicates (paddocks of 1.5 hectares each): 1) degraded pasture of *Urochloa* spp. (DEG); 2) recovered and fertilized pasture of *Urochloa* spp. (REC), and 3) pigeon pea intercropped with *Urochloa* spp pasture. (MIX). Enteric CH_4 emissions were estimated using the sulfur hexafluoride (SF6) tracer gas technique, animal performance was monthly monitored, and the stocking rate was adjusted by the "put and take" technique. The results indicated that intercropping pigeon pea with tropical grasses is a promising strategy for sustainable pasture-based livestock production considering that the MIX treatment presented lower CH_4 intensity in both the rearing and finishing phases. In addition, higher average daily weight gain (ADG) was observed in MIX during the rearing phase.

Key words: Average daily weight gain, CH_4, *Cajanus Cajan*, stocking rate

Introduction

The livestock activity is facing many challenges such as the need to sustainably increase food production to meet the demand of the growing world population (FAO, 2017; GILLER et al., 2021). The large contribution of the livestock sector to greenhouse gas (GHG) emissions highlights the need to better understand the potential strategies available for GHG mitigation (IPCC, 2022). Among the management strategies and agricultural practices, the use of legumes in pastoral systems has great potential to contribute to more sustainable livestock production and the recovery of degraded pastures (FURTADO et al., 2023). In this study it was evaluated the performance and enteric CH_4 emissions of Nellore cattle during the rearing and finishing phases grazing intercropped pigeon pea (*Cajanus cajan* (L.) Millsp.) and *Urochloa* spp. pastures.

Methods

A total of 36 Nellore steers from Embrapa Pecuária Sudeste (221 ± 7 kg of body weight; 15 to 16 months old) were randomly distributed in three treatments: 1) degraded *Urochloa* spp. pasture (DEG); 2) recovered and fertilized (200 kg of N-urea ha^{-1} year) *Urochloa* spp. pasture (REC), and 3) intercropped *Cajanus cajan* (L. Millsp.) cv. BRS Mandarim and *Urochloa* spp. pasture (MIX). Each treatment had three grazing units (replicates; 1.5 ha paddocks), totaling 9 grazing units (13.5 ha in total). During the rearing (2021) and finishing (2022) phases, the animals were monthly weighed (Parede Móvel Hidráulico/idBeck 3.0 -BechHouser®, 2009) to determine the average daily gain (ADG – kg/d) and the stocking rate [SR - Animal Unit per hectare (AU/ha)] adjusted according to the forage availability, using the "put and take" technique (MOTT and LUCAS, 1952). The SF_6 tracer gas technique was used for measuring enteric CH_4 emissions from rumination. The statistical model included the three pasture-based grazing systems and two seasons (dry and rainy) as fixed effects, and the interaction between treatment and season was tested.

Results and Discussion

Lower CH_4 emission intensity (g CH_4/kg ADG) was observed in MIX during both the rearing and finishing phases (Table 1) ($P < 0.05$). During the rearing phase, the animals in MIX presented higher ADG when compared to DEG and REC (Table 1) ($P < 0.05$). Significant treatment × season interactions showed higher ADG and lower CH_4 emission and CH_4 emission intensity in MIX during the dry season ($P < 0.05$), highlighting the potential of including pigeon pea in tropical pasture-based systems as a mitigating strategy.

Table 1. Enteric methane emission and animal performance during the rearing and finishing phases.

Effects		Variables									
		Rearing					Finishing				
Trat	Seasons	ADG (kg/d)	SR (AU/ha)	ADG/ha (kg/ha.d)	CH_4/Ani (g/Ani.d)	CH_4/ADG (g/kg)	ADG (kg/d)	SR (AU/ha)	ADG/ha (kg/ha.d)	CH_4/Ani (g/Ani.d)	CH_4/ADG (g/kg)
DEG		0.302^c	1.5^c	0.9^b	222.4	2022.7^a	0.531^b	2.5^b	1.5	305.6	511.9^b
REC		0.387^b	3.0^a	1.6^a	218.7	1053.6^b	0.657^a	3.2^a	2.1	304.2	633.5^a
MIX		0.478^a	2.6^b	1.8^a	204.2	614.1^c	0.707^a	3.4^a	2.2	291.8	446.6^c
	Rainy	0.667	2.4	2.0	236.6	351.8	0.887	2.6	2.2	297.6	358.8
	Dry	0.112	2.3	0.9	193.6	2108.4	0.376	3.4	1.6	303.4	702.5
Average		0.369	2.38	1.44	215.1	1254.5	0.640	3.04	2.02	300.3	464.3
SEM		0.013	0.08	0.14	8.30	97.2	0.025	0.15	0.15	6.4	21.3
Statistical Probabilities (P value)											
Treat.		**<.001**	**<.001**	**0.005**	0.302	**<.001**	**0.001**	**0.006**	0.161	0.536	**0.001**
Seasons		**<.001**	**0.438**	**0.001**	**0.001**	**<.001**	**<.001**	**0.003**	**0.002**	0.396	**<.001**
Treat. × Season		**0.006**	**<.001**	0.127	**0.016**	**<.001**	**<.001**	0.291	**0.004**	**0.002**	**0.001**

a, b, c Different lowercase letters in the same column indicate treatments that differ from each other ($P < 0.05$) by Fisher’s test. $CH_{4/}$ Ani: methane emissions by animal; ADG: Average daily weight gain; AU: Animal unit (450 kg of body weight); CH_4ADG: methane emissions by average daily weight gain; SR: stocking rate; DEG: degraded pasture of *Urochloa* spp.; REC: recovered and fertilized (200 kg of N-urea ha^{-1} year) *Urochloa* spp. pasture; MIX: *Cajanus cajan* (L. Millsp.) cv. BRS Mandarim intercropped with *Urochloa* spp. SEM: Standard error of the mean.

Conclusions

The inclusion of pigeon pea increased animal performance while reducing enteric CH_4 emissions, demonstrating the potential of this legume for feeding beef cattle during both the rearing and finishing phases, especially during the dry season of the year, when the reduced water availability and temperature impair the production of tropical grasses, decreasing their nutritional value.

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References

FURTADO, A. J.; ABDALLA FILHO, A. L.; BRUNO, J. F.; NETO, R. P.; LOBO, A. A. G.; DA SILVA, G. V.; PERNA JUNIOR, F.; ALVES, T. C.; BERNDT, A.; PEDROSO, A. F.; MEDEIROS, S. R.; OLIVEIRA, P. P. A.; RODRIGUES, P. H. M. Pigeon Pea intercropped with tropical pasture as a mitigation strategy for enteric methane emissions of Nellore steers. **Animals**, v. 13, 1323, 2023.

FAO. **The future of food and agriculture** - Trends and challenges. Rome, Italy, 2017.

GILLER, K. E.; DELAUNE, T.; SILVA, J. V.; DESCHEEMAEKER, K.; VAN DE VEN, G.; SCHUT, A. G. T.; WIJK, M. V.; HAMMOND, J.; HOCHMAN, Z.; TAULYA, G.; CHIKOWO, R.; NARAYANAN, S.; KISHORE, A.; BRESCIANI, F.; TEIXEIRA, H. M.; ANDERSSON, J. A.; VAN ITTERSUM, M. K. The future of farming: Who will produce our food? **Food Science**, v. 13, p. 1073-1099, 2021.

IPCC. Summary for Policymakers. Climate Change 2022. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2022.

MOTT, G.O.; LUCAS, H.L. The design, conduct and interpretation of grazing trials on cultivated and improved pastures. In Proceedings of the 6th International Grassland Congress, Philadelphia, PA, USA, 17-23 August 1952; pp. 1380-1395.

Meat quality of cattle raised on pastures with pigeon pea intercropping as a strategy for mitigating greenhouse gases: preliminary results

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Abstract - Pigeon pea (*Cajanus cajan* (L.) Mill sp.) intercropped with *Brachiaria* acts as a protein bank and green fertilizer, as well as having the potential to reduce greenhouse gas (GHG) emissions in the production system. This study aimed to evaluate meat quality by physicochemical analysis (pH, water holding capacity, cooking loss, shear force, and instrumental color); metabolomics analysis, by high-resolution nuclear magnetic resonance (NMR); fatty acids composition; volatile compounds; and sensory acceptance of meat from Nellore cattle grazing in three different pasture systems: degraded pasture; recovered pasture, and pasture intercropped with pigeon pea + *Brachiaria*. Steaks 2.5 cm thick were removed from the *Longissimus thoracis* muscle, aged for 0, 7, and 14 days at 0 to 2ºC. Steaks aged for seven days at 0 - 2ºC were cooked until they reached an internal temperature of 75ºC in an oven at 180ºC. The acceptance test was carried out in two locations: at the University of São Paulo (USP) in Pirassununga, SP (n=119) and Embrapa Pecuária Sudeste, São Carlos, SP (n=52), in a total of 171 consumers. Samples were evaluated by a 9-point structured hedonic scale (1=dislike extremely; 9=like extremely) for flavor, texture (tenderness), and overall acceptability. No differences ($p>0.05$) were found between the treatments for all attributes. The association between the different places of evaluation of the meat sensory attributes was also verified. The attributes were categorized as 1 = low (1 to 4), 2 = medium (5 to 7), and 3 = high (8 to 9). Samples evaluated as category 1 (low) presented the same category for all attributes, the same occurring for the other categories, regardless of the production system, meaning that all attributes were associated. This tendency was observed in the two places where the analyses were conducted. In conclusion, beef from the different production systems were equally accepted by consumers, and the attribute scores were associated with each other, regardless of the place where the analyses were carried out.

Keywords: beef cattle, enteric methane, sensory acceptance, sustainability

Introduction

Brazil is one of the world's most important beef producers, resulting from decades of investment in technology that has increased both productivity and the quality of the Brazilian product, making it competitive and reaching the market of more than 150 countries. The increase in the emission of greenhouse gases has been considered one of the main causes of global warming, and the animal production sector has been criticized for being responsible for the emission of these gases, the most important of which is methane (CH_4) and nitrous oxide (N_2O), from enteric fermentation. When intercropping pigeon pea with grasses, it acts as a protein bank (providing a high-quality diet during the dry season) and as a green manure (the remaining in the pasture is cut at the end of the dry season and left to decompose on the soil surface. These two aspects of introducing legumes have great potential to reduce GHG emissions in the production system. This study aims to evaluate meat quality and sensory acceptance from the intercropped production system between pigeon pea and pasture, which aims to mitigate greenhouse gases.

Methods

Twenty-seven Nelore young bulls (approximately 280 kg of live weight; between 15 and 16 months old) were randomly distributed in three treatments with different levels of intensification: degraded pasture; recovered pasture; and intercropped pasture (pigeon pea + *Brachiaria*). Animals remained on-site during one year. The animals were randomly allocated to nine grazing units, with each treatment assigned to one grazing unit in a randomized block design. After the period in the field, the animals were slaughtered in a certified commercial abattoir. After 24 h of cooling, samples of the *Longissimus thoracis* muscle from the left carcass of each animal were removed and taken to the meat analysis laboratory at Embrapa Pecuária Sudeste, São Carlos, SP. Steaks of 2.5 cm thick, aged 0, 7, and 14 days at 0 to 2ºC, were used for meat quality analysis: pH; instrumental color; water holding capacity; cooking loss; and shear force. In addition, steaks aged seven days at 0 to 2ºC were kept for sensory analysis; metabolomic analysis; fatty acid composition; and volatile compounds. For sensory analysis, the samples were prepared with 1g of salt and cooked to an internal temperature of 75ºC in an oven at 180ºC. The acceptance test was carried out at the University of São Paulo (USP) in Pirassununga, SP, and Embrapa Pecuária Sudeste, São Carlos, SP. A questionnaire was applied to verify the profile of consumers, and the samples were evaluated using a 9-point structured hedonic scale (1 = dislike extremely; 9 = like extremely) for flavor, texture (tenderness), and overall acceptance. The data obtained from the sensory acceptance test were analyzed using analysis of variance (ANOVA), and when there was a difference, Tukey's test was applied at a 5% significance level. The association between the different analysis sites used in the evaluation of meat sensory attributes was also verified. The acceptance attribute scores were categorized into 1 = low (1 to 4), 2 = medium (5 to 7), and 3 = high (8 to 9) and analyzed using the chi-square test and multiple factorial correspondence analysis.

Results and Discussion

Of the 171 consumers, 70% participated in the study at USP and 30% at Embrapa; of the total, 67% were women, and 33% were men; aged 21 to 35 years (51%) and had incomplete higher education (53%). Consumers mentioned that they are concerned about the GHG generated by beef production (83%) and would pay more for a product resulting from more sustainable agricultural practices (92%). No differences ($p>0.05$) were found between treatments for all analyzed attributes in the two locations. The averages obtained for global acceptance were 7.1 for the meat from degraded pasture and recovered pasture and 7.0 for the meat from pigeon pea + *Brachiaria* intercropped pasture, equivalent to "I liked it moderately." Meat samples evaluated in category 1 (low acceptance) for flavor showed the same category for texture and global acceptance attributes, regardless of the production system. Similar results were observed for categories 2 (medium) and 3 (high) for all studied attributes meaning they were associated. This trend was similar between the two locations where the analyses were carried out.

Partial Conclusions

In conclusion, consumers equally accepted beef from different production systems, and sensory acceptance attribute scores were associated and independent of the analysis location and production systems.

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References

ARCHIMÈDE, H.; EUGÈNE, M.; MARIE MAGDELEINE, C.; BOVAL, M.; MARTIN, C.; MORGAVI, D.P.; LECOMTE, P.; DOREAU, M. Comparação da produção de metano entre gramíneas e leguminosas C_3 e C_4. Animal Feed Science and Technology, v.166-167, p.59-64, 2011.

DE SENE, G. A., ASSUMPÇÃO, A. H. P. M., BAGIO, G., LELIS, J., TROPALDI[1], C. B., DA SILVA, G. V., ... & RODRIGUES[1], P. H. M. (2019). Práticas estratégicas com vistas à mitigação dos gases do efeito estufa na produção de bovinos a pasto. Novos desafios da pesquisa em nutrição e produção animal.

MONTEIRO, A. L. G., DE MORAES, T. B. P. A., BERNDT, A., BAYER, C., & DE FACCIO CARVALHO, P. C. (2020). EMISSÃO DE METANO EM BOVINOS PRODUZIDOS EM SISTEMAS INTEGRADOS DE PRODUÇÃO AGROPECUÁRIA (SIPA). Coletânea de Fatores de Emissão e Remoção de Gases de Efeito Estufa da Pecuária Brasileira, 52.

STONE, H.; SIDEL, J. L. Sensory evaluation practices. San Diego, CA: Academic Press, 1993. 308 p.

