Cattle production in silvopastoral systems compared to monoculture pasture in the Brazilian Cerrado

Produção de gado de corte em sistemas silvipastoris em comparação a pastagem em monocultivo no Cerrado brasileiro

R. G. Almeida[1]; E. M. Almeida[2]; R. C. Gomes[1]; F. V. Alves[1]; V. A. Laura[1]; M. C. M. Macedo[1]; G. F. Costa[3]; A. P. Mastelaro[4]; D. J. Bungenstab[1]*

[1]Embrapa Beef Cattle,
*roberto.giolo@embrapa.br;
[2]Federal University of Mato Grosso do Sul;
[3]State University of Mato Grosso do Sul;
[4]Federal University of Paraná.

Abstract

Adoption of silvopastoral systems (SS) in Brazil has been stimulated in the last decade. This work aimed to evaluate beef production under SS with eucalyptus using densities of 178 and 441 trees per ha and to compare it to a traditional monoculture Piatã grass pasture (PM) in the Brazilian Cerrado. Shading caused by the two tree densities, in the third year of the systems implementation did not cause changes neither on forage mass nor on its nutritive value. As consequence, results show that both SS did not differ from the PM for beef cattle production in the period studied, allowing better thermal comfort for grazing cattle, besides wood production and greenhouse gases mitigation.

Keywords: *Integrated systems, Piatã grass, thermal comfort, wood production*.

Resumo

Na última década, tem sido estimulada a adoção de sistemas silvipastoris (SS) no Brasil. O presente trabalho teve como objetivo avaliar a produção de gado de corte em SS com eucalipto em densidades de 178 e 441 de árvores por ha em comparação a uma pastagem de capim-piatã em monocultivo (PM), no Cerrado brasileiro. O sombreamento imposto pelas duas densidades de árvores, no terceiro ano de implantação dos sistemas, não causou alteração na massa de forragem e no seu valor nutritivo e, consequentemente, os SS não diferiram da PM para produção de gado de corte, além de possibilitarem melhor conforto térmico aos animais em pastejo, produção de madeira e mitigação de gases de efeito estufa.

INICIO
CRÉDITOS
ENTIDADES
COMITÉS
CONTENIDO
SECCIÓN 1
SECCIÓN 2
SECCIÓN 3
SECCIÓN 4

Palavras-chave: *Capim-piatã, conforto térmico, produção de madeira, sistemas integrados.*

Introduction

Silvopastoral systems have been adopted in all regions of Brazil with different forestry species and spatial and temporal arrangements. The most common design is using eucalyptus species with densities ranging from 150 to 350 trees per hectare (Almeida et al., 2013). In the last decade, the Brazilian government has encouraged adoption of these systems through the Plan for Low Carbon Agriculture or ABC Plan. This is one of the official strategies to mitigate greenhouse gases emissions from the agricultural sector, being also possible to produce carbon neutral beef (Alves et al., 2017). These systems provide natural shade, a cheap and efficient way to minimize adverse effects of hot climate on animal production in the tropics. It leads to farm produce diversification and extra revenue through professional livestock and forestry farming. The state of Mato Grosso do Sul (MS), located in Central Brazil, stands out with the largest area covered by integrated systems in the country, comprising about two million hectares, being 16% of which silvopastoral/agroforestry systems (Rede de Fomento, 2017). Most of these systems are in the Cerrado biome. Similar initiatives exist also in the eastern zone of Paraguay (Almeida, 2017). Silvopastoral systems with a focus on cattle ranching have spatial arrangements with lower tree density, in order to reduce shading and allow for satisfactory forage production (Oliveira et al., 2014), while those with focus on forestry have higher tree density arrangements. In this context, an experiment was carried out in a commercial farm in the Cerrado biome of MS to evaluate two silvopastoral systems with eucalyptus using densities of 178 and 441 trees per ha and to compare them against a Piatã grass monoculture regarding beef cattle production.

Materials and methods

A trial was carried out at a technological reference unit (URT) of Embrapa Beef Cattle, the Fazenda Boa Aguada, located in the municipality of Ribas do Rio Pardo, MS (latitude 20º19 'S, longitude 53º17' W and altitude of 499 m) from April 2017 to July 2018. The climate, according to Köppen classification, is in the transition zone between Cfa and humid tropical Aw, with hot-rainy summers.

