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Articles

Silvopastoral system implementation in *Uruchloa brizantha* pasture under continuous cattle grazing

Implantação do sistema silvipastoril em pastagem de *Uruchloa brizantha* sob pastejo contínuo de bovinos

Larissa de Souza Reis[I], Sthéfany Noronha dos Santos[I], Matheus Ferreira Paula[I], Jakeline Fernandes Cabral[I], Leandro Carlos[I], Tiago do Prado Paim[I], Tiago Pereira Guimarães[I], Thaisa Campos Marques[I], Karen Martins Leão[I]

[I]Instituto Federal de Educação, Ciência e Tecnologia Goiano, Rio Verde, GO, Brazil

ABSTRACT

Silvopastoral is a sustainable integration system of tree component and animal in the same area, aiding soil fertility and promoting animal comfort. The objective was to evaluate different planting systems of forest component, at restoration time of *Brachiaria brizanta* cv. Marandu (*Urochloa brizantha*) pastures, under continuous cattle grazing. Eucalyptus (*Corymbia citriodora*) was planted in four arrangements (tree dispositions) with 1, 3, 5 and 9 seedlings, with three entry times of animals, 1, 30 and 60 days after planting the trees. Probability of survival of seedlings per arrangement and probability of survival of at least one seedling per arrangement with the presence of animals for 60 days, under continuous grazing, were evaluated. Probability of survival of at least one tree per arrangement regardless of disposition was higher at entry times 30 and 60 days. Arrangements 3, 5, and 9, there was a greater probability of a live tree than in arrangement 1. The results showed that it is possible to implement the silvopastoral system at the same time as pasture restoration, being more viable the entry of animals from 30 days after planting the seedlings, with greater probability of tree survival with more seedlings per arrangement.

Keywords: Cattle farming; Forage farming; Forest arrangement; Integrated production systems

RESUMO

O sistema silvipastoril é um sistema de integração sustentável que contém o componente arbóreo e animal em uma mesma área, auxiliando na fertilidade do solo e promovendo o conforto animal. O objetivo foi avaliar diferentes sistemas de plantio do componente florestal, em época de restauração da pastagem de *Brachiaria brizanta* cv. Marandu (*Urochloa brizantha*), sob pastejo contínuo de bovinos. O eucalipto (*Corymbia citriodora*) foi plantado em quatro arranjos (disposições de árvores) com 1, 3, 5 e 9 mudas, e três épocas de entrada dos animais, 1, 30 e 60 dias após o plantio das árvores. Foram avaliadas a probabilidade de sobrevivência de plântulas por arranjo e a probabilidade de sobrevivência de pelo menos uma plântula por arranjo com a presença de animais por 60 dias, sob pastejo contínuo. A probabilidade de sobrevivência de pelo menos uma árvore por arranjo independente da disposição foi maior nos tempos de entrada 30 e 60 dias. Nos arranjos 3, 5 e 9, houve maior probabilidade de uma árvore viva do que no arranjo 1. Os resultados mostraram que é possível implantar o sistema silvipastoril ao mesmo tempo em que a restauração de pastagens, sendo mais viável a entrada de animais de 30 dias após o plantio das mudas, com maior probabilidade de sobrevivência das árvores com mais mudas por arranjo.

Palavras-chave: Pecuária; Forrageira; Arranjo florestal; Sistemas integrados de produção

1 INTRODUCTION

Seeking to improve the production rates of sustainable agricultural systems, new production systems have been surveyed. The silvopastoral system integrates trees, forage and animal in the same area and time, characterizing a sustainable system, aiming at economic, social development and environmental preservation (Silva, 2004). In addition, it improves soil fertility and provides thermal comfort for the animals, leading to better productive performance (Paciullo *et al*., 2014).

Sensitivity of dairy cows to heat stress is evident, presenting as responses drop in production and reproductive performance. High-producing animals subjected to heat stress may have reduced feed intake, thus, nutritional requirements are not met, resulting in a drop in production, solids and yield of milk products (Collier *et al*., 2006).

Cattle can identify shady places that provide protection against solar radiation (Shutz *et al*., 2009). By, it is important to use shade to reduce the animal heat stress and consequently better productive performance (Linhares *et al*., 2015). In this sense, the livestock-forest integration system can be an excellent alternative to improve the productivity of pasture milk production since it favors greater production and quality of forage and provides animal thermal comfort.

According to Pereira *et al*. (2017), in Brazil there is a demand for technologies that apply to production systems, aiming to reduce the problems caused by heat stress. However, the Bos taurus taurus breeding is hampered in tropical regions by climatic conditions. Then, improving pasture nutritional quality and animal thermal comfort by silvopastoral system implementation can be an innovative way to produce better quality meat and milk, coming from Bos taurus raised in tropical regions.