Mixed grass-legume pasture and supplementation with ammonium nitrate effect on cow enteric methane emission

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Abstract - The objective of the study was to assess the enteric methane emissions from cows in mixed pastures containing Macrotyloma legume and Marandu palisadegrass, in comparison to Marandu palisadegrass exclusive pasture with or without ammonium nitrate supplementation, under continuous stocking conditions. The study was conducted at the Instituto de Zootecnia in Nova Odessa, São Paulo. Twelve Jersey cows (372.83 ± 44.62 kg) were used in the experiment. The experimental period comprised two consecutive years, from October 2019 to August 2021.The experimental treatments were: G: Exclusive pasture of *Urochloa brizantha* cv. Marandu; GP: Exclusive pasture of *Urochloa brizantha* cv. Marandu with ad libitum protein supplementation; GL: Mixed pasture with *Urochloa brizantha* cv. Marandu and *Macrotyloma axillare* legume (E. Mey. Verd accession NO 279). Statistical analyses were performed using SAS 9.4 MIXED procedure, and a significant effect was considered when P≤0.05 (LSD test). Results: CH_4 emission was 269[a]; 197[b] and 234[ab] g/animal/day for G, GP, and GL, respectively; CH_4/ADG 3.20[a]; 0.52[b] and = 0.73[b] g/kg for G, GP, and GL, respectively; Ym (percentage of gross energy ingested converted to methane)was 8.33%[a]; 6.34%[b] and 8.03%[a] for G, GP and GL, respectively. The supplementation of cows on pasture with ammonium nitrate and the introduction of *Macrotyloma axillare* in tropical pastures as an intercropped system, hold great potential for improving the sustainability of livestock production based on pastures. These practices can play a significant role in reducing greenhouse gas emissions and enhancing animal productivity.

Key words: Continuous stocking, Greenhouse gases, *Macrotyloma axillare* (NO 279), *Urochloa brizantha* cv. Marandu

Introduction

The objective of the study was to assess the enteric methane emissions from cows grazing mixed pastures containing Macrotyloma legume and Marandu palisadegrass, in comparison to Marandu palisadegrass exclusive pasture with or without supplementation of ammonium nitrate, under continuous stocking conditions.

Methods

The study was conducted at the Instituto de Zootecnia in Nova Odessa, São Paulo. Twelve Jersey cows (372.83 ± 44.62 kg) were used in the experiment. The experimental period comprised two consecutive years, starting in October 2019 and ending in August 2021 and data collection was carried out for forty days during each season. The experiment followed a completely randomized block design. Enteric methane emissions from rumination were measured using the SF6 tracer gas technique.

The experimental treatments were as follows: (1) G: Exclusive pasture of *Urochloa brizantha* cv. Marandu (54% grass and 46% dead material; 8% CP and 69% NDF); (2) GP: Exclusive pasture of *Urochloa brizantha* cv. Marandu (54% grass and 46% dead material; 8% CP and 69% NDF) with ad libitum protein supplementation; (3) GL: Mixed pasture with *Urochloa brizantha* cv. Marandu and *Macrotyloma axillare* legume (E. Mey. Verd accession NO 279) (43% grass, 15% legume and 42% dead material; 13% CP and 65% NDF). The composition of the protein supplement was: Rainy Seasons: 69% ground corn; 8% mineral mixture; 5% NaCl and 18% ammonium nitrate; Chemical composition: 81% DM; 14% ASH; 46% CP; 9% NDF 3% ADF and 0.7% EE. Dry Seasons: 45% ground corn; 15% mineral mixture; 10% NaCl and 30% ammonium nitrate; Chemical composition: 81% DM; 31% ASH; 65% CP; 9% NDF; 2% ADF and 0.9% EE.

Statistical analyses were performed using the SAS 9.4 MIXED procedure and data were evaluated using the least significant difference test, and a significant effect was considered when P≤0.05.

Results and Discussion

Table 1. Average values of methane (CH_4) emissions of Jerseys cows in exclusive pasture of Marandu grass (G), exclusive pasture of Marandu grass with protein supplementation (GP) and mixed pasture with Marandu grass and Macrotiloma legume (GL) during the seasons.

Factors[1]		Variables[2]							
Treat.	**Seasons**	**CH_4 g/Ani.day**	**CH_4 kg/ani.day**	**CH_4/ha kg/ha**	**CH_4/UA g/UA.ha**	**CH_4/BW g/kg**	**CH_4/ADG kg/kg**	**CH_4/ DMI_T g/kg**	**Ym %**
G		269.4^{a}	0.26^{a}	0.53^{a}	66.79^{a}	0.59^{a}	3.20^{a}	26.63^{a}	8.38^{a}
GP		197.9^{b}	0.19^{b}	0.38^{b}	52.67^{b}	0.47^{b}	0.52^{b}	19.82^{b}	6.34^{b}
GL		$234.^{ab}$	0.23^{ab}	0.47^{ab}	57.03^{ab}	0.51^{ab}	0.73^{b}	22.44a	8.03^{a}
	Spring	218.1	0.22	0.44	60.15	0.53	0.34^{B}	19.78^{B}	5.84^{C}
	Summer	230.4	0.23	0.46	60.66	0.54	0.28^{B}	23.48^{AB}	8.20^{AB}
	Autumn	243.0	0.24	0.49	55.78	0.52	0.53^{B}	21.73^{B}	6.97^{BC}
	Winter	250.6	0.25	0.48	60.01	0.54	4.77^{A}	26.87^{A}	9.31^{A}
Average Data									
Average		235.5	0.24	0.47	59.15	0.53	1.49	48.37	7.58
SEM[3]		12.67	0.01	0.02	2.77	0.03	0.20	3.48	0.49
Statistic Probabilities[4]									
Treatments		0.0111	0.0063	0.0033	0.0037	0.0238	<.0001	0.0037	0.0026
Seasons		NS	NS	NS	NS	NS	<.0001	0.0078	<.0001
Treatments*Seasons		NS	NS	NS	NS	NS	NS	NS	NS

[1]Treat: G: Exclusive pasture of *Urochloa brizantha* cv. Marandu; GP: Exclusive pasture of *Urochloa brizantha* cv. Marandu with ad libitum protein supplementation; GL: mixed pasture with *Urochloa brizantha* cv. Marandu and legume *Macrotyloma axillare* (E. Mey. Verd accession NO 279). First year: Spring 2019; summer 2020; autumn 2020; winter 2020. Second year: Spring 2020; summer 2021; autumn 2021; winter 2021.[2] CH_4/Ani: Methane emissions by animal; CH_4/ha: Methane emissions by hectare; CH_4/AU: Methane emissions by animal unit (450 kg of live weight); CH_4/ LBW: Methane emissions by live body weight; CH_4/ADG: Methane emissions by average daily weight gain; CH_4/DMIT: Methane emissions by dry matter intake total; Ym: Percentage of gross energy ingested converted to methane. [3]SEM: Standard error of mean. abc Means followed by different lowercase letters in the columns differ significantly by the protected LSD test at 5% of significance level; ABC Means followed by different uppercase letters in the columns differ significantly by the protected LSD test at 5% of significance level (Seasons); NS: Non-significant.

The inclusion of the legume Macrotyloma in the system resulted in lower methane emissions per unit of weight gain; the legumes generally contain higher protein levels than grasses, along with better digestibility and lower fiber content, leading to improved animal productivity (Lima et al., 2017). In the case of cows on exclusive Marandu pasture and receiving supplementation with ammonium nitrate, a decrease in methane emissions was observed. The conversion of nitrate into ammonia by anaerobic microorganisms in the rumen competes with the methane-producing pathway, utilizing eight hydrogen electrons per nitrate molecule (Van-zijderveld et al., 2010), which is equivalent to two methane molecules.

Conclusions and/or Implications

The supplementation of cows on pasture with ammonium nitrate and the introduction of *Macrotyloma axillare* in tropical pastures, as an intercropped system, hold great potential for improving the sustainability of livestock production based on pastures. These practices can play a significant role in reducing greenhouse gas emissions, enhancing animal productivity.

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References

LIMA, P. M. T.; MOREIRA, G. D.; SAKITA, G. Z.; NATEL, A. S.; MATTOS, W. T. de.; GIMENES, F. M. A.; GERDES, L.; MCMANUS, C.; ABDALLA, A .L.; LOUVANDINI, H. Nutritional evaluation of the legume *Macrotyloma axillare* using *in vitro* and in vivo bioassays in sheep. **Journal of Animal Physiology and Animal Nutrition**, v.102, p.669-676, 2017.

VAN ZIJDERVELD, S. M.; GERRITS, W. J. J.; DIJKSTRA, J.; NEWBOLD, J. R.; HULSHOF, R. B. A.; PERDOK, H. B. Persistency of methane mitigation by dietary nitrate supplementation in dairy cows. **Journal of Dairy Science, Champaign**, v.94, p.4028-4038, 2010.

Intercropping of tropical grass and pigeon pea: Impact on soil water dynamics and forage production

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Abstract - This study aimed to assess soil water dynamics and production of tropical grasslands intercropped with pigeon pea. The research was conducted from 2020 to 2022 in signalgrass [*Urochloa decumbens* Stapf cv. Basilisk] pastures managed under continuous stocking in São Carlos, SP, Brazil. A degraded pasture (DEG),a pasture restored with nitrogen fertilization (200 kg N·ha^{-1}·year^{-1}) (REC), and a pasture intercropped with pigeon pea (*Cajanus cajan* L. Millsp. cv. BRS Mandarim) (MIX) were assessed. Soil moisture in the 0–60 cm layer was assessed using time-domain reflectometry sensors and biomass accumulation was assessed with the aid of grazing exclusion cages. In general, there was no water competition in MIX as in a high-water demand period the pigeon pea explored the 30-60 cm soil layer. The biomass accumulation in MIX was superior to DEG, both in the rainy and dry seasons of the year. The results highlight the potential of intercropping pigeon pea with forage grasses.

Key words: biomass, *Brachiaria decumbens*, *Cajanus cajan*, forage accumulation, soil water competition

Introduction

Brazil has the largest commercial cattle herd in the world and is cited as the country with the highest potential to meet future animal protein demand (Greenwood et al., 2021). Nevertheless, pasture degradation and the contribution to greenhouse gas emission by livestock systems are still important challenges to be addressed (IPCC, 2022). Intercropping legumes and forage grasses for livestock production can be an interesting alternative to increase feed quality for the animals, fix atmospheric nitrogen, and supplement animal diet during forage grass shortages, while reducing methane enteric emission (Boddey et al., 2020). Despite that, interspecific competition for resources as water can be acute (Pezzopane et al., 2015) impairing the growth of one or more species in integrated systems. Thus, it is of pivotal importance to understand the interaction between the components of integrated systems to evaluate their synergy. The aim of this study was to assess the soil water consumption and biomass accumulation in an intercropping setting with tropical grass and pigeon pea.

Methods

The study was conducted at Embrapa Pecuária Sudeste, in São Carlos, SP, Brazil (21°57′S, 47°50′W; 860 m asl), from 2020 to 2022. The livestock systems were: 1) degraded signalgrass (*Urochloa decumbens* Stapf. cv. Basilisk) pasture (DEG); 2) signalgrass pasture recovered with nitrogen fertilization (200 kg N·ha^{-1}·year^{-1}) (REC); and 3) signalgrass and pigeon pea (*Cajanus cajan* L. Millsp. cv. BRS Mandarin) intercropping (MIX); with three repetitions, managed under continuous stocking and using the “put and take” technique to regulate forage availability (Mott and Lucas; 1952). Pigeon pea was sown in January of 2020 and the animals (Nelore young bulls) entered the area in June 2020.

Soil-water analysis was conducted from Jul/2020 to Aug/2022, using time-domain reflectometry sensors (CS615 model, Campbell Scientific, Logan, UT, USA) at 0–30, 30–60 cm, with three repetitions, using 30 cm-stem sensors connected to a datalogger. Forage samples were collected monthly at ground level using three grazing exclusion cages per experimental unit (0.50×0.50 m cages for DEG and REC and 1.00x0.50 m for MIX). The total (signalgrass + pigeon pea) biomass accumulation was calculated by deducting the forage mass outside the cage when it was installed from the forage mass inside the cage at the end of the exclusion period. The samples were weighed, and subsamples were dried in a forced air oven at 65 °C until constant weight. The monthly accumulation values were added up to each season: drought (from June to Nov) and rainy (from Dec to May). The data were analyzed with the aid of the software SAS (SAS Institute Inc., Cary, North Carolina, USA), as a completely randomized design repeated over time (subdivided plots), with experimental units as random factors and systems, seasons, and years as fixed effects. Significant fixed effects were considered at a 5% level and mean multiple comparisons were conducted by Fisher’s test ($p<0.05$).

Results and Discussion

From 01/20/2021 to 02/10/2021, the humidity in the 30-60 cm soil layer was much lower in MIX as compared with REC and DEG, with daily averages of 0.194, 0.209, and 0.209 cm^3 cm^{-3}, respectively. In spite of that, the 0-30 cm soil layer was similar between the systems with values for MIX, REC, and DEG of 0.218, 0.232, and 0.220 cm^3 cm^{-3}, respectively. The total biomass accumulation had significant interaction between year x season x system ($p=0.0107$) (Table 1).

Table 1. Total [signalgrass (*Urochloa decumbens* Stapf cv. Basilisk) + pigeon pea (*Cajanus cajan* cv. BRS Mandarim)] biomass accumulation in different production systems from 2020 to 2022 in São Carlos/SP, Brazil.

System	Year 1		Year 2	
	Dry season	Rainy season	Dry season	Rainy season
DEG	2896.7 Aa(A)	3940.9 Ba(A)	2342.1 Ba(A)	1993.6 Ba(A)
REC	3597.0 Aa(A)	6461.1 Ba(A)	3127.5 Bb(A)	9091.2 Aa(A)
MIX	5548.0 Ab(A)	16511.0 Aa(A)	8974.6 Aa(A)	6018.9 ABa(B)

Means followed by the same letter do not differ. Uppercase letters compare systems in the same year x season; lowercase letters compare seasons in the same system x year; letters between parenthesis compare years in the same system x season. DEG, signalgrass degraded pasture; REC, recovered signalgrass pasture; MIX, signalgrass and pigeon pea mixture.

There was no water competition in MIX in the experimental period. In a period of high-water consumption during a dry spell, pigeon pea in MIX utilized water from the 30–60 cm depth range, what may be linked to its taproot system. Exploring abiotic resources in different niches decreases interspecific competition and increases the total resource exploitation. The MIX was a good alternative for pasture recovery with higher biomass production as compared to the DEG, and even higher than the REC during two seasons of the experimental period (Table 1). Noteworthily, MIX provided feed for the animals during the dry seasons, as particularly observed in the year 2. This resulted from the animals not consumingpigeon pea during the rainy season, what changes during the dry season when the species bloom. Providing feed as legumes in the dry season decreases seasonality and increases forage quality during this period of the year.

Conclusions and/or Implications

The absence of water competition between pigeon pea and signalgrass highlights the potential of intercropping these species. The intercropping showed high potential for pasture recovery and biomass accumulation both in the rainy and dry seasons of the year.

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References

BODDEY, R. M.; CASAGRANDE D. R.; HOMEM, B. G. C; ALVES, B. J. R. Forage legumes in grass pastures in tropical Brazil and likely impacts on greenhouse gas emissions: A review. **Grass and Forage Science**, v. 75, p. 357-371, 2020.

GREENWOOD, P. L. Review: An overview of beef production from pasture and feedlot globally, as demand for beef and the need for sustainable practices increase. **Animal**, vol. 15, 2021.

