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FORESTRY SCIENCE

Associations between tree spacing and features of native grassland grown in silvopastoral systems in Pampa biome

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ABSTRACT: The current study assessed the association of eucalyptus-tree spacing with forest growth and yield, as well as with the floristic composition, diversity and yield of natural grassland grown in silvopastoral systems in Pampa biome. Data were collected in six family cattle-ranching area in Bagé County (RS). The effect of two different genetic materials (seminal-origin *Eucalyptus dunnii* plant and one *Eucalyptus grandis* clone) on shading features of plants grown in 3 planting-spacing dimensions (625, 312 and 208 trees ha^{-1}) was assessed, as well as their association with herbaceous extract (bare soil; green cover; forage dry matter; floristic composition; species richness; and grass, legumes and winter - and summer-growth species rates) and forestry (litter accumulation, diameter at breast height, total height and volume per hectare) variables. Planting carried out at the highest tree density (625 trees ha^{-1}) has increased forest yield. However, it reduced green cover, herbaceous extract dry-matter yield and species richness, mainly in grasses and legumes with greater forage potential. Conversely, it is possible combining forestry and animal yield to the preservation of native forage species at low tree densities (204 to 312 trees ha^{-1}).
Key words: natural grassland, floristic composition, eucalyptus.

Relações entre o espaçamento arbóreo e características do campo nativo em sistemas silvipastoris no bioma Pampa

RESUMO: O trabalho foi desenvolvido com o objetivo de avaliar as relações entre o espaçamento de árvores de eucalipto com o crescimento, produção florestal e a composição florística, diversidade e produção de pastagens nativas em sistemas silvipastoris no bioma Pampa. Os dados foram coletados em seis unidades de referência tecnológicas instaladas em área de pecuaristas familiares no município de Bagé (RS) e foi avaliado o efeito de dois materiais genéticos (*Eucalyptus dunnii* de origem seminal e um clone de *Eucalyptus grandis*) em três densidades arbóreas (625, 312 e 208 árvores ha^{-1}) sobre o sombreamento e suas relações com variáveis do extrato herbáceo (solo descoberto, cobertura verde, massa seca de forragem, composição florística, riqueza de espécies e o percentual de gramíneas, leguminosas e espécies de crescimento hibernal e estival) e florestais (acúmulo de serapilheira, diâmetro a altura do peito, altura total e volume por hectare). Concluiu-se que o plantio em maior densidade arbórea (625 árvores ha^{-1}) promoveu o aumento na produção florestal, mas reduziu a cobertura verde, a produção de matéria seca do extrato herbáceo e a riqueza de espécies, especialmente, as gramíneas e leguminosas de maior potencial forrageiro. Em baixas densidades arbóreas (204 a 312 árvores ha^{-1}) é possível conciliar a produção florestal com a preservação de espécies forrageiras nativas.
Palavras-chave: campo nativo, composição floristica, eucalipto.

INTRODUCTION

The Pampa biome covers 62.2% of Rio Grande do Sul State's territory; moreover, it is a great cultural heritage given its remarkable floral and faunal biodiversity (BOLDRINI et al., 2010). Extensive livestock farming carried out in native grasslands has been one of the main economic activities in place in this region, since the colonization period. Nowadays, the aforementioned region houses 48%, 66% and 8% of cattle, sheep and dairy cow herds bred in Rio Grande do Sul State, respectively (IBGE, 2020).

However; although, extensive livestock farming carried out in natural grasslands is a traditional practice, it often presents low yield and economic profitability (MALAFAIA et al., 2014; LAMPERT et al., 2015). This issue has encouraged the de-characterization and replacement of natural grasslands by other economic activities, such as agricultural and forestry monocultures and exotic pasture cultures, a fact that has reduced the native vegetation cover in the investigated biome (approximately 64%), as well as cattle and sheep herds, by 1.5 million (22%) and 691.8 thousand (25 %) heads, respectively, between 2004 and 2019 (OLIVEIRA, 2021).