Agroforestry systems are acknowledged as a promising solution for restoring degraded areas caused by livestock production. Nevertheless, insufficient understanding of the benefits associated with this cultivation strategy could impede the widespread adoption of these systems (Silva *et al*., 2023).

In this system, the forest component and the pasture can be implemented simultaneously since the first one can be introduced in already planted pastures. Tree component in this system can have a great influence on the forage used due to shading. That way, management practices must be adopted to keep dry matter production to feed the animals throughout year, without compromising the persistence of forage over the years (Anjos *et al*., 2021).

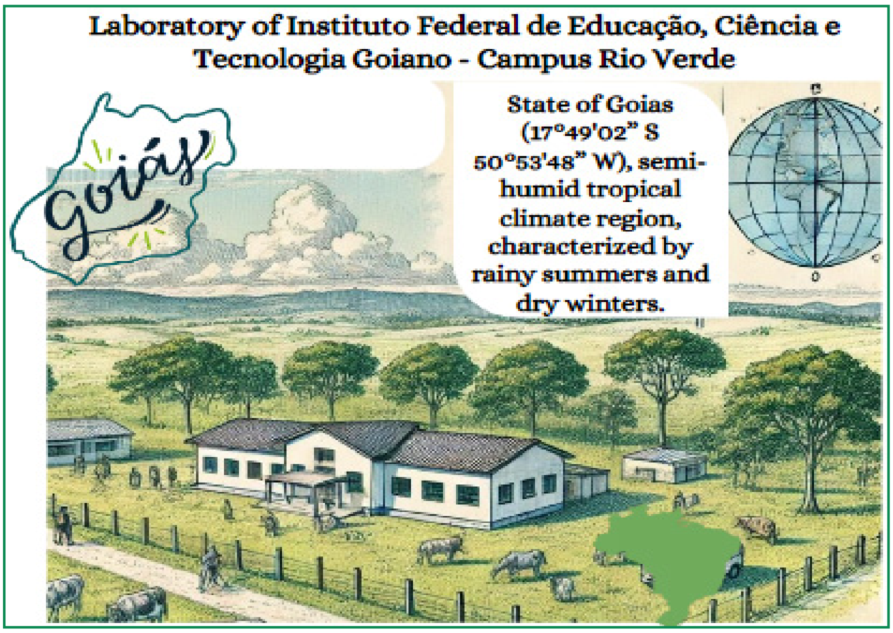
In general, small producers have few resources for investment to improve the herd and pasture itself. It is not feasible for them making part of the productive area unavailable for afforestation or the use of fences to prevent the initial damage caused by animals to newly planted seedlings.

In this regard, to make possible the afforestation of pastures with eucalyptus, due to its rapid growth, the objective was to evaluate different systems of incorporation of the forest component, at the time of restoration, of pastures already planted with *Brachiaria brizanta* cv. Marandu under continuous cattle grazing.

2 MATERIALS AND METHODS

This study was previously approved by the Ethical Committee on the Use of Experimental Animals of Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde.

Figure 1 - Experiment Location and Regional Climate



Source: Authors (2022)

During the experimental period, the minimum, maximum and average temperatures were 18.0±2.3°C, 29.5±1.9°C and 23.78±1.44°C, respectively. The rainfall was 266.3 mm with the highest value in March (Table 1).

Table 1 – Rainfall in the experimental period (February 08, 2021 to June 10, 2021)

Months	Amount of rainfall (mm)
February	51.4
March	100.1
April	56.7
May	57.9
June	0.2

Source: Authors (2022)

In where: mm = millimeter.

The soil fertility in the experimental area was performed in the 0–20 cm layer (Table 2) was evaluating the physical and chemical properties (Tedesco *et al*., 1995). Soil restoration started on September 23, 2020 with liming, using 2.3 tons per hectare and then invasive plant control was carried out. On January 19, 2021, soil preparation was performed applyng of 350 kg per hectare of single superphosphate (Ca(H2PO4)2 + CaSO4.2H2O), 320 kg per hectare of potassium chloride (60% K2O) and subjected to subsoiling to a depth of 30 cm. After 6 months of pasture restoration, in July 2021, a second soil analysis was performed (Table 2).