IPCC. Summary for Policymakers. Climate Change 2022. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2022.

MOTT, G.O.; LUCAS, H.L. The design, conduct and interpretation of grazing trials on cultivated and improved pastures. In Proceedings of the 6th International Grassland Congress, Philadelphia, PA, USA, 17–23 August 1952; pp. 1380–1395.

PEZZOPANE J.R.M.; BOSI C.; NICODEMO M.L.F.; SANTOS P.M.; DA CRUZ P.G.; PARMEJIANI R.S. (2015) Microclimate and soil moisture in a silvopastoral system in southeastern Brazil. **Agrometereology** 74, 110–119.

Forage accumulation in silvopastoral and intensified pasture-based systems

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Abstract - This study evaluated forage accumulation during two experimental years (September 2019 - September 2021) on five pasture-based production systems: 1) intensively managed and irrigated *Megathyrsus maximus* (syn. *Panicum maximum*) Jacques cv. Tanzânia pasture, overseeded in the dry season with A*vena byzantina* and *Lolium multiflorum* (IHS); 2) intensively managed rainfed *M. maximus* cv. Tanzânia pasture (RHS); 3) intensively managed rainfed pasture with a mix of *Urochloa* (syn. *Brachiaria*) *decumbens* Stapf cv. Basilisk and *U. brizantha* (Hochst ex A. Rich) cv. Marandu (RMS); 4) intensively managed silvopastoral system with rainfed *U. decumbens* cv. Basilisk pasture and Brazilian native trees (LFS); and 5) extensively managed rainfed degraded *U. brizantha* cv. Marandu and *U. decumbens* cv. Basilisk pasture (DP). All pastures were submitted to stocking rate adjustments using the “put and take” technique, and except for DP, received liming and macro and micronutrients fertilization. Samples were collected in pre and post-grazing conditions to determine forage accumulation. For the warm-season grasses (C4 plants), higher forage mass accumulation was observed in IHS and RHS ($P < 0.001$) while DP presented the lowest value. For the cool-season C3 grasses, higher forage mass accumulation was observed in the winter ($P < 0.001$). Our results showed that more intensified systems had better productive characteristics when compared to DP, especially during the seasons with more water availability.

Key words: grazing systems, cool-season C3 grasses, sustainable intensification, warm-season C4 grasses

Introduction

Agricultural activities play an important role in meeting the food demand from the growing world population, and Brazil has a prominent position in the livestock sector, being the main beef exporter in the world with 2.5 million tons/year (ABIEC 2022). However, the country is the target of criticism as the livestock production system occupies a large area of pastures extensively exploited, with a considerable portion under some stage of degradation, reflecting a certain level of inefficiency of the livestock production activity. In this context, employing better pasture management strategies, aiming to increase forage grass productivity, becomes important to improve the sustainability of these pasture-based production systems. In this study we evaluated the effects of pasture intensification and integration with trees on forage accumulation in beef cattle pasture-based production systems in the Southeast of Brazil.

Methods

The study was carried out at Embrapa Southeast Livestock, São Carlos, SP, Brazil from September 2019 to September 2021. Treatments were classified according to different levels of pasture intensification, consisting of five representative Brazilian pasture-based production systems, with two replicates (paddocks), as follows: 1) intensively managed and irrigated *Megathyrsus maximus* (syn. *Panicum maximum*) Jacques cv. Tanzânia pasture, overseeded in the dry season with *Avena byzantina* and *Lolium multiflorum* (IHS); 2) intensively managed rainfed *M. maximus* cv. Tanzânia pasture (RHS); 3) intensively managed rainfed pasture with a mix of *Urochloa* (syn. *Brachiaria*) *decumbens* Stapf cv. Basilisk and *U. brizantha* (Hochst ex A. Rich) cv. Marandu (RMS); 4) intensively managed silvopastoral system with rainfed *U. decumbens* cv. Basilisk pasture and Brazilian native trees (LFS); and 5) extensively managed rainfed degraded *U. brizantha* cv. Marandu and *U. decumbens* cv. Basilisk pasture (DP). All pastures were grazed by Nellore steers and submitted to stocking rate adjustments using the “put and take” technique (Mott and Lucas, 1952) (continuous in DP and rotational in IHS, RHS, RMS, and LFS). Except for DP, all pastures received liming and macro and micronutrients fertilization annually: during the rainy season, IHS and RHS were fertilized with 400 kg N ha^{-1} year^{-1}, and RMS and LFS with 200 kg ha^{-1} year^{-1}; while during the dry season, only IHS was fertilized with more 200 kg N ha^{-1} year^{-1}. Forage samples were collected at 18 days intervals, at pre and post-grazing conditions, within an area delimited by metallic structures (0.50 × 0.50 m) randomly thrown in the experimental units in IHS; RHS; RMS; LFS; and inside exclusion cages (0.50 × 0.50 × 0.70 m; with 0.25 m^2 of base) in DP. Samples were weighed to determine fresh mass, homogenized, and dried in a forced air circulation oven (60ºC - 72h) to determine the dry mass (DM). The differences between the pre-grazing/ inside the cage mass (n) with the post-grazing/outside the cage (n^{-1}) mass were considered to determine the forage mass accumulation (kg of DM ha^{-1}). The statistical model included the pasture-based grazing unit systems (paddocks) and seasons (spring, summer, autumn and winter) as fixed effects, and the interaction between treatments × season was tested. Means of the variables were submitted to analysis of variance and comparison by Fisher test at 5%, using the PROC MIXED of SAS.

Results and Discussion

Treatments and seasons affected the forage accumulation of warm-season C4 grasses (P < 0.0001), while effect of season was found for the cool-season C3 grasses (P = 0.0103) (Table 1).

Table 1. Forage accumulation in pasture-based production systems with different levels of intensification.

Treatments	Seasons	Forage accumulation (kg DM ha^{-1} season^{-1})	Forage accumulation (kg DM ha^{-1} day^{-1})
Warm-Season C4 Grasses			
DP		2016.4^{c}	22.2^{c}
LFS		2549.7^{bc}	28.0^{bc}
RMS		3702.7^{b}	40.7^{b}
RHS		7080.7^{a}	78.0^{a}
IHS		7733.0^{a}	85.0^{a}
	Spring	4933.8^{B}	54.2^{B}
	Summer	7448.9^{A}	82.0^{A}
	Autumn	3678.0^{C}	40.4^{C}
	Winter	2405.3^{D}	26.4^{D}
Means		4590.2	50.4
Standard Error		340.04	3.74
Statistical Probabilities (P Value)			
Treatments		**<.0001**	**<.0001**
Seasons		**<.0001**	**<.0001**
Treatments × Seasons		0.1327	0.2089
Cool-Season C3 Grasses			
IHS		689.7	7.6
	Autumn	237.6^{B}	2.6^{B}
	Winter	2001.8^{A}	22.0^{A}
Standard Error		3.01	0.03
Statistical Probability (P Value)			
Seasons		**0.0103**	**0.0103**

Means followed by the same letter in the column do not differ by Fisher's test (P < 0.05). DM: Dry matter; ha: hectare. Treatments: DP, Extensively managed rainfed degraded *Urochloa* spp. pasture; LFS, Intensively managed silvopastoral system with rainfed *U. decumbens* cv. Basilisk pasture and Brazilian native trees; RMS, Intensively managed rainfed *Urochloa* spp. pasture; RHS, Intensively managed rainfed *Megathyrsus maximus* cv. Tanzânia Pasture; IHS, Intensively managed and irrigated *M. maximus* cv. Tanzânia pasture, overseeded with *Avena byzantina* and *Lolium multiflorum.*

Greater forage accumulation of warm-season C4 grasses in IHS and RHS are due to the use of a more productive forage specie (*Megathyrsus* spp.) and its response to fertilization. In the systems with *Urochloa* spp., no significant difference was found between LFS and DP, which may be attributed to the lower solar radiation, and the interspecific competition for water and nutrients between the components in the LFS, mainly, during the autumn and winter seasons (Lopes et al., 2017). The higher nutritional value of cool-season C3 grasses observed in winter are due to the low minimum basal temperatures for biomass increment. Considering the effects of the consortium in the IHS (overseeding with *Avena byzantina* and *Lolium multiflorum*) as compared with the RHS, it is possible to conclude that the practices that aim to eliminate the effects of seasonality, promote greater productivity of the pastures.

Conclusions

More intensified systems resulted in higher forage accumulation when compared to DP, mainly when considering the seasons with more water availability. In IHS, the practices that aimed to ameliorate the effects of seasonality showed to be favorable to maintain better productive characteristics in seasons with great water deficit.

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References

ABIEC. **Beef Report:** Perfil da Pecuária no Brasil 2022, Relatório Anual. Associação Brasileira das Indústrias Exportadoras de Carne, 2022, 49 p. Available at: http://abiec.com.br/publicacoes/beef-report-2022.

LOPES, C. M., PACIULLO, D. S. C., ARAÚJO, S. A. C., GOMIDE, C. A. M., MORENZ, M. J. F., VILLELA, S. D. J. Herbage mass, morphological composition and nutritive value of signal grass, submitted to shading and fertilization levels. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, 69, 2017, 8 p.

MOTT, G.O.; LUCAS, H.L. **The design, conduct and interpretation of grazing trials on cultivated and improved pastures**. In Proceedings of the 6th International Grassland Congress, Philadelphia, PA, 1952, p. 1380–1395.

C isotopic composition in C_3 and C_4 plants for forage intake estimation

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Abstract - Carbon (C) constitutes 40 to 50% of the organic matter on the planet and is present in various reservoirs. It naturally occurs as two stable isotopes: ^{12}C and ^{13}C; the lighter isotope represents 98.89% of all the carbon. The ratio between the heavier and lighter isotopes can vary due to the isotopic fractioning that occurs during physical, chemical, and biological processes. The isotopic ratio of a sample is commonly expressed using the delta notation ($\delta^{13}C$), which represents the deviation of this ratio from the PDB standard. The isotopic methodology compares the $\delta^{13}C$ of a source with the $\delta^{13}C$ of a specific product. In the case of vegetation studies, the source is atmospheric CO_2, and the product is the organic molecule produced by plants during photosynthesis. Due to the characteristics of their photosynthetic processes, C_3 and C_4 plants exhibit distinct isotopic fractioning, with C_3 plants showing more negative $\delta^{13}C$ values than C_4 plants. This difference allows us to use a simple mixing model to estimate the intake of different proportions of C_4 and C_3 plants under grazing conditions. In a recently published study, samples of pigeon pea (C_3), *Urochloa* spp. (C_4), and steers feces were collected in an intercropped system, during the dry and rainy seasons of the year, and isotopically analyzed. The results showed low intake of pigeon pea during the rainy period, but during the dry period the proportion of the legume in the diet reached about 40%. This allowed us to present the nutritional characteristics of the diet, considering the proportion of pigeon pea in the diet during the experimental period.

Key words: *Cajanus cajan*, intercropped systems, pigeon pea, *Urochloa* spp., ^{13}C

Introduction

Carbon (C) naturally occurs as two stable isotopes: ^{12}C and ^{13}C, with approximately 98.89% of all C being ^{12}C. The ratio between these two isotopes ($^{13}C/^{12}C$) varies due to isotopic fractioning during physical, chemical, and biological processes. The analysis of C isotopic composition is done by measuring the $^{13}C/^{12}C$ ratio of samples in relation to the international PDB standard (a limestone rock found in a geological formation called Pee Dee in North Carolina, USA). Deviations from the standard are known as delta units (δ), and since they are very small values, they are conventionally expressed in parts per thousand (‰). The $\delta^{13}C$ values of atmospheric CO_2 are relatively constant and range from -7 to -8‰ due to the isotopic equilibrium between atmospheric CO_2 and bicarbonate (HCO_{3-}) dissolved in ocean water. On the other hand, plants have $\delta^{13}C$ values ranging from -11 to -35‰, and the greatest differences in C isotopic composition in plant tissues are found between species that have the C_3 carboxylation cycle and those that have the C_4 cycle. C_3 plants (Calvin cycle) fix atmospheric CO_2 through the Rubisco enzyme, while C_4 plants fix CO_2 through PEP carboxylase, which has a high affinity for CO_2. Since Rubisco has a lower affinity for CO_2, this enzyme discriminates the heavy isotope ^{13}C relative to ^{12}C, and thus, C_3 plants accumulate less ^{13}C. This isotopic characteristic of plants allows a variety of studies on climate change and their impacts on natural vegetation, the identification of production systems, the origin of plant-based products, food and beverage adulteration, as well as estimating contrasting diets intake. In pasture-based production systems with C_4 tropical grasses and C_3 legumes, the isotopic methodology can be used as a tool to estimate the intake proportion of the different plants. For this reason, in a recently published article (Furtado et al., 2023) we chose this approach to estimate forage intake in intercropped pastures of *Urochloa* spp. and *Cajanus cajan* (pigeon pea) during the dry and rainy seasons of 2021 at Embrapa Pecuária Sudeste, São Carlos, SP.

Methods

This study was conducted in three paddocks (1.5 ha each) of *Urochloa* spp. and *Cajanus cajan* (L. Millsp.) cv. BRS Mandarim, grazed by Nellore cattle (221 ± 7 kg of live weight and 15-16 months old) during the rainy (January) and dry (July) seasons of 2021. Samples of grass and legume were separately collected through grazing simulation by hand-plucking, and feces were collected after voluntary defecation. To determine the isotopic ratio ($^{13}C/^{12}C$) of the samples, an isotope ratio mass spectrometer (Delta Plus, ThermoFisher Scientific, Bremen, Germany) coupled with an elemental analyzer (CHN-1110, Carlo Erba, Rodano, Italy) was used, and the values expressed using the following equation 1:

$$\delta\ (‰) = \left[\left(\frac{Rsample}{Rstandad}\right) - 1\right] \times 1000 \qquad (1)$$

where R is the $^{13}C/^{12}C$ ratio and PDB is the standard.

The principle of isotopic differences between C_3 and C_4 plants was then used to estimate the intake proportion of each plant during the rainy and dry seasons, following the equation 2 presented by Norman et al. (2009):

$$C_4\ (\%) = 100 - \left(100 \times \left(\frac{(A-B)}{(C-B)}\right)\right) \qquad (2)$$

where A = feces $\delta^{13}C$; B = C_4 plant (*Urochloa* spp.) $\delta^{13}C$ and C = C_3 plant (*Cajanus cajan*) $\delta^{13}C$.

Results and Discussion

Table 1. *Cajanus cajan* (L.) Millsp. and *Urochloa* spp. C isotopic composition during the experimental period.

Plant Species	Seasons	$\delta^{13}C$ (‰)
Cajanus cajan (L.) Millsp.	Rainy	-30.5
	Dry	-26.1
	Average	-28.3
	SEM	0.68
Urochloa spp.	Rainy	-13.2
	Dry	-13.7
	Average	-13.4
	SEM	0.10

$\delta^{13}C$: carbon isotope ratio; SEM: standard error of the mean.