Thus, silvopastoral systems can be used as sustainable and integrated land-use alternative to promote production matrix diversification in rural properties based on forestry activity introduction in them, and to enable environmental services, such as

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animal welfare, by reducing extreme temperatures or thermal sensations in summer and winter (SCHINATO et al., 2023). It is so, because those are limiting factors for animal yield in the investigated region (LUCAS et al., 2015).

However, from the natural grassland conservation perspective, the afforestation of these pastures should not imply natural grassland`s suppression; they should remain productive to help supporting animal yield and the delivery of ecosystem services, such as the ones mentioned by VOLK & TRINDADE (2020), as well as to help maintaining the biodiversity of forage species and their potential to store water and fix carbon in the soil.

In Silvopastoral systems, trees and ground vegetation compete for both above ground (light) and below ground (soil moisture and nutrients) site resources. These complex interactions among direct and indirect effects of microclimatic conditions, soil properties, herbivore behavior and disturbance regimes can widely change depending on local conditions (BERNARDI et al., 2016).

The presence of trees changes both the availability and quality of light reaching forage species; besides, it can influence their structure, floristic composition and dynamics, growth, yield and nutritional value (PACIULLO et al., 2011; NORDENSTAHL et al., 2011; BERNARDI et al., 2016; FEDRIGO et al., 2019).

The availability of light for forage species and competition can be regulated by the density and arrangement of trees in the pasture area (VARELA et al., 2019) and some studies have shown that appropriately spaced trees have potential to positively alter botanical composition, growth, and nutricional value, in natural grasslands (CLAVIJO et al., 2005; FEDRIGO et al., 2019). Therefore, defining tree spacing that allow the maintenance of natural grassland throughout the forest component age rotation in the edaphoclimatic conditions of Pampa in the state of Rio Grande do Sul is fundamental for conserving native vegetation.

The current study was to assess the association of eucalyptus tree spacing with forest growth and yield, as well as with the floristic composition, diversity and yield of natural grassland grown in silvopastoral systems in Pampa biome.

MATERIALS AND METHODS

The region's climate, according to the Köppen classification, is subtropical (Cfa) with rainfall regularly distributed throughout the year with annual normals between 1.350 mm and 1.650 mm and monthly normals of 90 to 170 mm (MACHADO, 1950).

The average annual temperature is 17.6 °C, with the average for the hottest month (January) being 24 °C and the coldest month (June) being 12.5 °C. Extreme temperatures vary between -4 °C in the coldest month and 41 °C in the hottest month. Frost formation occurs from April to November, with a greater incidence from June to August (MACEDO, 1984).

Based on data obtained at the Bagé climatological station of the National Institute of Meteorology, it was observed that in 2019, it rained slightly above the historical average with 1,703.6 mm, a result of the el niño recorded in 2018/2019 with precipitation in the month driest of 20.7 mm (March) and the wettest of 445.1 mm (January). Regarding temperature, the lowest averages were recorded in June and July (7.3 ºC) and the highest in December (31.3 ºC).

The predominant soils in the region studied, more precisely in the subdistricts of Palmas and Joca Tavares, where most of the plantations evaluated here are located, are of the Chernosol type, shallow, with clayey texture and granite or andesite substrate and of the Neosol type Dystrophic or Eutrophic texture medium, granite or sandstone substrate (MACEDO, 1984)

Data were collected between December and February 2020/2021, in 6 Technological Reference Units (TRUs) installed by *Embrapa Pecuária Sul* and *Emater* in a family cattle-ranching area in Bagé County (RS), between 2013 and 2014.

Two different genetic materials (seminal-origin *Eucalyptus dunnii* and *Eucalyptus grandis* clone) were assessed in 3 planting-spacing dimensions (8 m x 2 m, 16 m x 2 m and 24 m x 2 m) comprising 625, 312 and 208 trees ha^{-1} arranged in simple lines, in natural grassland. Each URT was implanted with an area of 3 hectares subdivided into two spacings with 1.5 hectares. *E. dunni* had been planted for 91 months with 625 and 312 trees ha^{-1} and *E. grandis* for 85 months, with 312 and 208 trees ha^{-1}.Further details on the planting and management of these areas can be seen in the study by LUCAS et al. (2015).