Table 2 – Soil physical and chemical properties in the experimental area before and six months after the forage recovery in paddocks with and without eucalyptus planting

Soil parameters	Before pasture restoration	6 months after pasture restoration – paddocks without trees	6 months after pasture restoration – paddocks with trees
pH-SMP (UN)	6.3	-	-
pH $CaCl_2$ (UN)	5.1	5.3	5.47
Ca+Mg (cmolc.dm^{-3})	3.58	4.34	4.6
Ca (cmolc.dm^{-3})	2.42	3.17	3.43
Mg (cmolc.dm^{-3})	1.16	1.17	1.17
Al (cmolc.dm^{-3})	0.16	0.0	0.0
H+Al (cmolc.dm^{-3})	3.9	3.3	3.10
CEC (cmolc.dm^{-3})	-	8.11	8.22
K (cmolc.dm^{-3})	0.18	0.48	0.52
K (mg.dm^{-3}(ppm))	70	186	202
P (Mehlich (mg.dm^{-3}(ppm)))	1.4	6.67	6.47
S (mg.dm^{-3}(ppm))	2.2	-	-
B (mg.dm^{-3}(ppm))	0.22	-	-
Cu (mg.dm^{-3})	2.8	-	-
Fe (mg.dm^{-3})	24	-	-
Mn (mg.dm^{-3})	21.4	-	-
Zn (mg.dm^{-3})	0.9	-	-
Na (mg.dm^{-3})	2.5	-	-
O.M. (g.kg)	28.3	21	22
O.M. (%)	-	2.10	2.2
T (cmolc.dm^{-3})	7.7	-	-
t (cmolc.dm^{-3})	3.9	-	-
V (%)	48.8	58.67	61.67
Al Sat. (%)	4.1	0.0	0.0
Ca/CEC (%)	31.4	38.7	41.47
Mg/EC (%)	15.1	14.07	13.97
K/CEC (%)	2.3	5.93	6.23
H+Al/CTC (%)	50.6	41.03	38.13
Clay (g.dm^{-3})	525	-	-
Silt (g.dm^{-3})	75	-	-
Sand (g.dm^{-3})	400	-	-

Source: Authors (2022)
In where: Ca = calcium, CEC = cation exchange capacity, K = potassium, Al = aluminum, Mg = magnesium, Al Sat. (%) = aluminum saturation, Cu = copper, Fe = iron, H+Al = total or potential acidity, O.M. = organic matter, t= effective CEC, T= CEC at pH 7.0, m%= Percentage of base saturation, S= Sulfur, B= Boron, P= Phosphorus, Na= Sodium Content.

The experimental area of 9 hectares of Brachiaria brizantha cv. Marandu pasture, already restored, was divided into 18 paddocks (0.5 ha/paddock), with nine forestry arrangements and nine control treatments.

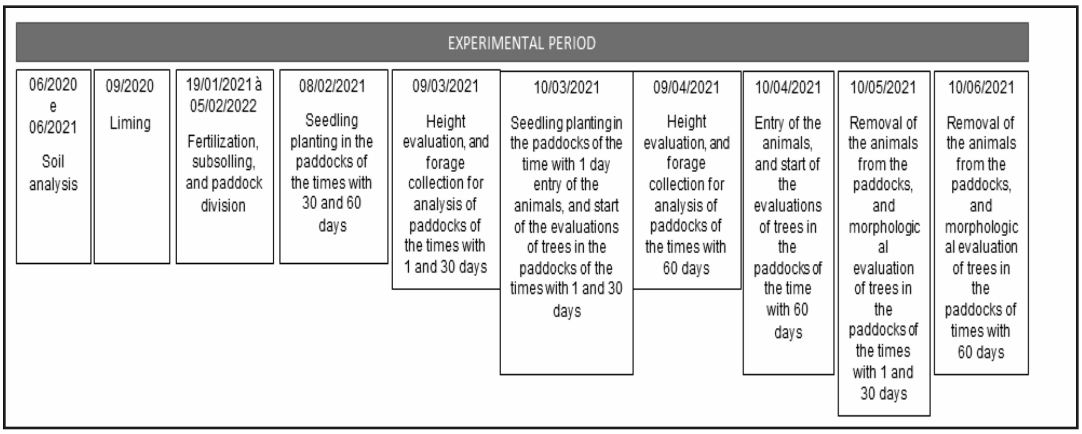
In nine of the 18 paddocks, 648 eucalyptus seedlings (*Corymbia citriodora*) were planted in dense groups, in a completely randomized design with three protective models and a single planting, totaling four (1, 3, 5 and 9) arrangements, and three (1, 30 and 60 days) entry times of the animals into the paddocks after planting the seedling were evaluated. At the entry time of the animals with 30 and 60 days (D30 and D60), seedlings were planted on February 8, 2021, and at the entry time of the animals with 1 day (D1), planting took place on March 10, 2021, along with the entry of the animals.