The feces isotopic results ($\delta^{13}C$ = -13.8 ± 0.23‰ in the rainy season and -18.7 ± 1.33‰ in the dry season) indicated low legume intake during the rainy period (4.1 ± 0.01%), which is in line with the characteristics of pigeon pea in intercropping systems (Oliveira et al., 2017). However, during the dry season the proportion of pigeon pea intake in the animals’ diet reached around 41% (40.7 ± 0.11%), indicating the potential of including this legume as a forage source, especially during the dry season, when tropical grasses are most affected by production seasonality.

Conclusion

The isotopic methodology turned out to be a promising tool for estimating the legume intake in an intercropping system, which allowed the determination of the diet nutritional quality considering the proportion that each plant was consumed throughout the experimental period.

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References

FURTADO, A. J.; ABDALLA FILHO, A. L.; BRUNO, J. F.; NETO, R. P.; LOBO, A. A. G.; DA SILVA, G. V.; PERNA JUNIOR, F.; ALVES, T. C.; BERNDT, A.; PEDROSO, A. F.; MEDEIROS, S. R.; OLIVEIRA, P. P. A.; RODRIGUES, P. H. M. Pigeon Pea intercropped with tropical pasture as a mitigation strategy for enteric methane emissions of Nellore steers. **Animals**, v. 13, 1323, 2023.

NORMAN, H. C.; WILMOT, M. G.; THOMAS, D. T.; MASTERS, D. G.; REVELL, D. K. Stable carbon isotopes accurately predict diet selection by sheep fed mixtures of C3 annual pastures and salthbush or C4 perennial grasses. **Livestock Science**, v. 121, 162-172, 2009.

OLIVEIRA, P. P. A.; MATTA, F. P.; GODOY, R. **Consorciação com guandu na recuperação de pastagens degradadas, uma tecnologia de duplo propósito**: adubação verde e pastejo consorciado diferido – Circular Técnica 75; Embrapa Pecuária Sudeste, São Carlos, Brazil, ISSN 1981-2086, 2017.

Emission of nitrous oxide from soils in different pasture-based beef cattle production systems - partial results

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Abstract - Pastures occupy extensive areas in Brazil, being used mostly for beef cattle production. The adoption of intensive pasture management has shown the potential high productivity of tropical grasses when nitrogen fertilizer is used. In this context, to know the environmental impact from nitrogen fertilization is very important. Here is presented part of results from Diavolemenos, 2020. The aim of this study was to evaluate the emission of nitrous oxide from pastures submitted to different application rates of N-fertilizer. N_2O emissions were monitored, in the months of December 2019 and February 2020, in grazing areas of five systems for beef cattle production, with two replicates, in a dystrophic Red Latosol (Oxisol): 1) intensively managed and irrigated *Megathyrsus maximus* cv. Mombaça pasture, overseeded in the dry season with oats and annual ryegrass and fertilized with 600 kg N ha^{-1} $year^{-1}$ (IP600); 2) intensively managed rainfed *M. maximus* cv. Mombaça pasture fertilized with 400 kg N ha^{-1} $year^{-1}$(RP400); 3) intensively managed rainfed pasture with a mix of *Urochloa decumbens* cv. Basilisk and *U. brizantha* cv. Marandu fertilized with 200 kg N ha^{-1} $year^{-1}$ (RP200); 4) intensively managed silvopastoral system with rainfed *U. decumbens* cv. Basilisk pasture and Brazilian native trees fertilized with 200 kg N ha^{-1} $year^{-1}$ (SP200); 5) rainfed degraded pasture with a mix of *U.brizantha* cv. Marandu and *U. decumbens* cv. Basilisk and no liming or fertilization (DP). Emissions from the soil of the Native Forest (Altantic Forest) were also evaluated. The results indicated very low N_2O emissions and emission factors calculated as a function of N input via fertilizer.

Key words: emission factor, grasslands, nitrous oxide

Introduction

The Brazilian production of beef cattle is based on tropical pastures. The direct recovery of degraded pastures and the adoption of pasture intensive management have shown potential for the mitigation of greenhouse gases (GHG) due to the high productivity of tropical grasses, when nitrogen fertilizer is efficiently used, and the accumulation of soil organic matter.

The aim of this study was to evaluate the impact of pasture management on soil N_2O emissions.

Methods

The experiment was conducted at the experimental station of the Brazilian Agricultural Research Corporation (Embrapa), in São Carlos, state of São Paulo, Southeast of Brazil. Five pasture based livestock systems and the native forest (Altantic Forest) were evaluated: 1) intensively managed and irrigated *Megathyrsus maximus* cv. Mombaça pasture, overseeded in the dry season with oats and annual ryegrass, and fertilized with 600 kg N ha^{-1} $year^{-1}$ (IP600); 2) intensively managed rainfed *M. maximus* cv. Mombaça pasture fertilized with 400 kg N ha^{-1} $year^{-1}$(RP400); 3) intensively managed rainfed pasture with a mix of *Urochloa decumbens* cv. Basilisk and *U. brizantha* cv. Marandu fertilized with 200 kg N ha^{-1} $year^{-1}$ (RP200); 4) intensively managed silvopastoral system with rainfed *U. decumbens* cv. Basilisk pasture and Brazilian native trees fertilized with 200 kg N ha^{-1} $year^{-1}$ (SP200); 5) rainfed degraded pasture with a mix of *U.brizantha* cv. Marandu and *U. decumbens* cv. Basilisk and no liming or fertilization (DP).The native forest was the positive control and the degraded pasture the negative control. The intensive system was managed under rotational stocking and the degraded pasture under continuous stocking. All pastures (except DP) were limed and fertilized with superphosphate and potassium chloride to achieve 20 mg/dm^3 of P and 4 % K in CTC - soil cation exchange capacity, according to Oliveira et al. (2008). Lime was applied once a year. Annual top-dressing N-fertilizer was applied at the rate of 600 kg N/ha in IP600, 400 kg N/ha in RP400, and 200 kg N/ha in RP200 and SP200. Doses were divided into five applications during the rainy season in RP400, RP200 and SP200 and into ten applications in IP600 (five during the rainy - 80 kg N/ha each - and five during the dry season - 40 kg N/ha each). The degraded pasture was not fertilized or limed. The native forest (Atlantic Forest), near the experimental area, was sampled as reference, representing the original atmosphere conditions of the site. There were two replications of each livestock systems in the experimental area. Three static chambers were allocated randomly in each area of the livestock systems after grazing and fertilization. The experimental design was randomized chamber (n=3) into each area, repetitions (n=2). Gases samples were collected for 20 days. The N_2O concentration was determined by gas chromatography. Climate conditions and soil characteristics were evaluated. The emission factor was calculated by the Equation 1, considering emission expressed in mg N-N_2O/cycle:

Equation 1:
Emission factor (%) = ((treatment emission – DP emission)/N fertilizer use) * 100

Results and Discussion

The amplitude of nitrous oxide emissions ranged between 178,1415 and 30.003,5536 mg N_2O/cycle. The IP600 intensive system presented the highest emission, however, it represented only 0,0233% and 0,0149% of 80 kg N/ha applied at each cycle grazing in summer and spring, respectively; DP presented the lowest emission (Table 1, Figure 1). In the intensive system there were two peaks of nitrous oxide emission, after each fertilization (Figure 1, Table 1).

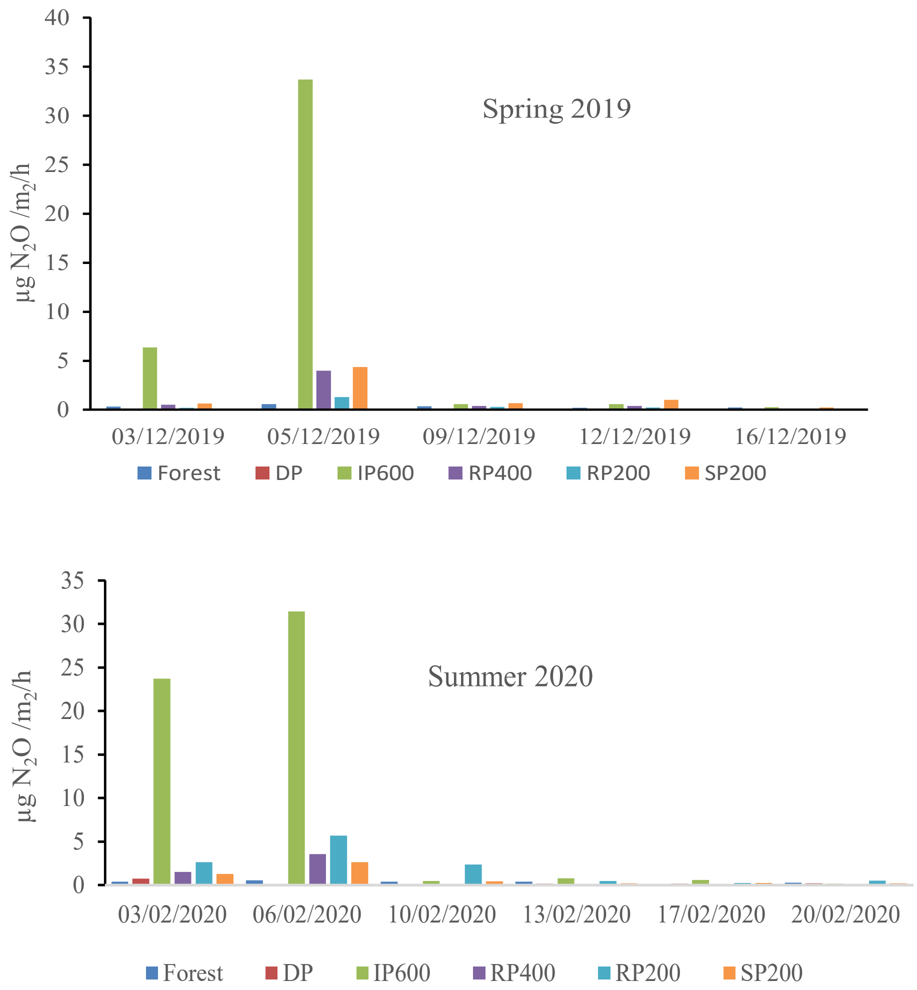

Figure 1. Nitrous oxide emissions from soils in different pasture-based beef cattle production systems.

Table 1. Accumulated nitrous oxide emissions and emission factor from soils in different pasture-based beef cattle production systems.

Treatment	Summer 2020			Spring 2019		
	mg N_2O/cycle	mg N-N_2O/cycle	Emission factor (%)	mg N_2O/cycle	mg N-N_2O/cycle	Emission factor (%)
Forest	1466,6006	933,2912b	*	1081,4524	688,1970b	*
DP	768,6448	489,1376b	*	178,1415	113,3628b	*
IP600	30003,5536	19093,1694a	0,0233a	18916,1557	12037,5529a	0,0149a
RP400	3120,6836	1985,8895b	0,0019b	2730,7666	1737,7604b	0,0020b
RP200	7933,4419	5048,5537ab	0,0114ab	1163,3495	740,3133b	0,0016b
SP200	3113,2476	1981,1575b	0,0037b	3872,8573	2464,5454b	0,0059b
Average	-	4921.86	0.0101	-	2963,62	0.0061
SEM	-	3376,67	0.0053	-	1591.44	0.0035

[3]SEM: Standard error of mean. [abc] Means followed by different lowercase letters in the columns differ significantly by the protected LSD test at 5% of significance level.

Conclusions

The results indicated very low N_2O emissions and emission factors, calculated as a function of N input via fertilizer, in the evaluated soils.

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References

Oliveira PPA, Penati MA and Corsi M 2008. **Soil correction and pasture fertilization in intensive milk production systems**. Retrieved on 31 January 2020, from http://ainfo.cnptia.embrapa.br/digital/bitstream/item/37957/1/Documentos86.pdf

Diavolemenos CMC, 2020. **Fluxos de N_2O e CH_4 do solo sob sistemas de produção de bovinos de corte mantidos a pasto**. Trabalho de conclusão de curso.ESALQ/USP. 59 p.

Emission of greenhouse gases from soils under pastures submitted to diferent grazing managements and nitrogen fertilization rates, and intercropping with macrotyloma

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Abstract - Pastures occupy extensive areas in Brazil and represent the main land use in the country. The recovery of pastures and intensification of management are part of a public policy for higher productivity and environmental efficiency in the agricultural sector. The objective of this research was to evaluate emissions of nitrous oxide and methane from pastures submitted to different strategies for production intensification. To achieve this objective, N_2O and CH_4 emissions were monitored in two pastures of *Urochloa brizantha*, between the months of September 2019 and March 2020. Treatments involved the application of nitrogen fertilizer, the use of intercropping with *Macrotyloma axillare* and two grazing systems (deferred and rotational) combined with animal protein supplementation (urea and ammonium nitrate). The results indicated very low N_2O emissions. The emission factors calculated as a function of N input via fertilizer varied between 0.06 and 0.54. Soils under pasture acted as consumers of CH_4.

Key words: emission factor, nitrous oxide, Macrotyloma axillare, *Urochloa brizantha*

Introduction

Land is mostly used in Brazil as pastures; therefore, management practices for the sustainable intensification of pasture and livestock productivity have important effects on the economy and the achievement of clean development goals. It should also be considered that in Brazil the agricultural and livestock sectors and land use change are responsible for around 70% of greenhouse gas emissions, which makes it important to assess the impacts of management practices and production systems on the emission of greenhouse gases.
Based on this context, the objective of this research was to evaluate the emission of nitrous oxide and methane from pastures submitted to strategies for production intensification.

Methods

Two experiments were carried out involving *Urochloa brizantha* pastures: one of them in an area belonging to the Instituto de Zootecnia (IZ), in Nova Odessa, SP, and another at USP in Pirassununga, SP. The climate of both locations is classified as humid subtropical. The soil in the IZ area was classified as Ultisols of medium texture, and the soil at USP was classified as Oxisol of clayey texture.
In Nova Odessa, there were three treatments involving fertilization and intercropping: (i) *Urochcloa* pasture fertilized with 60 kg ha^{-1} of N; (ii) *Urochloa* pasture fertilized with 60 kg ha^{-1} of N and protein supplementation; and (iii) *Urochloa* pasture intercropped with macrotyloma (*Macrotyloma axillare*).
At USP, the treatments involved grazing systems (rotational or deferred), combined with two forms of protein supplementation to the animals (with urea or ammonium nitrate). All pastures received 100 kg ha^{-1} per year of N.
Nitrous oxide (N_2O) and methane (CH_4) emissions were monitored for about six months, from Sptember 2019 to March 2020, with two assessments per week. Static chambers were used (Varner et al., 2003) and the gas samples were analyzed by gas chromatography, using the Shimadzu GC-2014 equipment (Shimadzu Co., Columbia, MD, USA).

The results were treated in terms of daily flows and accumulation of N_2O in the period, in addition to the estimation of N_2O emission factors (N_2O-EF, %), which is the emission of nitrous oxide in relation to the total N applied.
Comparison between treatments was based on mean values and a 95% confidence interval.