Experimental plots were established in December 2015, being: (PM) monoculture pasture with *Urochloa brizantha* cv. BRS Piatã under full sun, (SS1) silvopastoral system with *U. brizantha* cv. BRS Piatã and a single row of eucalyptus (*Eucalyptus grandis* x *E. urophylla*, clone I144) in an arrangement

INICIO
CRÉDITOS
ENTIDADES
COMITÉS
CONTENIDO
SECCIÓN 1
SECCIÓN 2
SECCIÓN 3
SECCIÓN 4

of 28m between rows and 2m between trees in the row, resulting in tree density of 178 trees per ha; (SS2) silvopastoral system with *U. brizantha* cv. BRS Piatã and triple rows of eucalyptus in arrangement of 28m between tree alleys, 3x2 m between trees in the alleys resulting in tree density of 441 trees per ha. Tree rows were planted in northwest alignment, following terrain level. Tree heights (H; m) were measured with clinometer and diameter at breast height (DBH; cm) with a caliper in August 2018, when trees were in average 2.7 years old. These data were used to calculate volume of wood produced (V, m^3). The Mean Annual Increment (MAI; m^3 ha^{-1} $year^{-1}$) was calculated dividing volume (V) by trees age.

Site soil was characterized as Quartzarenic Neosol, presenting sand contents of 90 to 91%, silt of 6 to 7% and clay of 3 to 4%. Results of soil analysis from the treatments, collected in April-May 2018 can be observed in Table 1.

Table 1. Phosphorus (P) and potassium (K) contents through Mehlich^{-1}, base saturation (V) and total carbon content (C) of the 0-30 cm depth layers of the treatments: monoculture pasture (PM), silvopastoral system with 178 trees per ha (SS1) and silvopastoral system with 441 trees per ha (SS2).

System	**PM**			**SS1**			**SS2**		
Depth (cm)	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
P (mg dm^{-3})	11.3	5.1	5.1	9.1	6.1	5.7	10.7	4.7	3.7
K (mg dm^{-3})	11	11	10	11	9	7	10	9	5
V (%)	42	37	23	15	16	16	23	25	20
C (%)	0.56	0.50	0.31	0.55	0.47	0.47	0.58	0.44	0.43

Each paddock had 4.01 ha, equipped with water and dry feeding troughs. Paddocks were managed under continuous grazing and variable stocking rates. Stocking rate adjustments were made at animal weightings. Nellore steers were used for all systems. Each paddock hosted three test-animals and a variable number of extra animals, added according to forage mass available, following recommendations from Machado and Kichel (2004). In the growing phase, grazing animals received water *ad libitum* and a dry supplement (minerals+protein+energy) at rate of 0.2% of live weight (LW). Finishing animals received water *ad libitum* and protein-energy dry supplement at rate of 1.2% of live weight (LW). Animals were weighed individually, without previous restriction to food and water. For growing animals, weightings were carried out on 05th April, 25th May, 18th July, 19th September and 30th November 2017 and, at the finishing phase, weightings were carried out on 20th February, 13th April, 23th May and 12th July 2018. Animals were surgically castrated by end of February 2018. Weighting data were used to calculate average daily weight gain (ADG; kg day^{-1}), stocking rate (SR, animal unit, AU ha^{-1}) and animal weight gain per hectare (AWG; kg ha^{-1}).

Forage evaluations for the growing phase were carried out on 17th May, 05th July, 30th August, 01st November and 07th December 2017 and, at finishing, on 09th April, 10th May and 05th July 2018. Evaluations were done on two transects per paddock perpendicular to tree rows. In each transect, five equidistant points (A, B, C, D and E) were defined, totaling 10 samples per paddock. For such, A and E were 2 m from the tree lines and C was the intermediate position between tree rows, considering the border row on the triple line arrangement. At each point, in a sampling area of 1.0 m^2, measurements were made for sward height and forage mass. Forage harvest was performed close to soil, with a brush cutter. The cut grass was weighed and composite samples were formed for each paddock point. Composite samples were sorted manually as leaf blade, stem (stem + sheath) and dead material. These fractions were dried in a forced air circulation oven at 65ºC and weighed afterwards. The leaf blade fraction was crushed in a mill using 1 mm sieve. Nutritive value of this fraction was analyzed using infrared light reflectance spectroscopy (NIRS), according to Marten et al. (1985), for crude protein (CP; %) neutral detergent fiber (NDF), and *in vitro* digestibility of organic matter (IVDOM; %).