Trees seedlings were planted in the paddocks with entry times D1 and D30 after pasture restoration because after subsoiling the pasture required 30 days to establish and grow before the animals entered. The arrangements consisted of 1, 3, 5 and 9 eucalyptus (*Corymbia citriodora*) plants (A1, A3, A5 and A9) spaced 30 cm apart.

The arrangements were spaced 10 x 10m apart, and distributed randomly in the area, totaling the planting of 24 protective models in each paddock, six of each arrangement.

The entry times D1 and D30 after planting the seedlings was on March 10, 2021, and the entry time D60 after planting on April 10, 2021, as can be seen in Figure 1. Animals remained for 60 days, in all paddocks, with a stocking rate of 2.41 ± 0.06 AU per hectare, under continuous grazing.

Figure 2 – Experimental schedule



Source: Authors (2022)

At entry times, forage height was measured and samples were also collected to assess the availability of dry matter per hectare.

During the permanence of the animals in the paddocks (60 days), the survival of the trees was evaluated weekly in all arrangements and paddocks, totaling 10 evaluations in the period of 60 days.

The animals' exit from the paddocks was determined by the forage height at the pre-determined target of 15 cm, which occurred 60 days after the animals' entry, regardless of the entry time. After the animals leaving the paddock, the trees had the height, and the crown average diameter measured by tape and the stem thickness base evaluated using a caliper.

The design used was completely randomized, in a 3 x 4 factorial arrangement of three entry times of the animals after planting (1, 30 and 60 days) and four types of arrangements (1, 3, 5 and 9 eucalyptus seedlings per arrangement), to assess tree survival. Dry matter availability and forage quality were evaluated at the entry of the animals into the paddocks.

The results of forage analysis, height, stem thickness, and average diameter were obtained through statistical analysis using the R software with "ExpDes.pt" package (Ferreira *et al*., 2013), subjecting to the analysis of variance model ANOVA in DIC, at 5% significance, according to Tukey's test. Tree survival analysis with a 95% probability interval, was suitable for the logistic regression model, using the "Car" (Fox *et al*., 2019) and "MASS" (Venables *et al*., 2002) packages. Significant effects were interpreted by the "Odds Ratio (OR)" using the "Broom" package. Graphs were constructed using the "ggplot" package (Wickham, 2016).

3 RESULTS AND DISCUSSIONS

The average stocking rate of the paddocks with the entry time of the animals at 1, 30, and 60 days were 2.48, 2.37 and 2.36 AU per hectare, respectively, with no difference between the times (P=0.199). The average sward height in the paddocks with the entry time of the animals with 1, 30 and 60 days was 29.84 ± 6.00 cm; 31.08 ± 5.18 cm and 42.37 ± 4.07 cm, respectively, being higher ($P<0.001$) in the paddock with animals entering 60 days after planting. In the entry at 60 days, there was a higher amount of dry matter (DM kg ha-1) and neutral detergent fiber (NDF) content compared to the entry at 30 days, and the mineral matter (MM) was higher at the entry of the animals with 30 days compared to entry at 60 days (Table 3).

Table 3 – Dry matter availability and forage quality, at the entry of the animals, at different times, 1, 30 and 60 days after planting the trees

Variable	**Time (days)**			***P-value***	**CV (%)**
	1	**30**	**60**		
DM (kg ha^{-1})	3141.9 ab	2687.40 b	3453.59 a	0.0483	15.37%
NDF (%)	79.46 ab	77.76 b	81.99 a	0.0157	2.67%
ADF (%)	49.44	42.28	48.63	0.1625	14.09%
MM (%)	7.75 ab	8.58 a	7.04 b	0.00804	8.88%
EE (%)	1.98	1.35	1.55	0.7119	81.93%
LIG (%)	27.74	27.44	21.91	0.4570	11.89%
CP (%)	6.01	6.07	5.73	0.6160	10.61%
TDN (%)	50.72	56.91	50.88	0.1174	10.2%

Source: Authors (2022)

In where: DM: Dry matter; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; MM: Mineral matter; EE: Ether extract; LIG: Lignin; CP: Crude Protein; TDN: Total digestible nutrients. Different lowercase letters (a, ab, b), in the same row, indicate significant differences. Results obtained by Tukey's test at 5% probability.