Results and Discussion

In Nova Odessa the average daily fluxes of nitrous oxide (N_2O) during the experimental period were the following: 178.15 ug N m^{-2} day^{-1} in exclusive pasture; 117.14 ug N m^{-2} day^{-1} on pasture with protein supplementation; and 47.20 ug N m^{-2} day^{-1} in pasture intercropped with macrotyloma.
In Pirassununga, the highest N_2O fluxes were in the rotational grazing system (200 to 600 ug N m^{-2} day^{-1}), regardless of the type of protein supplementation. The daily flows in the deferred treatments were below 100 ug N m^{-2} day^{-1}.
Cumulative N-N_2O results weighted by N input via fertilization were used to derive N_2O emission factors (Table 1).

Table 1. Nitrogen emitted as nitrous oxide (N_2O) and N_2O emission factors (N_2O-EF) from pasture soils.

Identification	N_2O-N emitted	N applied (fertilizer)	N_2O-EF
	kg ha^{-1}	kg ha^{-1}	%
Brizantha grass ††	0.14 (0.04) †	60	0.17
Brizantha grass + protein supplementation ††	0.11 (0.04)	60	0.12
Brizantha grass + macrotyloma ††	0.07	-	
Rotated + ammonium nitrate †††	0.60 (0.06)	100	0.54
Rotated + urea†††	0.20 (0.02)	100	0.18
Deferred + ammonium nitrate †††	0.12 (0.01)	100	0.11
Deferred + urea †††	0.07 (0.01)	100	0.06

† Values in parentheses refer to the accumulated emission of N_2O-N in the soil without fertilization, which was deducted from the accumulated value emitted in the treatment with fertilization in the calculation of the respective emission factor. †† Experimental area in Nova Odessa, SP. ††† Experimental area in Pirassununga, SP.

The N_2O emission factors obtained were much lower than the 1% default value recommended by the IPCC (IPCC, 2007) and also lower than the 1.12% value found in a literature review carried out by Mazzetto et al. (2020) for nitrogen sources in Brazil. The observed N_2O emissions can be explained by the low levels of nitrate and ammonium in the soil (data not shown), in addition to lower levels of soil moisture.
In general, there was consumption of methane in most of the evaluation dates, resulting in the removal of something around 0.04 to 0.14 kg CH_4 ha^{-1} in the period. Higher rates of CH_4 consumption were observed in treatments that received nitrogen fertilization, which also suggests a relationship, even if indirect, between lower N_2O flows and better forage development.

Conclusions

N_2O emission factors for the nitrogen applied as fertilizer in pastures subjected to intensification strategies are much lower than the default value recommended by the IPCC.
Soils under grazing consume atmospheric methane.

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References

IPCC (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE), 2006. N_2O emissions from managed soils, and CO_2 emissions from lime and urea application. Chapter 11. In: IPCC guidelines for national greenhouse gas inventories. v.4: Agriculture, forestry and other land use. **Institute for Global Environment Strategies**, Hayama, Japan.

MAZZETTO, M.; STYLES, D.; GIBBONS, J.; ARNDT, C.; MISSELBROOK, T.; CHADWICK, D. Region-specific emission factors for Brazil increase the estimate of nitrous oxide emissions from nitrogen fertiliser application by 21%. **Atmospheric Environment**, v.230, n.1, jun. 2020. 8p.

VARNER R.K.; KELLER M.; ROBERTSON J.R.; DIAS, J.D.; SILVA, H.; CRILL, P.M.; MCGRODDY, M.; SILVER, W. Experimentally induced root mortality increased nitrous oxide emission from tropical soil. **Geophysical Research Letters**, v.29, n.3, feb.2003. 7p.

Carbon in pasture soil: stock change factor for the land-use and carbon sequestration rate due to the adoption of better management

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Abstract - In Brazil, agriculture contributes to the emission of greenhouse gases, but has great power to sequester carbon (C) in the soil. The objective of this research was to quantify the C stock in the soil due to land use change (LUC) from forest (Atlantic Forest biome) to *Urochloa brizantha* pasture, obtaining LUC factors; as well as determining C sequestration rates resultant of the adoption of better pasture management practices. The soil C stocks with the change of land use from forest to pasture was investigated in two locations, one with Dystrophic Red Oxisol and Dystrophic Red Argisol, and the other with Dark Red Oxisol, in the cities of Nova Odessa and Pirassununga, both in the State of São Paulo. Soil C stocks were obtained from soil sampling in pits with an auger, in different layers, down to 100 cm deep. The LUC factor was calculated from the ratio between the C stock in the forest soil and the C stock in the soil under pasture, for each location and soil type. The intensification of pasture management was studied in Pirassununga, resultant ofnitrogen fertilization and deferred or rotated grazing, while in Nova Odessa nitrogen fertilization and intercropping between *U. brizantha* and *Macrotyloma axillare* were tested. Soil sampling to obtain initial C stocks and after two years of implementing the new management was carried out in a similar way to that mentioned for LUC, but only considering the soil downto 30 cm deep. The factors for LUC varied between 0.76 and 0.98, demonstrating that inadequate management can affect the C stock in the soil in relation to the forest (standard IPCC value of 1), but that these factors increased when an appropriate management was applied, varying between 1.04 and 1.18, when compared to the IPCC factor standard value of 1.17. Furthermore, management practices resulted in C sequestration rates ranging between 1.2 and 4.4 t C ha^{-1} $year^{-1}$, relatively high values that demonstrate the high potential of soils under pasture for C sequestration.

Key words: Atlantic Forest, fertilization, global climate change, grass-legume intercropping soil, organic matter

Introduction

Pastures occupy around 160 million hectares in Brazil and are the main land use in the country. Understanding the change in carbon (C) stock in the soil due to the land use change (LUC) from native vegetation to pasture is important in understanding the impact of the livestock sector on the emission/removal of greenhouse gases. No less important is determining the impact of adopting good pasture management practices and grazing systems on the sequestration and stabilization of C in the soil Data will support sectoral, regional, and national C accounting, allowing the evaluation of greenhouse gases reduction targets, improving market competitiveness. In this context, the objective of the research is to quantify the variation in soil carbon stock due to LUC from forest to pasture and determine C sequestration rates in the soil resultant of the adoption of better pasture management practices.

Methods

The research was carried out in areas of the Institute of Animal Science (IZ), in the city of Nova Odessa, SP, and the University of São Paulo (USP), in the city of Pirassununga, SP. The forest areas evaluated are from the Atlantic Forest biome and the pastures are formed with *Urochloa brizantha* cv. Marandú.
The effect of LUC from forest to pasture on C stock in the soils was evaluated in three areas: (i) soil classified as a typical Dystrophic Red Oxisol, in Nova Odessa (RO-NO); (ii) soil classified as Dystrophic Red Argisol, in Nova Odessa (RU-NO); and (iii) soil classified as a typical Eutrophic Dark Red Oxisol, in Pirassununga (RO-Piras).

The quantification of C stock in the soils under forest and pasture was carried out in samples from four trenches per area. Undisturbed samples, for density evaluation, and auger samples (deformed soil samples) were collected to evaluate the C content in the soil. The layers (depth) sampled were: 0-5, 5-10, 10–20, 20–30, 30–40, 40–60, 60–80 and 80–100 cm. Soil density was determined using the gravimetric method after drying at 105°C for 48 hours. The deformed soil samples were dried at 38°C, sieved through a 2 mm mesh and sub-samples of 5 to 8 g were ground and passed through a 0.150 mm sieve to quantify the total C content using dry combustion in a CN elemental analyzer.

Carbon stocks were calculated using soil density and C content. Carbon stocks in pasture soils were corrected using the equivalent mass method, according to Wendt & Hauser (2013), using the soil under forest as a reference.

Statistical comparisons were carried out using mean values and confidence intervals at 95% probability. LUC factors, considering each location and soil type, were obtained by the ratio between the soil C stock in the forest and the soil C stock in the pasture, based on the IPCC Guidelines (2006).

The adoption of better management practices and grazing systems were evaluated in Nova Odessa (MS-NO) and Pirassununga (MS-Piras).

In Pirassununga, *U. brizantha* pastures were fertilized with nitrogen, under four grazing systems: deferred pasture; deferred pasture + protein supplement for the animals; rotational grazing and rotational grazing + protein supplement.

In Nova Odessa, the treatments were: *U. brizantha* pasture fertilized with mineral N; *U. brizantha* pasture fertilized with mineral N and protein supplement; and the consortium of *U. brizantha* and the legume *Macrotyloma axillare*.

Soil C stocks, in layers 0-5, 5-10, 10-20, 20-30 and 30-40 cm, were quantified initially (baseline) and after two years of adopting the managements, using the same procedures used in the LUC assessments. Sample preparation and analysis also followed what was already described, however, for correction by equivalent mass, the baseline soils were used as a reference.

The initial and final stocks for each grazing system and/or management practices were compared using a 95% probability t-test and, in the case of significance, the respective C sequestration rates were calculated.

Results and Discussion

Considering LUC in RO-NO, there was no difference between forest and pasture (Table 1) in any of the soil layers. The RU-NO and RO-Piras differed in the 0-30 cm layers, where the forest surpassed the pasture in both places. In the 0-100 cm layer, the forest differed from the pasture in RU-NO and RO-Piras, what can be explained by the short time since the change in land use, insufficient for forage inputs to overcome the impact of C loss caused by the removal of trees and often by the use of fire and/or some level of mechanical tillage of the soil. The factor for LUC was 0.87, 0.76, and 0.98 in RU-NO, RO-Piras and RO-NO, respectively, when compared to the IPCC default value of 1 (IPCC, 2006). These factors are a reflection of pastures that do not have an adequate management system, resulting in less vegetation, fewer species diversity, and greater soil disturbance, damaging the carbon stock in the soil compared to a forest, where there is greater dynamic balance.

The accumulated C values in the 0-100 cm layer differ from the sum of the 0-30 cm and 30-100 cm C layers due to differences in the composition and distribution of organic carbon in the soil at different depths, such as decomposition, input of organic material, climatic factors, erosion and transport, type of vegetation and land use, and geological processes, among others.

Table 1. Results of accumulated C stocks in layers 0–30, 30-100, and 0-100 cm in RO-NO, RU-NO, and RO-Piras and Factors of Land Use Change (F-LUC) in layer 0–30 cm.

Place	Pasture	Forest	Pasture	Forest	Pasture	Forest	F-LUC
	0-30 cm		30-100 cm		0-100 cm		
RO-NO	67,4±71,8	69,0±76,3	115,6±156	67,1±133,1	183±226,7	136,1±207,6	0,98
RU-NO	55,2±59,2	63,8±71,5	52,5±57,8	74,8±82,3	104±112	138,6±149,9	0,87
RO-Piras	62,6 ±64,5	82,3±88,9	77,4±82,5	93,2±103,5	135,8±143,7	175,5±191,2	0,76

Considering management systems, MS-NO resulted in the sequestration of 4 t C ha^{-1} year^{-1} in the grass treatment, standing out in relation to the grass and legumes and grass and protein treatments which had sequestration rates of 3.2 and 2.4 t C ha^{-1} year^{-1}, respectively. The superiority of the grass treatment can be explained by the presence of the animals and the lowering of the pasture, allowing a renewal of the root systems in the area, increasing the biomass, and contributing to the sequestration of carbon, what was potentiated by an adequate management of the pastures. In MS-Piras, the rotational and deferred pastures treatments had a C sequestration rate of 3.3 and 3.6 t C ha^{-1} year^{-1}, respectively. Rotational grazing and supplemented pastures treatments had a C sequestration rate of 4.4 t C ha^{-1} year^{-1}, which can be explained by the bovine contribution to the soil-plant system, in constant renewal, associated with protein supplementation and bovine excreta contributing to increase the organic matter content in the soil.

Table 2. Carbon sequestration rate and factors for each treatment in MS-NO and MS-Piras Management Systems in the 0-30 cm layer.

Place	Treatment	C Rate (t ha^{-1}year^{-1})	Management system factors
MS-NO	Grasses	+4	1,18
MS-NO	Grasses and Legumes	+3,2	1,08
MS-NO	Grasses and Protein	+2,4	1,10
MS-Piras	Deferred	+3,6	1,13
MS-Piras	Deferred and Supplement	+1,2	1,04
MS-Piras	Rotated	+3,3	1,10
MS-Piras	Rotated and Supplement	+4,4	1,14

The factors for MS resulted in values that varied between 1.04 and 1.18, being below the default value of 1.17 estimated by the IPCC (IPCC, 2006). This shows the importance of sustainable management in pastures, associated with forage quality, cattle feed, soil conservation, and nutrient cycling, in the mitigation of climate change.

Conclusions and/or Implications

The land use change from forest to pasture resulted in carbon emissions into the atmosphere, which can be recovered with an adequate management system, combined with the application of fertilizers, consortium with legumes and an adequate grazing system, which resulted in high rates of carbon sequestration per year, ranging from 1.2 to 4.4 t C ha^{-1} yr^{-1}.

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References

IPCC, I. P. C. C. 2006. **Guidelines for national greenhouse gas inventories**. Prepared by the National Greenhouse Gas Inventories Programme. Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. Published: IGES, Japan.

WENDT, J. W., & HAUSER, S. (2013). An equivalent soil mass procedure for monitoring soil organic carbon in multiple soil layers. **European Journal of Soil Science**, 64(1), 58-65.

Soil characterization in long-term experiments with pastures and integrated production systems: Spectroscopic, physical-chemical and enzymatic analyses

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Abstract - Recently it has been demonstrated that no-till grain production systems in the tropical region can sequester more soil C than in temperate areas mainly due to a higher annual biomass production and, consequently, more plant residues incorporation in the soil. This is an important achievement and well managed pastureland, and integrated crop-livestock-forest systems (ICLFS) also can contribute to soil carbon sequestration. In the current work, soil characterization was carried out in intensively managed pastures and integrated production systems of a long-term experiment conducted at Embrapa Pecuária Sudeste, in São Carlos, São Paulo State, Brazil. The main soil parameters analyzed were: carbon content; bulk density; microbial biomass; basal respiration; activities of soil enzymes beta glucosidase and arylsulfatase; characterization of humic substances, including humification degree; and advanced structural analysis. Main results indicated that: the enzymatic measurements were able to identify differences due to management in pasture systems, including irrigation, and different animal stocking rates. Soil organic matter (SOM) structural aspects, detected by advanced spectroscopic and chromatographic methods, indicated faster transformation of organic residues and incorporation of more microbiologically active SOM in ICLFS than in native forest areas.

Key words: arylsulfatase, beta glucosidase, gas chromatography, mass spectrometry, soil organic matter, 2D Nuclear Magnetic Resonance

Introduction

Recently it has been demonstrated that no-till grain production in tropical regions can sequester more soil C than in temperate areas mainly due to a higher biomass production and, consequently, more plant residues incorporation in the soil. This can be observed also in well managed pasturelands and ICLFS. Therefore, it is important to understand the mechanisms of soil organic matter transformation in tropical regions to help to consolidate results within an imminent global soil C market. Several spectroscopic techniques, as laser-induced fluorescence, Nuclear Magnetic Resonance, Electron Paramagnetic Resonance, gas chromatography and mass spectrometry have been applied in the chemical characterization of soil organic matter in different agricultural production systems (Martin-Neto et al., 2023). Also, there is a growing interest in soil biological analysis, combining microbial biomass and enzymatic measurements. In this current work, these different tools and methodologies were applied to evaluate different well managed pasturelands and ICLFS of a long-term field experiment in the tropical region.