Measurements of photosynthetically active radiation (PAR; µmol m^{-2} s^{-1}) were performed with readings in the morning prior to forage cutting, with a portable ceptometer (model 197 AccuPAR-LP 80) at the top of forage sward. Evaluations of microclimatic parameters were performed simultaneously in the three systems during three consecutive days in the months of June and July 2018 (dry season), at 8:00, 11:00 and 17:00 according to Karvatte Jr. et al. (2016). Parameters evaluated were: air temperature (Ta; ºC), dew point temperature (Tpo; ºC), black globe temperature (Tgn; ºC), relative air humidity (RH; %) and wind speed (WS; m s^{-1}). From these, Temperature-Humidity Index (THI; Thom, 1958) and Black Globe Humidity Index (BGHI; Buffington et al., 1981) were calculated for each system.

The experimental design was complete randomized blocks, in a 3 x 2 x 2 factorial scheme, being three systems (PM, SS1 and SS2), two phases of cattle rearing (growing and finishing) and two seasons (rainy and dry), with two replicates. Data were submitted to analysis of variance, and means were compared by the Tukey test at 5% probability. Analyzes were performed using the statistical application SISVAR version 5.6.

Results and discussion

For forage mass there was no effect of system, rearing phase and season, as well as there was no effect of interaction among these factors. There was an effect of rearing phase and season on forage sward height.

The proportion of shading observed in the silvopastoral systems in relation to monoculture pasture for growing and finishing phases was 25 and 30%, respectively. As a whole, *Urochloa* spp. have satisfactory yields under shading levels up to 30-35% (Andrade et al., 2004; Paciullo et al., 2007).
The decrease in PAR was not sufficient to influence forage sward height (mean of 35.48 cm) and forage mass (mean of 2,859 kg ha^{-1}). These values fit in the recommendations for this cultivar managed under continuous grazing (Costa and Queiroz, 2017). Although no difference was observed in forage mass, grass height was higher in the finishing phase (42.59 cm) than in the growing phase (30.14 cm), possibly due to the supply of higher amounts of supplement in the finishing phase, with depressive effect over forage intake, bearing in mind that in this phase, stocking rate was higher. It was also higher, as expected, in the rainy season (40.33 cm) than in the dry season (29.01 cm), typical for this time of year, with higher availability of growth factors like light and temperature.

The CP content of Piatã grass was influenced by the interaction between rearing phase and season (Table 2).

Urochloa spp. under shading tend to show higher CP contents compared against full sun production, especially when closer to the tree ranks, between 7 and 10 m (Paciullo et al., 2007; 2011). However, 28 m distance between tree rows as used in this trial might have been large enough to minimize or even suppress this expected effect at the third year of the system's implementation.

In the rainy season, no difference was observed in the CP content of the pasture for the two rearing phases. However, in the dry season, CP content was higher in the growing than in the finishing phase. In the growing phase, the CP content was higher in the dry season due to out-of-season rainfall and grass regrowth.

Table 2. Crude protein contents (%) of Piatã grass in two phases of cattle rearing (growing and finishing) and two seasons (rainy and dry).

Season	Phase		MSE	*P value*
	Growing	**Finishing**		
Rainy	11.86^{Ba}	10.70^{Aa}	0.77	0.052
Dry	16.27^{Aa}	9.24^{Ab}		

INICIO
CRÉDITOS
ENTIDADES
COMITÉS
CONTENIDO
SECCIÓN 1
SECCIÓN 2
SECCIÓN 3
SECCIÓN 4

Means followed by the same capital letter in the columns, and small letters in the lines do not differ by the Tukey test at 5% probability. MSE: mean standard error. *P value*: probability of significant effect.

Regarding NDF content and the IVDOM of Piatã grass, they were influenced by the rearing phase (Table 3). During the growing phase of animal rearing, a better forage nutritional value was observed, with lower NDF content and higher IVDOM compared to the finishing phase, which may be associated with higher pasture height at this last phase, which leads to lower nutritive value.

Table 3. Neutral detergent fiber (NDF) content and *in vitro* digestibility of organic matter (IVDOM) of leaf blade in piatã grass pasture for two phases of cattle rearing (growing and finishing).

Content	**Phase**		**MSE**	***P value***
	Growing	**Finishing**		
NDF (%)	69.51^{b}	70.97^{a}	0.409	0.017
IVDOM (%)	66.97^{a}	60.42^{b}	1.681	0.010

Means followed by the same small letters in the lines do not differ by the Tukey test at 5% probability. MSE: mean standard error. *P value*: probability of significant effect.

Since forage mass and its nutritive value were not influenced by different systems, animal production variables, ADG, AWG and SR, followed the same pattern. Oliveira et al. (2014) assessed silvopastoral systems with eucalyptus planted with 22 m and 14 m between tree rows, using Piatã grass, also in the third year of the systems. There, in regards to animal performance, they observed that the silvopastoral system with larger distance between tree rows did not differ from the monoculture Piatã grass pasture.