There was a significant effect of the entry time of the animals on the forage composition in the percentage of DM kg ha-1, NDF and MM. The greater amount of DM and NDF content, at entry D60 compared to D30, must be to the advance of the maturity of the grass, which increased the volume and had greater growth for the longer time until the entry of the animals, and consequently, the amount of NDF increased. There is usually a thickening of the cell wall, causing an increase in the DM content and a decrease in the CP content (Coelho *et al*., 2014), although there was no significance in the CP content between the times. Thus, the entry of the animals into the paddocks can be extended up to 60 days, because after it the forage begins to lose quality, increasing the fiber content and decreasing the CP content.

There was no difference for the variables DM kg ha^{-1}, NDF, MM, LIG, and CP, when evaluating the effects of the presence or absence of eucalyptus (*Corymbia citriodora*) on the amount and quality of forage in paddocks with and without eucalyptus, however, a difference was detected for the variables ADF and TDN (Table 4). The values of TDN and ADF were higher in the system with the presence of eucalyptus due to the better microclimate and greater moisture retention in the soil, which provided more uniform and healthy grass growth. Additionally, this influenced the quality of the fiber, making it more palatable and digestible for the animals.

Table 4 – Dry matter availability and forage quality, in paddocks with and without eucalyptus (*Corymbia citriodora*) before the entry of the animals

Variables	**Paddock**		***P-value***
	with eucalyptus	**without eucalyptus**	
DM (kg ha^{-1})	3136.10	3052.61	0.7163
NDF (%)	79.63	79.84	0.8315
ADF (%)	50.60	42.98	0.0309
MM (%)	7.76	7.88	0.8758
EE (%)	1.94	1.30	0.3178
LIG (%)	27.15	24.27	0.5019
CP (%)	5.85	6.01	0.6070
TDN (%)	56.08	49.60	0.0252

Source: Authors (2022)

In where: DM: Dry matter; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; MM: Mineral matter; EE: Ether extract; LIG: Lignin; CP: Protein; TDN: Total digestible nutrients.

In paddocks with eucalyptus, there was a higher percentage of ADF and TDN (Table 4), which may be because the trees influenced the increase of dry matter in the pasture, energy and minerals, being responsible for reducing the NDF content by the physical and chemical improvements of the soil (Rivera-Herrera, 2017).

According to Bernardino and Garcia (2009), Marandu and Mombaça cultivars produced, respectively, 30% and 14% more mass in paddocks with trees than in full sun, and the evaluation occurred at the time of low rainfall, showing that the presence of trees in the environment can be efficient in retaining soil moisture, making a difference in forage growth and quality.

Tree species can absorb water from greater depths compared to the grass root system. This may be an additional advantage for paddocks with trees, since the tree component, by absorbing water from greater depths and making it available to the microenvironment, through transpiration and exudates, provides nutrients for forages, whose roots are mostly superficial (Bernardino; Garcia, 2009). However, in this study, the tree component was newly planted and its search for nutrients was lower compared to the root system of the pasture that was deeper.

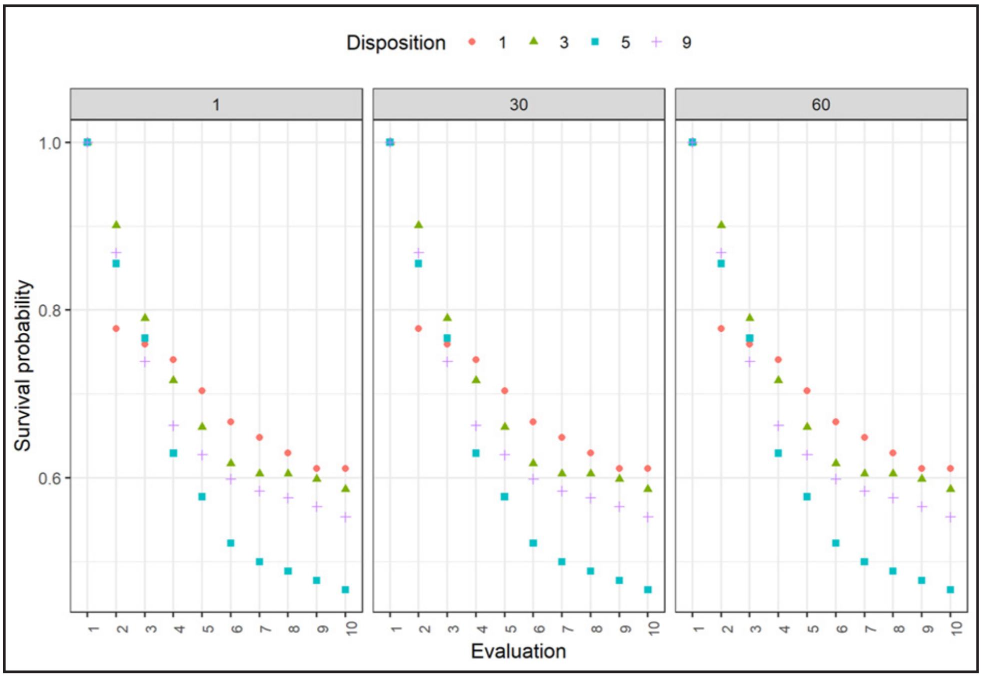
Oliveira *et al*. (2007) evaluated the productive performance of Brachiaria brizantha (Hochst. ex A. Rich.) Stapf cv. Marandu under different structural arrangements of an agrosilvopastoral system with eucalyptus in the Cerrado of the Minas Gerais state. They concluded that the available forage was always higher between the rows (shaded) than in the planting row, regardless of the eucalyptus planting arrangement. And the varied arrangements of the agrosilvopastoral system practically did not cause variation in the fiber, nitrogen and phosphorus content in the forage. The calcium, potassium and manganese contents in the forage were higher under the planting rows.