Methods

Areas of ICLFS, with eucalyptus trees, and different production systems, including extensively and intensively managed pastures; integrated crop-livestock system (ICLS); and integrated livestock-forest system (ILFS), were evaluated after 5 years since implementation. Also, a long-term field experiment with different pastures, including degraded pasture (DP); irrigated pasture with high stocking rate (HIS); rainfed pasture with high stocking rate (RHS); rainfed pasture with moderate stocking rate (RMS) and a silvopastoral system with moderate stocking rate (SPS, with native trees from the Cerrado region), were monitored. In both sets of experimental areas, native forest (FO) areas, typical of Atlantic Forest in a transition region to Savannah biome, were also evaluated. Several spectroscopic techniques, as laser-induced fluorescence; 2D- Nuclear Magnetic Resonance; Electron Paramagnetic Resonance; gas chromatography; and mass spectrometry were applied in the chemical characterization of the soil organic matter.. Also soil biological analysis, as microbial biomass and enzymatic measurements of beta glucosidase and arylsulfatase, were performed.

Results and Discussion

Soil samples from ICLFS and FO areas for humic acids determination were analyzed with 2D 1H-13C HSQC NMR coupled with lignin phenol; fatty acid measurements were done using tetramethylammonium hydroxide (TMAH) thermochemolysis – two-dimensional gas chromatography – mass spectrometry (TMAH-GC × GC-MS). Results indicated that there are significant oxidative processes with increasing soil depth, which are more pronounced in the ICLFS relative to the FO area. Degradation of stearic acid with increasing depth in the ICLFS soils indicated that ICLFS soils are more microbiologically active than the soil in FO. Previous results using whole soil samples with laser-induced fluorescence spectroscopy analysis also had demonstrated higher humification degree in ICLFcompared with FO areas. This is a very interesting result demonstrating the ability of ICLF to contribute to diversification of agricultural production areas as well as having biologically and chemically improved soil (Tadini et al., 2022).
Regarding the pastureland long-term field experiments, it was observed that, relatively to the FO area there was a decrease in the humification degree of SOM, indicating incorporation of less transformed organic residues to the soil down to 1 m depth. Using enzymatic analysis was possible to demonstrate that the area of rainfed pasture with moderate stocking rate (RMS) had higher values of beta glucosidase (reaching 160 µg p-nitrophenol g^{-1} soil h^{-1}) and arylsulfatase (reaching 525 µg p-nitrophenol g^{-1} soil h^{-1}) than all other types of pasture (Santos et al., 2022). This result was probably due to higher biomass input to the soil, what indicated a situation of soil carbon sequestration, as it was demonstrated in the past and in more recent evaluations still to be published. Additional analysis and studies are in progress using different analytical tools, including spectroscopies, chromatography, and mass spectrometry

Conclusions

The use of different analytical tools for soil chemical and biological analysis permitted deep evaluation of SOM structural changes and soil enzymatic content in different pastures and ICLFS areas. The enhanced bio-reactivity of ICLFS, as detected by the combined use of 2D NMR spectroscopy and TMAH-GC × GC-MS, is likely driving the enhanced carbon sequestration in the ICLFS soils. This is perhaps due to the diversity of biomass remnants available at the ICLFS soil rhizosphere which allows for more different types of biomasses to be sequestered as oxidized ligninaceous phenols. For well managed pastureland the soil enzymatic analysis, with measurements of beta glucosidase and arylsulfatase, indicated that the area of rainfed pasture with moderate stocking rate (RMS) had the highest values comparatively to other areas, including the pasture with irrigation. This result is consistent with other data on soil carbon stock and can indicate that enzymatic activities area sensitive to land use and management and could be used as soil quality indicators in pasture-based beef cattle production, for different systems with tropical soils.

Acknowledgements

This study was supported by FAPESP (grant 17/20084-5), Sisfoton/CNPq (grant 440226/2021-0) and L.R.B. acknowledges the scholarship from FAPESP (grant 19/18267-0/ 22/07259-9).

References

MARTIN-NETO, L.; TADINI, A.M.; BENTO, L.R.; SANTOS, J. V.; MILORI, D.M.B.P. **Estrutura e natureza química da matéria orgânica do solo, in “Entendendo a matéria orgânica do solo em ambientes tropical e subtropical**”, Wagner Bettiol ... [et al.], editores técnicos. – Brasília, DF : Embrapa, 2023. PDF (788 p.) : il. color. Cap. 5, páginas 145-184. ISBN 978-65-89957-66-9.

SANTOS, J.V.; BENTO, L.R.; BRESOLIN, J.D.; MITSUYUKI, M.C.; OLIVEIRA, P.P.A.; PEZZOPANE, A.C.C.B.; MENDES, I. C.; MARTIN-NETO, L. The long-term effects of intensive grazing and silvopastoral systems on soil physicochemical properties, enzymatic activity, and microbial biomass. **Catena**, 219, 106619, 2022.

TADINI, A.M.; GORANOV, A.I.; MARTIN-NETO, L.; BERNARDI, A.C.C.; OLIVEIRA, P.P.A.; PEZZOPANE, J.R.; HATCHER, P.G. Structural characterization using 2D NMR spectroscopy and TMAH-GC × GC-MS: Application to humic acids from soils of an integrated agricultural system and an Atlantic native forest. **Science of Total Environment**, 815,152605, 2022.

Intensified pasture systems as a strategy to increase soil carbon stocks

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Abstract - Soil represents an opportunity for carbon sequestration, especially in Brazilian pastures which are under degradation due to the lack of adequate management. Pasture intensification uses tools such as fertilization, liming, and irrigation as a strategy to increase forage production, which can increase soil C stocks by introducing more organic matter into the soil. To assess the effects of pasture intensification in soil C stocks, soils in a long-term experiment were evaluated. In this experiment degraded pastures (DP) were converted into different intensified systems: (i) IHS: irrigated with high stocking rate, (ii)RHS: rainfed pasture with high stocking rate, and (iii) rainfed pasture with moderate stocking rate (RMS). The soil was sampled down to 1m depth to evaluate the C stocks. The origin of soil organic matter (SOM) was evaluated by the natural abundance of ^{13}C and its composition was accessed by HLIFS index obtained by laser-induced fluorescence spectroscopy and H/C atomic ratio. To understand the mechanisms of C sequestration in the areas, a physical fractionation by density and granulometric size, was performed. The less intensively managed RMS showed C stocks higher than the other systems (IHS and RHS) but showed a higher content of SOM preserved from the native vegetation. While in IHS, which contains more sand, the intensified management replaced almost all the SOM from the native vegetation, but not enough to increase the C stocks in relation to the previous established system (DP). RMS and RHS were the systems that had C stocks equal to the native vegetation and the SOM composition was mainly aliphatic, as suggested by lower HLIFS index and higher H/C atomic ratio. The C stocked in the pastures is mainly associated to minerals. The results suggest that intensified pastures can introduce C into the soil, which is microbially processed into aliphatic C and attached to mineral surfaces. Then, the adoption of systems such as RHS and RMS in degraded pasture areas can increase C stocks in the soil.

Key words: natural isotopic abundance of ^{13}C, soil carbon sequestration, soil physical fractionation

Introduction

The conversion of native forest areas to pasture generally causes a decrease in soil C content. Brazilian pastures offer a unique opportunity to increase soil C stocks because in many areas they are under degradation (Oliveira et. al 2023); degradation is caused mainly by the lack of adequate management, what results in low forage production and small amounts of organic matter been added into the soil. In addition, Brazilian soils are mainly Ferrasols rich in iron and aluminum oxides, what can result in more organo-mineral associations. To understand how the adoption of intensification in degraded pasture areas can increase the C stocks in these Ferralsols, soils in a long-term field experiment, carried out at a transition zone between Cerrado and Atlantic Forest, were evaluated. Furthermore, to provide information on C sequestration mechanisms, this study compared C stocks, C distribution in soil physical fractions, and the quality of soil organic matter (SOM).

Methods

An area of degraded pasture (DP) located in São Carlos, state of São Paulo, Brazil, was converted into different intensified systems: (i) IHS: irrigated pasture with high animal stocking rate, (ii) RHS: rainfed pasture with high stocking rate, (iii) RMS: rainfed pasture with moderate stocking rate. As a control, the adjacent native forest (FO) was also evaluated as a positive reference. The adoption of intensified systems started in 1996 for RMS and in 2002 for IHS and RHS areas. Except for DP, all areas were limed and fertilized. Soil sampling was carried out in 2020 and C stocks were evaluated down to 1 m deep. The C stocks (Mg ha^{-1}) were calculated by multiplying soil C content (%), bulk density (Mg m^{-3}), and soil thickness (cm). Then, the stocks were corrected by the equivalent soil mass, considering the native vegetation as a reference, according to the method proposed by Ellert and Bettany (1995). Soil organic matter quality was assessed by laser-induced fluorescence spectroscopy of which HLIFS index was obtained by the emission area normalized by the C content (Tadini et. al 2021) and H/C atomic ratio. To characterize the change of the vegetation from C3 to C4, the natural isotopic abundance of ^{13}C was measured. To evaluate the SOM distribution, a physical fractionation by granulometric size and density was performed with sodium polytungstate solution (1.8 g cm^{-3}).

Results and Discussion

The results indicated that the conversion of FO into pasture without adequate management reduced the C stocks in 50 Mg ton ha^{-1}. On the other hand, the adoption of better management in DP using the RMS and RHS systems increased C stocks, reaching levels equal to those in FO (150 Mg ton ha^{-1}). RMS had the highest C stocks with the lowest N-fertilizer dosage and moderate stocking rate. The IHS system did not increase C stocks in relation to DP. About 50% of the C stored in the RHS and RMS systems are derived from the pastures. These areas contain a higher percentage of clay and, together with management; it seems to have preserved more SOM from the native vegetation (C3). In the IHS and DP systems, which contain more sand, the SOM composition is mainly derived from pastures (C4 plants). The SOM accumulated in the RMS and RHS systems differed from the other systems by a more aliphatic composition, evidenced by lower HLIFS values and higher H/C atomic ratio. Preliminary physical fractionation data indicated that both DP and RMS pastures have less free particulate organic matter (fPOM) in relation to FO, in the topsoil. The increase in C stock in relation to DP and the low amount of fPOM suggests that there is a higher turnover of this fraction in pasture areas. Most of SOM is associated with clay, showing that in the pastures fPOM is highly processed into aliphatic C and attached to minerals.

Conclusions

With pasture intensification it was possible to recover the productivity o DP areas and increase soil C stocks, by increasing the input of C derived from pasture (C4) and maintaining the C from the native vegetation (C3).

Acknowledgements

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References

ELLERT, B.H., BETTANY, J.R. Calculation of organic matter and nutrients stored in soils under contrasting management regimes. **Canadian Journal of Soil Science**, v. 75, n.4, p. 529–538, November 1995.

OLIVEIRA, D.M. DA S.; TAVARES, R.L.M.; LOSS, A.; MADARI, B.E.; CERRI, C.E.P.; ALVES, B.J.R.; PEREIRA, M.G.; CHERUBIN, M.R. Climate-smart agriculture and soil C sequestration in Brazilian Cerrado: a systematic review. **Rev. Bras. Ciência do Solo**, v. 47, 1–20, March 2023.

TADINI, A.M.; XAVIER, A.A.P.; MILORI, D.M.B.P.; OLIVEIRA, P.P.A.; PEZZOPANE, J.R.; BERNARDI, A.C.C.; MARTIN-NETO, L. Evaluation of soil organic matter from integrated production systems using laser-induced fluorescence spectroscopy. **Soil Tillage Res**., v. 211, July 2021.

Economic evaluation of pasture-based production systems, including Pigeon pea intercropped with *Urochloa* spp

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Abstract - This study evaluated the economic viability of three pasture-based beef cattle production systems in order to determine which one offers the better profitability and can be effectively adopted by farmers. The following treatments were conducted from June 2020 to June 2022 at Embrapa Southeast Livestock, São Carlos, SP, Brazil: 1) degraded *Urochloa* (syn. *Brachiaria*) *decumbens* Stapf cv. Basilisk pasture (DEG); 2) recovered and fertilized (200 kg of N-urea ha^{-1} $year^{-1}$) *U. decumbens* cv. Basilisk pasture (REC), and 3) intercropped *Cajanus cajan* (L. Millsp.) cv. BRS Mandarin and *U. decumbens* cv. Basilisk pasture (MIX). Microsoft Excel™ computational software was used to organize and calculate the costs of the production activity. The analysis took place through the calculation of project analysis indicators such as “Statement of Cash Flow” (SCF), using simulation techniques to extrapolate the experimental results to commercial scale farms, representative of the reality of the Brazilian Southeast. The techniques applied were: Net Present Value (NPV) and Internal Rate of Return (IRR). Our results indicated that MIX had the highest SCF and NPV, followed by DEG, while REC had negative values. Considering the IRR, the most profitable system was MIX, followed by DEG, and lastly by REC. In general, the economic viability is directly related to the investments applied in each treatment, and the lower need for investment in MIX compared to REC explains the better results that consider the effect of time.

Key words: economic profitability, feasibility, grazing systems, sustainable intensification

Introduction

The great importance of the livestock sector in the Brazilian economy and the relevance of actual indicators related to the sustainability of pasture-based production systems point to the widespread use of more intensive management techniques. In this aspect, public and private organizational entities use part of their efforts and investments in the research and application of technological alternatives that make beef cattle production more efficient (Rodrigues et al., 2012). In this study, we evaluated the economic viability of three pasture-based beef cattle production systems, to understand which of these treatments offers better profitability and can be effectively adopted commercially by rural producers.

Methods

The experiment was carried out at Embrapa Southeast Livestock, São Carlos, SP, Brazil from June 2020 to June 2022. Treatments consisted of three pasture-based beef cattle production systems, distributed in a completely randomized design with three replicates (paddocks with 1.5 ha), totaling 9 grazing units (13.5 ha in total), as follows: 1) degraded *Urochloa* (syn. *Brachiaria*) *decumbens* Stapf cv. Basilisk pasture (DEG); 2) recovered and fertilized (200 kg of N-urea ha^{-1} $year^{-1}$) *U. decumbens* cv. Basilisk pasture (REC), and 3) intercropped *Cajanus cajan* (L. Millsp.) cv. BRS Mandarin and *U. decumbens* cv. Basilisk pasture (MIX). The economic evaluation resulted from the survey and systematization of the experimental information: resources needed for its execution, the technologies to be applied in the production to obtain the products, and the foreseen monetary income. Microsoft Excel™ computational software was used to organize and calculate all the costs of the production activity. The analysis was carried out using the estimated “Statement of Cash Flow” (SCF), obtained directly by tracking the expected cash inflows and outflows of available cash (Weil and Maher, 2005) through 25 years. The cash inflows resulted from two situations, namely: the annual gross revenues resulting from the commercialization of the rearing (2020 to 2021) and finishing (2021 to 2022) phases of Nellore steers. Gross income was obtained by multiplying the number of animals available for sale by the monetary value stipulated per category, according to the average experimental stocking rates [SR – Animal Units per hectare (AU/ha)] in each treatment. Cash outflows were projected based on initial investments resulting from the expenses on infrastructure implementation, maintenance and reforms of pastures, and herd management in its various aspects. Monthly averages of daily nominal prices were obtained throughout the analyzed period. Afterwards, the monthly nominal averages were deflated in order to update them to real values equivalent to august 2022, according to the methodology presented by Rodrigues et al. (2012). Finally, the representative farms for the analyzes were defined from a data survey in the 2017 Agricultural Census (IBGE, 2017). Among the intermediate regions of the state of São Paulo, Presidente Prudente region stood out for all parameters. The profile of each representative analysis farm is an average property, with an area of 70 ha, 1 tractor of 75 hp, 1 employee and 1 day laborer. The economic analysis techniques used were: Net Present Value (NPV) and Internal Rate of Return (IRR).