In the present work, there was an interaction effect of the rearing phase *vs.* season over ADG (Table 4). In the growing phase, ADG was higher in the rainy season than in the dry season, as expected due to the seasonality of forage production. However, in the finishing phase, there was no difference in the ADG, since animals were castrated during the rainy season, with negative impact on this variable. Therefore, in the rainy season, ADG observed in finishing phase was low than for growing phase.

For AWG, there was no difference among systems, with a cumulative value of 178 kg ha^{-1} during the entire rearing period (growing + finishing). However, during the rainy season AWG was higher than that of the dry season, with values of 55.51 kg ha^{-1} and 26.35 kg ha^{-1}, respectively.
There was effect of phase of rearing and season over stocking rate, being 1.10 AU ha^{-1} for the growing phase and 1.91 AU ha^{-1} for finishing and 1.04 AU ha^{-1} in the dry season and 1.62 AU ha^{-1} in the rainy season.

INICIO
CRÉDITOS
ENTIDADES
COMITÉS
CONTENIDO
SECCIÓN 1
SECCIÓN 2
SECCIÓN 3
SECCIÓN 4

Table 4. Average daily gain (kg day^{-1}) in Piatã grass pasture for two phases of cattle rearing (growing and finishing).

Season	Phase		MSE	*P value*
	Growing	Finishing		
Rainy season	0.972^{Aa}	0.475^{Ab}	0.115	0.0018
Dry season	$0,310^{Ba}$	$0,489^{Aa}$		

Means followed by the same capital letter in the columns, and small letters in the lines do not differ by the Tukey test at 5% probability. MSE: mean standard error. *P value*: probability of significant effect.

In the months of June and July (dry season), higher values for Ta, THI and BGHI were observed at 11:00 (GWM, -04:00) in monoculture pasture. According to Hahn and Mader (1997), these values are not compatible with those expected for a comfortable environment, even for cattle breeds considered heat tolerant, such as the zebu used in this work. In the shade, in both months, the lowest values for Ta, THI and BGHI were obtained in systems with trees (Table 5).

Table 5. Microclimatic and thermal comfort indexes for cattle systems with monoculture pasture (PM), silvopastoral with 178 trees ha^{-1} (SS1) and silvopastoral with 441 trees ha^{-1} (SS2), data read under full sun and shade.

Month	System	Day time	Full sun			Shade		
			Ta (°C)	THI	BGHI	Ta (°C)	THI	BGHI
June	PM	08:00	29.5	76	81	--	--	--
		11:00	34.5	88	87	--	--	--
		17:00	26.8	75	76	--	--	--
	SS1	08:00	27.1	74	78	25.1	72	73
		11:00	32.8	80	83	29.3	76	78
		17:00	24.2	72	74	25.2	73	73
	SS2	08:00	27.2	74	77	22.1	69	69
		11:00	33.3	80	82	29.4	76	79
		17:00	25.4	73	73	25.1	73	74
July	PM	08:00	28.1	76	81	--	--	--
		11:00	36.0	83	89	--	--	--
		17:00	28.2	75	75	--	--	--
	SS1	08:00	27.4	74	78	23.8	70	72
		11:00	32.7	80	85	30.5	77	78
		17:00	27.9	74	74	27.4	74	75
	SS2	08:00	27.5	75	78	23.6	70	70
		11:00	31.9	79	82	30.7	77	78
		17:00	27.2	74	74	27.1	74	75

Ta: environment temperature; THI: temperature-humidity index; BGHI: black globe humidity index.

Regarding the forestry component in the silvopastoral systems, SS1 had trees with a mean DBH of 14.1 cm, mean height of 15.3 m and MAI of 6.4 m^3 ha^{-1} year^{-1}, while SS2 had trees with a mean DBH of 12.4 cm, mean height of 16.1 and MAI of 13.5 m^3 ha^{-1} $year^{-1}$, so that no differences were observed in DBH and trees height, only higher MAI for the SS with higher tree density. Higher wood yields can improve farm revenues (Pereira et al., 2018) as well as to mitigate or even neutralize greenhouse gases emitted by grazing cattle, being possible to produce carbon neutral beef, as demonstrated by Almeida et al. (2016) in another trial conducted on the same farm.

Conclusions

Silvopastoral systems with eucalyptus at densities of 178 and 441 trees per hectare in the third year of implementation in the Brazilian Cerrado did not differ from a monoculture pasture in regards to forage mass production and its nutritive value, as well as for beef cattle yields, in addition to providing better thermal comfort to animals, producing wood and mitigating greenhouse gases.