After the animals entered the paddocks at entry times D1, D30 and D60, tree survival analysis was performed, which were divided into survival of each tree and survival of at least one tree within each arrangement. Survival probability of each tree by arrangement, no difference was observed between them, regardless of the entry time of the animals (P>0.05) (Figure 3).

Survival analysis of each tree by entry time of the animals, a difference was observed between times at D1, D30, and D60, regardless of the arrangement (Figure 4).

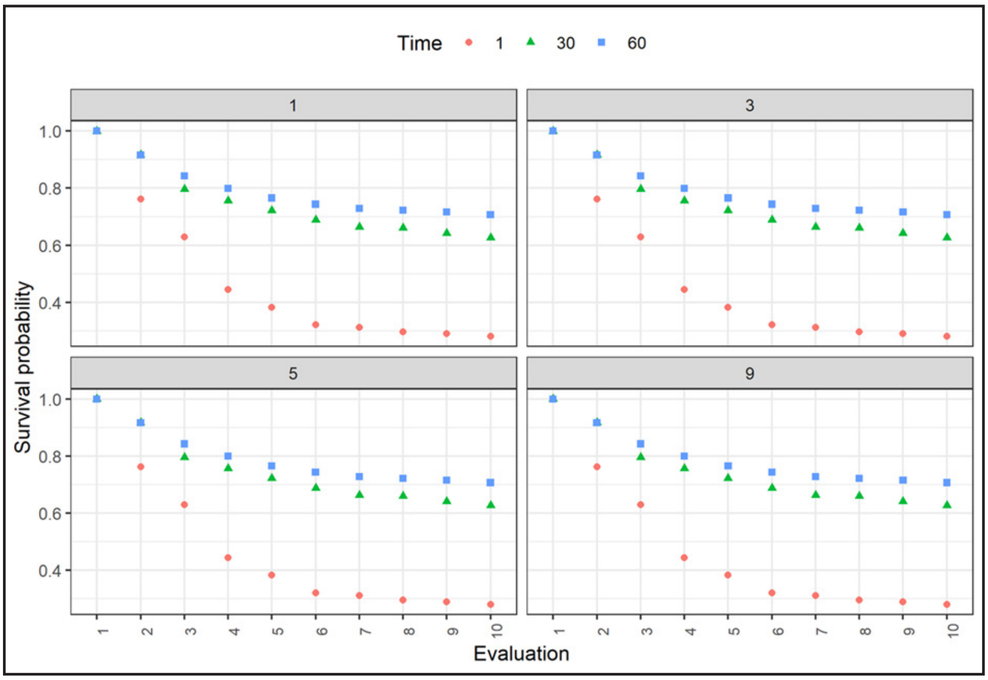
In Table 5, the entry time of the animals with 60 days (D60), the survival probability of the trees was 21.07 times greater than D1, and at D30, the survival probability was 5.96 times higher than D1. Trees planted at the same entry time D1 were more damaged and had a lower probability of survival with the presence of cattle, since they did not have time to establish up in the soil.

Figure 3 – Probability of survival of each tree in different dispositions 1 (with only one tree in the arrangement), 3 (three trees in the arrangement), 5 (five trees in the arrangement), and 9 (nine trees in the arrangement) at three



Source: Authors (2022)

Figure 4 – Probability of survival of each tree by entry time of the animals with 1 day, 30 days, and 60 days after planting the trees in different dispositions



Source: Authors (2022)

Higher probability of tree survival at the entry time of the animals at D60 can be explained by the longer period for establishment in the soil, before the entry of the animals, favoring the growth and survival of the trees.