Results and Discussion

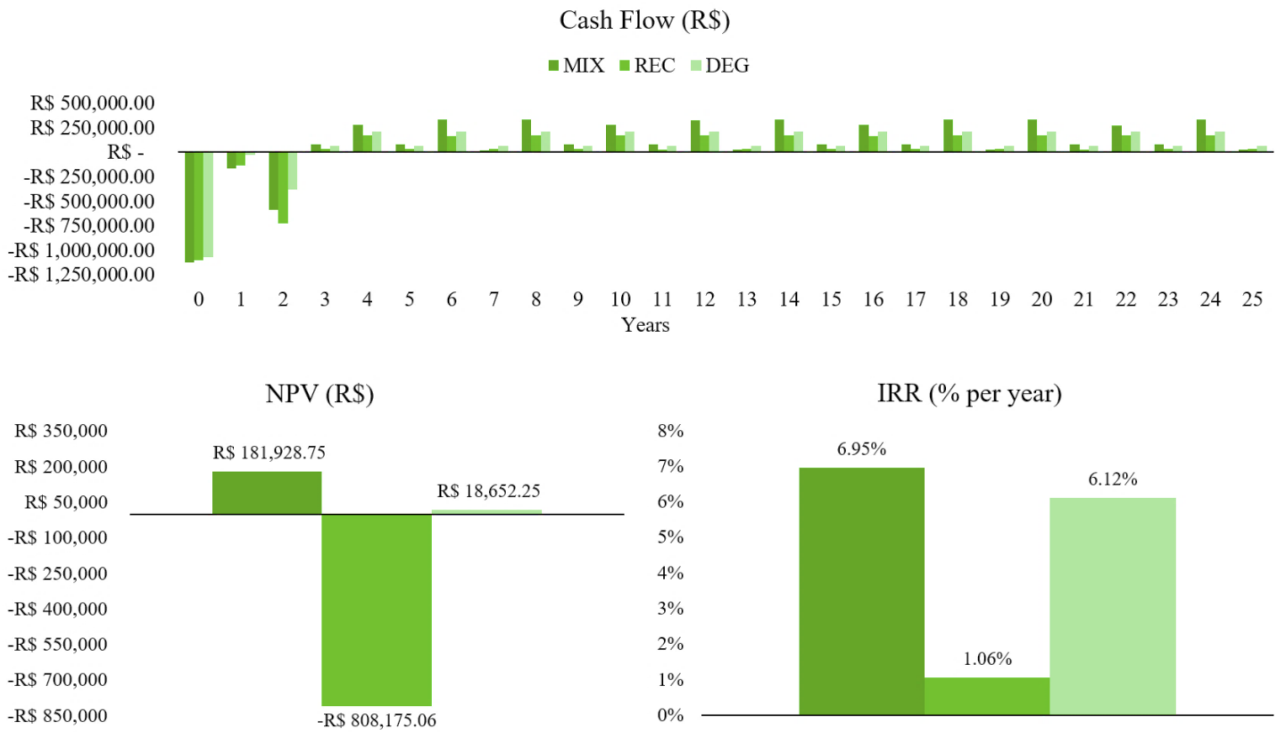

Figure 1. Economic evaluation (Cash Flow, NPV and IRR) in pasture-based beef cattle production systems.

The NPV is important to evaluate the economic viability of treatments considering the analyzed period. If the result is negative, it indicates unviability. Our results showed that MIX had the highest positive values of both SCF and NPV parameters, followed by DEG, while REC had negative NPV, indicating that the economic viability of REC is compromised by the high investments required. Considering the IRR (the rate of return that makes future Cash Flows equal to zero), the most profitable system was MIX (6.95%), followed by DEG (6.12%), and lastly by REC (1.06%). The low IRR found in REC indicates low feasibility, and all investments applied will take more than 25 years to be diluted in time.

Conclusions

In general, the economic viability is directly related to all the investments applied in each treatment, and the lower need for fertilization investment in MIX compared to REC explains the better profitability results, considering the effect of time.

Acknowledgements

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References

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTITÍSTICA. **Censo Agropecuário 2017:** Resultados Definitivos. IBGE: Rio de Janeiro, Brasil, 2017.

RODRIGUES, R., GAMEIRO, A.H., SILVA, L.F.P.E., ALVES, T.C. Viabilidade econômica de um sistema de produção de pecuária bovina sob alta lotação: uso na pesquisa e na pecuária comercial. **Revista Brasileira de Saúde e Produção Animal**, v. 13, 2012, 13 p.

WEIL, R.L.; MAHER, M.W. (ed.) Handbook of cost management (2nd ed). John Wiley & Sons, Inc., Hoboken, New Jersey, 2005, 848p.

Prospecting priority areas for technology transfer in low-carbon livestock farming in the state of São Paulo

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Abstract - There is a need to understand and assess the variability of beef cattle farming in different regions of the country and evaluate its impacts on the use of available natural resources, as well as recognizing and valuing sustainable production systems alternatives in each region. The objective of this study was to identify potential areas in the State of São Paulo for transferring technologies for production intensification with sustainable pasture management. The Presidente Prudente region stood out in most of the analyzed parameters, mainly, for having the largest total area, the largest herd with beef cattle raised on pastures and the higher number of farms, with more than 50 head of cattle, that sold cattle for breeding, rearing, and fattening. The São José do Rio Preto region presented similar parameters to those of the Presidente Prudente region for the effective number of farms with cattle and number of farms with more than 50 heads of cattle that sold cattle for slaughter. The results obtained and the identification of the potential areas demonstrated that it is possible to transfer the technologies studied in the project "Strategic practices for mitigating greenhouse gas emissions in grassland systems of the Brazilian Southeast" to both areas. The regions of Bauru, Araçatuba, and Vale do Paraíba Paulista are also potential areas for the adoption of the technologies studied in the project.

Key words: technology transfer, geospatial criteria, sustainable technologies

Introduction

Brazilian livestock farming, especially the beef cattle sector, is present in all regions of the country and has been one of the economic pillars of agribusiness (IBGE, 2017). Furthermore, the sector has ample development capacity, both in terms of exploitation of arable land and technological improvements in production processes, playing an important role in satisfying the growing demand for food, contributing to the social and financial stability of the population (Pulido et al. al., 2018; FAO, 2019).

There is a need to understand and assess the variability of beef cattle farming in different regions of the country and evaluate its impacts on the use of available natural resources, as well as recognizing and valuing sustainable production systems alternatives in each region, reducing the environmental impact and the pressure in more sensitive areas (Dick et al., 2015; Cardoso et al., 2016; Oliveira et al., 2020).

Additionally, due to the large territorial dimension, pasture production in Brazil (with approximately 159.5 million ha) (IBGE, 2017) varies from fully extensive systems, dominated by small enterprises with degraded pastures and native vegetation, to systems that use the most advanced agronomic techniques, increasingly widespread because they present better technical and economic performances (Oliveira et al., 2018). These systems have different edaphoclimatic characteristics, and regional and socioeconomic peculiarities that result in different productivity models.

In this way, identifying the diversity of beef cattle production systems in the state of São Paulo is an important step to guide research work and technology transfer (TT), as well as to support the formulation of public policies related to the sector, that increase the adoption of sustainable technologies in the region.

The objective of this study was to identify potential areas in the State of São Paulo for transferring technologies for production intensification with sustainable pasture management.

Methods

The identification of potential areas for transferring technologies studied in the project was based on the geospatial identification of the mesoregions of the territory of São Paulo that present characteristics for the intensification of livestock production in pastures. Data from the special tabulation of the last Agricultural Census (2017) by the Brazilian Institute of Geography and Statistics (IBGE, 2017) was used to understand, differentiate, classify, characterize, and map the predominant pasture livestock production systems based on the statistics available in the different levels of aggregation referring to establishments of beef cattle producers. The computational software Microsoft Excel™ was used for the organization and identification of the areas. The aggregation levels defined were: the total pasture area of establishments with cattle (Hectares); the effective number of agricultural establishments with cattle (Units); the number of cattle heads in agricultural establishments (Heads); the number of agricultural establishments with more than 50 head of cattle that sold cattle for breeding, rearing, or fattening (Units); and the number of agricultural establishments with more than 50 heads of cattle that sold cattle for slaughter (Units).

The *QGIS* software version 9.28.3 was used to generate and reclassify maps and create all layouts. In addition, the method of natural breaks of Jenks's algorithm was used to minimize the intraclass variance and maximize the interclass variance. In this classification method, classes are based on natural groupings inherent in the data, and data with less variation are grouped, statistically establishing the spatial patterns of the data used (Smith; Goodchild; Longley, 2018).

Results and Discussion

Considering the critical challenges of the animal production systems based on pastures in the regions and municipalities of the São Paulo state, the identified priority areas are organized in Table 1 and in layouts (Figures 1, 2, 3, 4, and 5), according to the different levels of aggregation.

The total pasture area of agricultural establishments with cattle was bigger in the region of Presidente Prudente than in the other regions, with 934.256 ha, followed by São José do Rio Preto and Bauru regions (633.419, 436.429 ha, respectively), Araçatuba and Vale do Paraíba Paulista (371.909 and 344.716, respectively), while all other regions presented less than 265.578 ha (Figure 1).

São José do Rio Preto and Presidente Prudente regions presented the highest effective number of agricultural establishments with cattle, with 17.561 and 16.322 units, respectively, followed by Araçatuba, Bauru, Vale do Paraíba Paulista and Itapetininga regions (8.136, 7.018, 6.952 and 6.416 units, respectively), while all other regions presented less than 4.561 units (Figure 2).

For the number of cattle heads in agricultural establishments, the region of Presidente Prudente presented the highest value, with 1.582.580 heads, followed by São José do Rio Preto, Bauru and Araçatuba regions (1.299.522,770.243 and 730.125 heads, respectively), Vale do Paraíba Paulista and Marília (468.620 and 468.379 units, respectively), while all other regions presented less than 370.163 units (Figure 3).

The region of Presidente Prudente also presented the highest number of farms, with more than 50 heads of cattle, that sold cattle for breeding, rebreeding, and fattening (2.661 units), followed by São José do Rio Preto and Bauru regions (2.307 and 1.222 units, respectively), Araçatuba, Marília and Itapetininga (1.032, 747, 665 units), while all other regions presented less than 627 units (Figure 4).

For the number of farms with more than 50 heads of cattle that sold cattle for slaughter, São José do Rio Preto and Presidente Prudente regions presented the highest values, with 2.107 and 1.998 units, followed by Araçatuba, Bauru and Vale do Paraíba Paulista regions (1.156, 878, and 792 units, respectively), while all other regions presented less than 516 units (Figure 5).

The lowest values for all levels of aggregation were found for the Metropolitan region of São Paulo, Litoral Sul Paulista, and Araraquara regions.

Table 1. Geographic mesoregions in the state of São Paulo and different levels of aggregation.

Geographic Mesoregions in the State of São Paulo	Land-Use Pasture Area of Agricultural Establishments	Number of Agricultural Establishments	Number of Heads in Agricultural Establishments	Number of Heads (Breeding, Rebreeding and Fattening) Sold in Agricultural Establishments	Number of Heads (Slaughter) Sold in Agricultural Establishments
	(Hectares)	(Units)	(Units)	(Units)	(Units)
Araçatuba	371.909	8.136	730.125	1.032	1.156
Araraquara	43.659	1.514	97.712	151	162
Assis	161.999	3.055	298.955	557	395
Bauru	436.429	7.018	770.243	1.222	878
Campinas	162.635	4.561	318.732	445	516
Itapetininga	238.306	6.416	370.163	665	452
Litoral Sul Paulista	72.916	704	47.330	53	87
Macro Metropolitana Paulista	109.736	2.614	186.135	327	272
Marília	265.578	3.091	468.379	747	455
Metropolitana de São Paulo	14.126	508	16.586	20	17
Piracicaba	101.152	2.511	192.149	362	311
Presidente Prudente	934.256	16.322	1.582.580	2.661	1.998
Ribeirão Preto	132.844	4.105	288.460	390	455
São José do Rio Preto	633.419	17.561	1.299.522	2.307	2.107
Vale do Paraíba Paulista	344.716	6.952	468.620	627	792

Source: Agricultural Census (2017) by the Brazilian Institute of Geography and Statistics (IBGE, 2017).

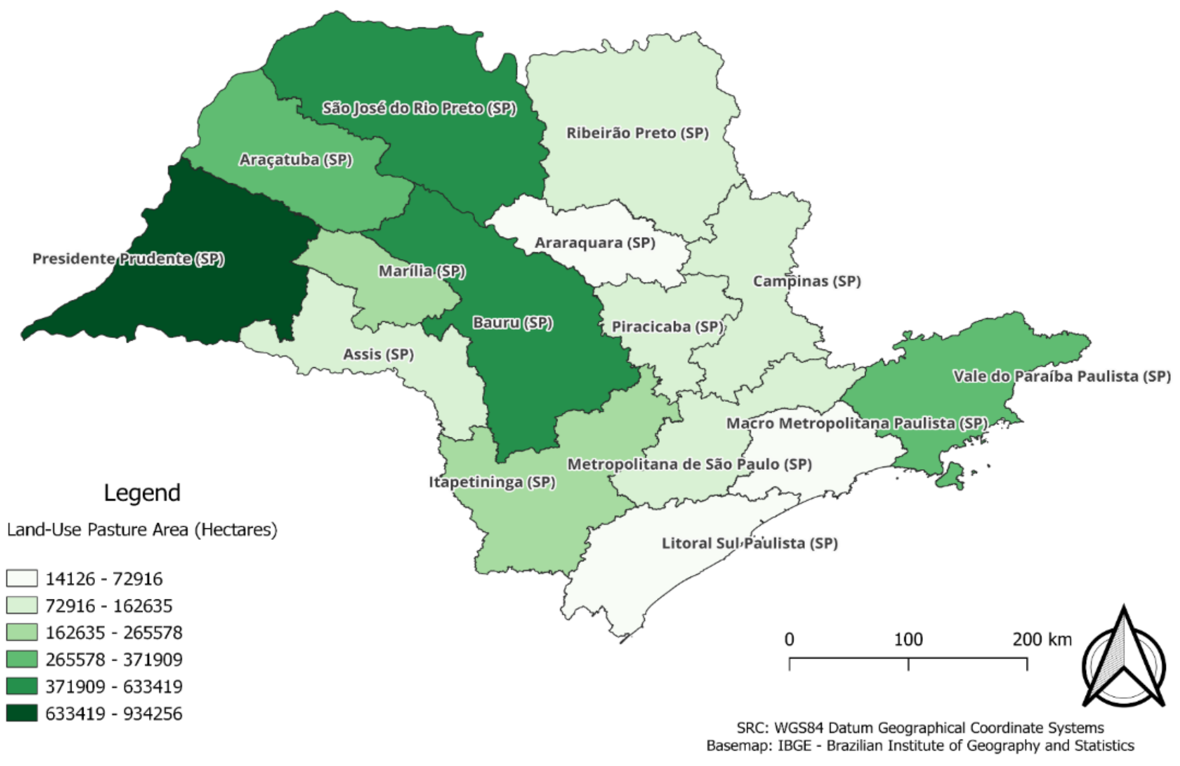

Figure 1. Pasture area of agricultural establishments with cattle (Hectares).