References

Almeida, R.G. 2017. Integración agrícola-ganadera-forestal con enfoque al ganado de carne. In: 25º Congreso CEA, Asunción, PY, pp. 117-144.

Almeida, R.G., Andrade, C.M.S., Paciullo, D.S.C. et al. 2013. Brazilian agroforestry systems for cattle and sheep. Tropical Grasslands, Forrajes Tropicales, v. 1, pp. 175-183.

Almeida, R.G., Gomes, R.C., Silva, V.P. et al. 2016. Carbon Neutral Brazilian Beef: testing its guidelines through a case study. In: II International Symposium on Greenhouse Gases in Agriculture, 2016, Campo Grande, MS. Proceedings... Campo Grande, MS, Embrapa Gado de Corte, pp. 277-281.

Alves, F.V., Almeida, R.G., Laura, V.A. 2017. Carbon Neutral Brazilian Beef: a new concept for sustainable beef production in the tropics. Brasília, DF, Embrapa, Documentos, 243, pp. 36.

Andrade, C.M.S., Valentim, J.F., Carneiro, J.C. et al. 2004. Crescimento de gramíneas e leguminosas forrageiras tropicais sob sombreamento. Pesquisa Agropecuária Brasileira, v. 39, pp. 263-270.

Buffington, D.E., Collazo Arocho, A., Canton, G.H. et al. 1981. Black globe humidity index (BGHI) as a comfort equation for dairy cows. Transactions of The Asae, v. 24, pp. 711-714.

Costa, J.A.A., Queiroz, H.P. 2017. Régua de manejo de pastagens: edição revisada. Campo Grande, MS, Embrapa Gado de Corte, Comunicado Técnico, 135, pp. 7.

Hahn, G.L., Mader, T.L. 1997. Heat waves in relation to thermoregulation, feeding behavior and mortality of feedlot cattle, Minneapolis. St. Joseph, ASAE. Proccedings of the international livestock environment symposium, pp. 563-567.

Karvatte Jr., N., Alves, F.V., Klosowski, E.S. et al. 2016. Microclima e índices de conforto térmico em sistemas de integração lavoura-pecuária-floresta no município de Campo Grande, Mato Grosso do Sul. Campo Grande, MS, Embrapa Gado de Corte, Documentos, 225, pp. 40.

Machado, L.A.Z., Kichel, A.N. 2004. Ajuste de lotação no manejo de pastagens. Dourados, MS, Embrapa Agropecuária Oeste, Documentos, 62, pp. 55.

Marten, G.C., Shenk, J.S., Barton II, F.E. 1985. Near infrared reflectance spectroscopy (NIRS), analysis of forage quality. Washington: USDA, ARS, Agriculture Handbook, 643, pp. 110.

INICIO
CRÉDITOS
ENTIDADES
COMITÉS
CONTENIDO
SECCIÓN 1
SECCIÓN 2
SECCIÓN 3
SECCIÓN 4

Oliveira, C.C., Villela, S.D., Almeida, R.G. et al. 2014. Performance of Nellore heifers, forage mass, and structural and nutritional characteristics of *Brachiaria brizantha* grass in integrated production systems. Tropical Animal Health and Production, v. 46, pp. 167-172.

Paciullo, D.S.C., Carvalho, C.A.B., Aroeira, L.J.M. et al. 2007. Morfofisiologia e valor nutritivo do capim-braquiária sob sombreamento natural e a sol pleno. Pesquisa Agropecuária Brasileira, v. 42, pp. 573-579.

Paciullo, D.S.C., Gomide, C.A.M., Castro, C.R.T. et al. 2011. Características produtivas e nutricionais do pasto em sistema agrossilvipastoril, conforme a distância das árvores. Pesquisa Agropecuária Brasileira, v.46, pp.1176-1183.

Pereira, M.A., Costa, F.P., Almeida, R.G. 2018. Is the “F Word” an option for Brazilian farmers? The place of forestry in future integrated farming systems. International Journal of Agricultural Management, v. 6, pp. 134-140.

Rede de Fomento ILPF. 2017. ILPF em números: região 06, MS, SP e PR. Brasília, DF, Embrapa, pp. 16.

Souza, A., Pavão, H.G., Gabas, S.G. et al. 2010. Modelo de Thom para zoneamento bioclimático de Mato Grosso do Sul. Revista de Geografia Norte Grande, v. 46, pp. 137-147.

Thom, E.C. 1958. Cooling degree: day air conditioning, heating, and ventilating. Transaction of the American Society of Heating, v. 55, n. 7, pp. 65-72.