Table 5 – Probability of tree survival by entry time of the animals with 1, 30 and 60 days, regardless of arrangement

Entry time (days)	OR	p-value	95% CI[1]
1	Reference	-	-
30	5.96	*	4.24-8.48
60	21.07	*	13.16-35.29

Source: Authors (2022)

In where: CI = 95% Confidence interval, *= P<0.05.

Another factor that should be considered is that the greater amount of forage available in the paddocks at the entry of animals after D60, can lead to a lower movement of animals inside the paddocks in search of food. As a result, there may have been a reduction in physical damage, with greater strengthening of the root system, favoring the survival of plants.

Evaluating the probability of survival of at least one tree within each arrangement (1, 3, 5 and 9), it was observed that the entry time of the animals D30 and D60 were 4.41 and 20.9 times more chance of having a live tree than D1, respectively. Regarding the arrangements, A3, A5 and A9 were 3.03, 5.43 and 16.6 times more likely to have a living tree than A1, respectively (Table 6).

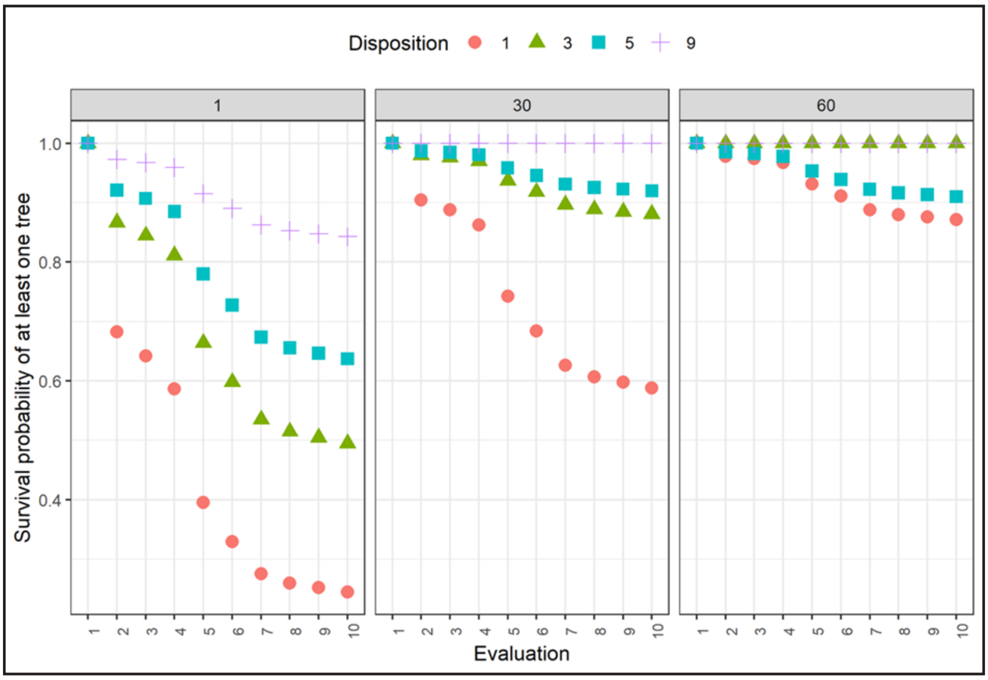
Table 6 – Probability of survival of at least one tree according to the entry time of the animals and arrangements

Time	OR	*p-value*	95% CI[1]
1	Reference	-	-
30	4.41	*	2.71-7.29
60	20.9	*	11.0-42.5
Arrangement	-		-
1	Reference	-	-
3	3.03	*	1.88-4.91
5	5.43	*	3.30-9.10
9	16.6	*	9.04-31.9

Source: Authors (2022)

In where: CI = 95% Confidence interval, *= p<0.05.

Figure 5 – Probability of survival of at least one tree within each disposition of plants 1, 3, 5 and 9 at different entry times



Source: Authors (2022)

In the morphological evaluation of the trees, there was no significant effect of the interaction between entry time and type of arrangement, on plant height (p=0.104) and stem thickness (p=0,217). The height of the trees was different between all entry times, and the stem thickness was smaller at entry time D1 than D30 and D60 (Table 7). In the evaluation of the average diameter of the crown, significance was observed in the interaction between entry time and type of arrangement (Table 8).