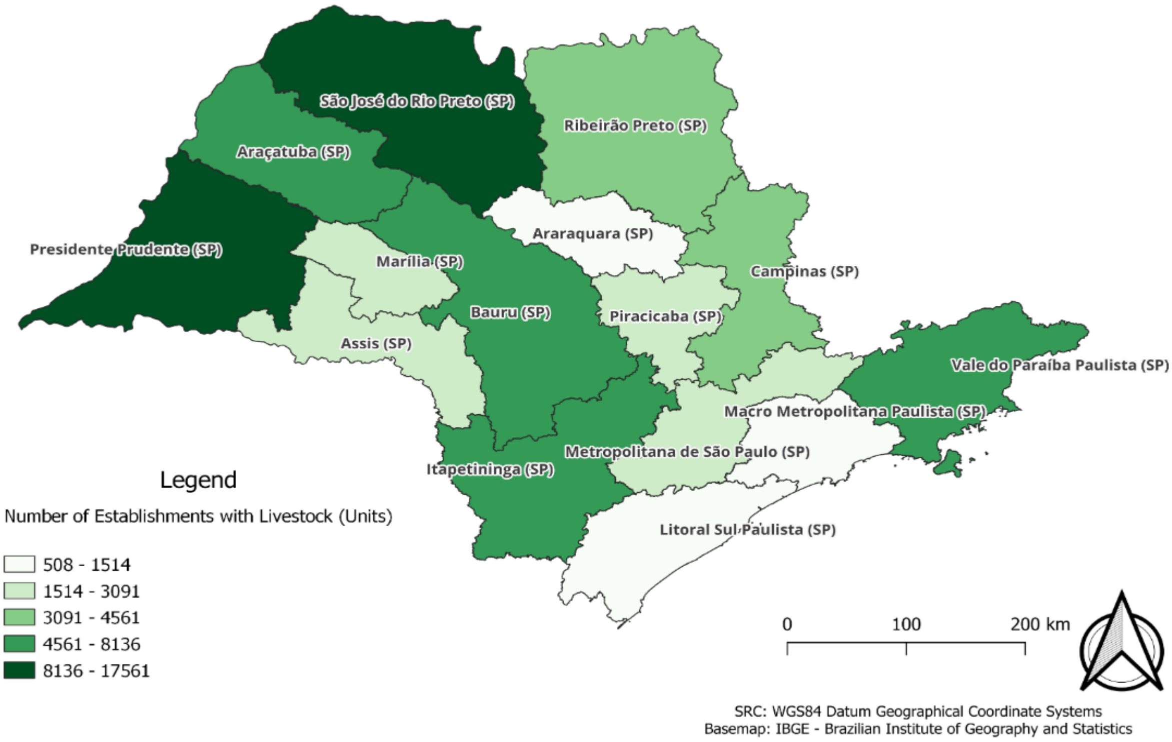

Figure 2. Effective number of agricultural establishments with cattle (Units).

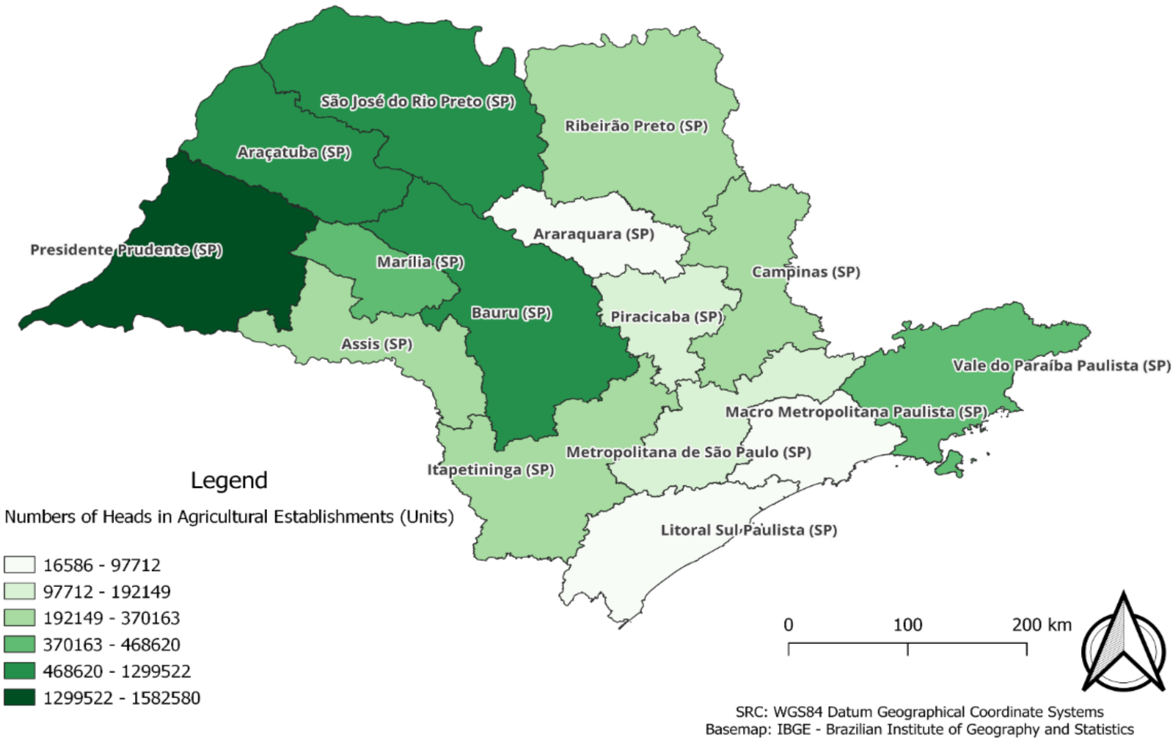

Figure 3. Number of cattle heads in agricultural establishments (Heads).

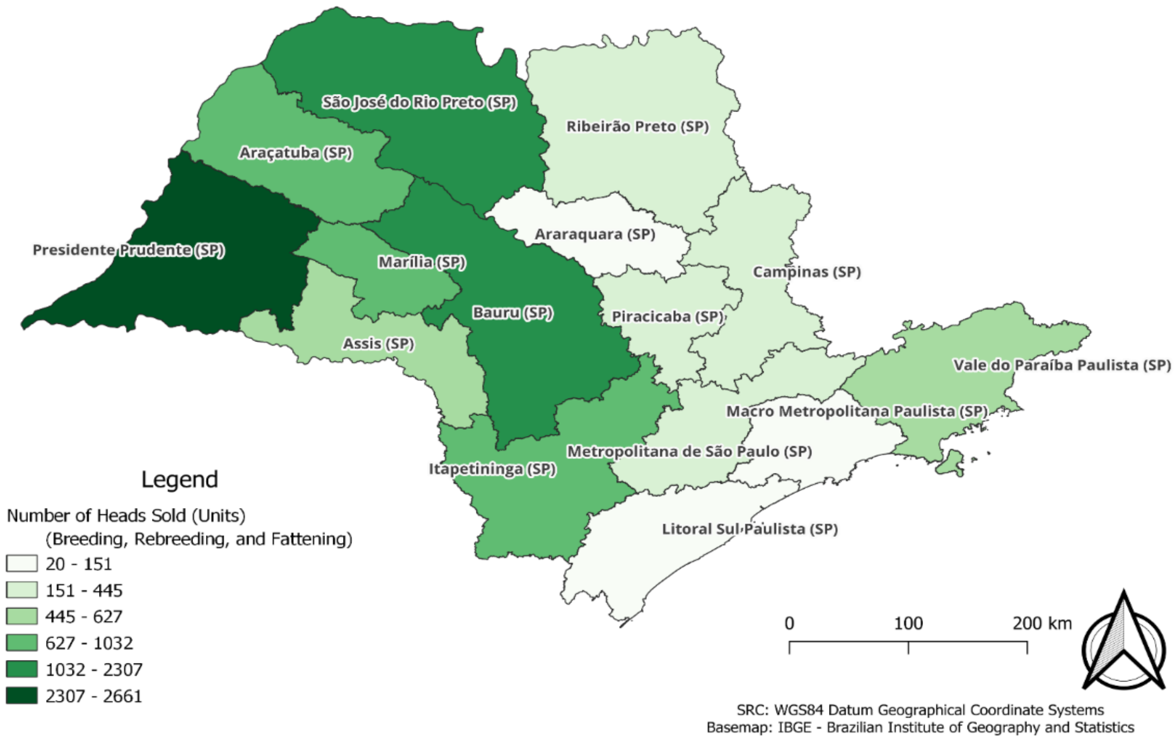

Figure 4. Number of agricultural establishments, with more than 50 head of cattle, that sold cattle for breeding, rebreeding, and fattening (Units).

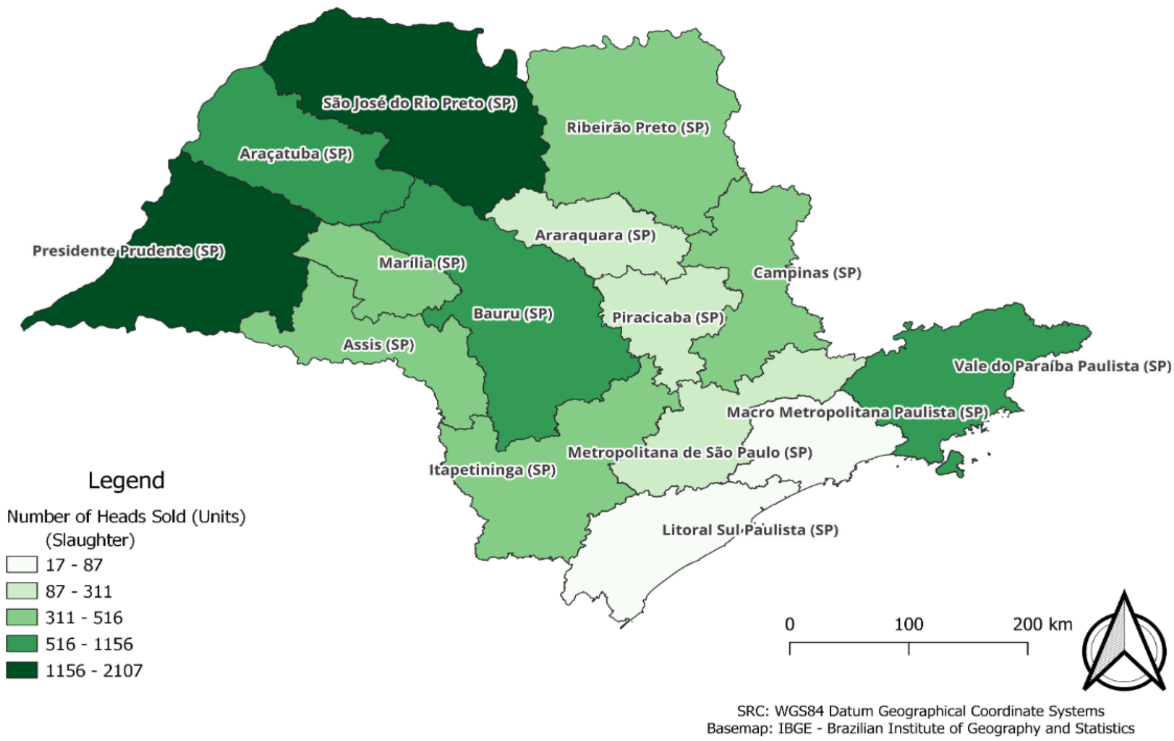

Figure 1. Number of agricultural establishments, with more than 50 heads of cattle, that sold cattle for slaughter **(Units).**

Conclusions

Among the intermediate mesoregions of the state of São Paulo, the Presidente Prudente region stood out in most of the analyzed parameters, mainly, for having the largest total area, the largest herd with beef cattle raised on pastures and the number of farms, with more than 50 head of cattle, that sold cattle for breeding, rebreeding, and fattening. The region of São José do Rio Preto and Presidente Prudente presented similar parameters for the effective number of farms with cattle, and number of farms, with more than 50 heads of cattle, that sold cattle for slaughter. Considering the results obtained and the identification of the potential areas, it is possible to transfer the technologies studied in the project “Strategic practices for mitigating greenhouse gas emissions in grassland systems of the Brazilian Southeast” to both areas. Bauru, Araçatuba, and Vale do Paraíba Paulista regions are also potential areas to adopt the technologies studied in the project; while the Metropolitanregion of São Paulo, Litoral Sul Paulista, and Araraquara regions were shown to be regions with other relevant agricultural activities or limitations to livestock farming due to socio-economic issues.

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References

CARDOSO, A. S. et al. Impact of the intensification of beef production in Brazil on greenhouse gas emissions and land use. **Agricultural Systems**, v. 143, p. 86–96, 2016.

DICK, M.; DA SILVA, M. A.; DEWES, H. Mitigation of environmental impacts of beef cattle production in southern Brazil– Evaluation using farm-based life cycle assessment. **Journal of Cleaner Production**, v. 87, p. 58-67, 2015.

FAO - Food and Agriculture Organization of the United Nations. Five Practical Actions Towards Low-Carbon Livestock, FAO, Rome, Italy, p. 40, 2019.

IBGE – Instituto Brasileiro De Geografia E Estatística. **Censo Agropecuário 2017:** Resultados Definitivos. IBGE: Rio de Janeiro, Brasil, 2017.

OLIVEIRA, P. P. A. et al. The effect of grazing system intensification on the growth and meat quality of beef cattle in the Brazilian Atlantic Forest biome. **Meat Science**, v. 139, n. December 2017, p. 157–161, 2018.

OLIVEIRA, P. P. A. et al. Greenhouse gas balance and carbon footprint of pasture-based beef cattle production systems in the tropical region (Atlantic Forest biome). **Animal**, v. 14, p. s427–s437, 2020.

PULIDO, M. et al. Sustainable grazing. Current Opinion in Environmental Science and Health, v. 5, p.42-46, 2018.

SMITH, M. J.; GOODCHILD, M. F.; LONGLEY, P. A. Geospatial Analysis: a comprehensive guide to principles techniques and software tools. **The Winchelsea Press**, v. 6, 2018.

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