Table 7 – Plant height (cm) and stem thickness (mm) of eucalyptus (*Corymbia citriodora*) according to animal entry times, types of disposition and interaction between entry times and disposition

	Time (TIM)			Disposition (DIS)					P-value		
	1	**30**	**60**	**1**	**3**	**5**	**9**	**CV%**	**TIM**	**DIS**	**TIM * DIS**
Height (cm)	41.90c	71.19b	81.95a	72.29	66.60	71.01	72.25	31.40	0.000	0.397	0.104
Thickness (mm)	4.53b	10.03a	8.46a	6.91	6.95	7.43	9.56	108.12	0.004	0.170	0.217

Source: Authors (2022)

In where: CV = coefficient of variation. Different lowercase letters, in the same row, indicate significant differences between entry times.

After breaking down (Table 8), in arrangements A3 at the entry time D60, the crown diameter was greater than at the entry times D1 and D30 (29.27 vs 16.52 and 18.38). In A9 at entry times D30 and D60 were higher than at entry time D1 (26.77; 21.12 versus 13.72).

Regardless of the entry time and arrangement, the trees developed below expectations. It can be explained by the planting density, since the number of plants per unit of area influences the height and diameter of the tree. In addition, competition with pasture can be harmful to the initial development of plants. Systems where there is less competition, individual performance is higher (Ribeiro *et al*., 2020).

Table 8 – Mean diameter (cm) of the eucalyptus (*Corymbia citriodora*) crown according to the entry times and the different dispositions evaluated

		Time (TIM)			**P-value**			
					CV%	**TIM**	**DIS**	**TIM * DIS**
		1	**30**	**60**	**48.9**	**0.000**	**0.863**	**0.002**
Disposition (DIS)	1	10.50 aA	22.10 aA	25.57 aA				
	3	16.52 bA	18.38 bA	29.27 aA				
	5	19.57 aA	21.45 aA	26.64 aA				
	9	13.72 bA	26.77 aA	21.12 aA				

Source: Authors (2022)

In where: * Different lowercase letters, in the same row, indicate significant differences by Tukey's test at 5% probability.

Consequently, the entry time of animals D30 and D60 was longer, favoring the development of trees and fixing their roots in the soil. Thus, the trees at entry time D1 suffered greater consequences due to the presence of animals on the same planting date. Further, the trees grew slowly due to competition with the already planted brachiaria.

4 CONCLUSIONS

It is feasible to implement the silvopastoral system simultaneously with pasture restoration. Allowing animals to enter the area 30 days after planting the seedlings increases the probability of tree survival, especially with planting arrangements of 3, 5, or 9 seedlings per grouping. This approach promotes both effective pasture recovery and higher tree survival rates, optimizing the system's long-term sustainability.

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Authorship Contribution

1 Larissa de Souza Reis

TMaster in Animal Science

https://orcid.org/0000-0002-9935-5383 • larissasouza321@hotmail.com

Contribution: Conceptualization; Formal analysis; Investigation; Supervision; Writing – original draft

2 Sthéfany Noronha dos Santos

Undergraduate student in Animal Science

https://orcid.org/0000-0001-9626-565X • sthefanysnds2001@gmail.com

Contribution: Investigation

3 Matheus Ferreira Paula

Undergraduate student in Animal Science

https://orcid.org/0000-0003-0099-6058 • matheusfpaula@hotmail.com

Contribution: Investigation

4 Jakeline Fernandes Cabral

Doctor in Animal Science

https://orcid.org/0000-0002-3664-4073 • kell-f@hotmail.com

Contribution: Investigation

5 Leandro Carlos

Doctor in Forest Engineering

https://orcid.org/0000-0003-1736-6079 • leandro.carlos@ifgoiano.edu.br

Contribution: Methodology; Formal analysis

6 Tiago do Prado Paim

Doctor in Animal Sciences

https://orcid.org/0000-0002-9486-7128 • tiago.paim@ifgoiano.edu.br

Contribution: Formal analysis; Data curation; Software

7 Tiago Pereira Guimarães

Doctor in Animal Sciences

https://orcid.org/0000-0002-3473-8148 • tiago.guimaraes@ifgoiano.edu.br

Contribution: Formal analysis

8 Thaisa Campos Marques

Doctor in Animal Production

https://orcid.org/0000-0003-1112-6699 • tcamposmarques@gmail.com

Contribution: Supervision; Conceptualization; Writing – original draft; Writing – review & editing

9 Karen Martins Leão

Doctor in Veterinary Medicine

https://orcid.org/0000-0001-5236-7558 • karen.leao@ifgoiano.edu.br

Contribution: Methodology; Supervision; Conceptualization; Writing – original draft; Writing – review & editing

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