One (1) in every 5 rows (20% of the total number of trees) in each TRU and planting arrangement was randomly measured to collect tree-growth data. All trees in the selected row had their diameter at breast height (DBH) measured with diameter tape (cm), whereas their total height (h) was measured with electronic hypsometer (m).

Tree volume was determined through the rigorous cubing of standing trees, based on using Criterium RD 1000 equipment. Sample trees were selected based on diameter class; each population (defined by genetic material and spacing) was divided into 10 classes - 2 trees belonging to each class were cubed (100 trees, in total). Tree height and volume estimates for each location (TRU) were obtained after selecting and adjusting the model by Stoffels: $lnh = b_0 + b_1 lnd$ and the combined variable model by Spurr: $logv = b_0 + b_1\ log(d^2h)$. Further details can be found in the study by TONINI et al. (2020).

The surface sampling method used for pastures comprised sample units (SUs) of 0.25 m^2 (0.5 m x 0.5 m), which were systematically distributed into 3 transects, based on spacing and location. SUs in each transect were arranged in the tree row (0D), at one quarter (25d) and at half the distance between tree rows (50d).

A full-sun field area (FSFA) free from trees' influence in a single pasture was selected as reference for dry matter production in this environment. Three (3) samples were collected per place by visually selecting areas of high, medium and low green matter yield.

All TRUs were operating under grazing system, without stocking control; most fields presented "shaved" or excessively used aspect, at assessment time. There were no fences dividing the areas and it enabled the herd to graze in areas with, and without, forest component.

Photosynthetically active radiation (PAR) measurements were taken at clear-sky days, with the aid of Accupar ceptometer, model LP 80, (Decagon, Pullman, WA, USA); shading rates were determined at different distances from the row of trees in each TRU.

Exposed soil (ES%), green cover (GC%), litter accumulation (LA) (leaves, branches, bark and fruits) rates were determined in each SU. Species composition was expressed by grass (G%), legume (L%), winter (W%) and summer-growth (S%) species rates.

Total herbaceous dry matter production (TDM) was separated into green (GDM) and dead (DDM) dry matter. In order to do so, fresh matter was cut and weighed in the field; subsequently, it was dried in forced air circulation oven at 65 °C, for 72 hours.

The coverage of all species was estimated and their absolute (Af) and relative frequency (Rf) values were calculated. Floristic similarity between spacing dimensions was compared through Sorensen Index (SI), whereas species richness was calculated based on the number of species (SN) in the investigated native grassland.

Species were gathered into 5 functional groups, based on NABINGER & DALL'AGNOL (2019), namely: 1 - summer-growing cespitose grasses; 2 - summer-growing prostrate grasses; 3 - winter-growing grasses; 4 - winter-growing legumes; 5 - non-forage plants. Relative grass and legume contribution, as well as that of their growth habit (winter/summer) to species richness, were calculated.

Since the eucalyptus materials were planted in different places and at different times, it was not possible to make comparisons between them. T-test for unpaired, unilateral and independent samples was performed to investigate the effect of spacing on the assessed variables in the same genetic material. F-test was used to assess whether the recorded means derived from treatments with equal or different variances; it was done to test the equality-of-variances hypothesis (Ho:$\sigma_1^2 = \sigma_2^2$), based on BHERING & TEODORO (2021).

Normality of residuals was assessed through Shapiro-Wilk test; effect size was measured based on Pearson's Correlation Coefficient (r), which, in its turn, was calculated based on Rosenthal's conversion and assessed based on Cohen scale, according to FIELD (2009). The amount of variation explained by spacing was measured through Coefficient of Determination (R^2).

RESULTS

Tree growth, yield and biomass composition under trees' canopy

Preliminary data analysis has indicated that all variables showed normality of residuals. Hypothesis Ho: $\sigma_1^2 = \sigma_2^2$ was rejected for variables shading (S%) and LA in both genetic materials, as well as for variable DDM in *E. grandis* - t value associated with these data was calculated for groups showing different variances.

Based on the assessment of spacing effect on *E. dunnii* (Table 1), differences observed in means recorded for BS% ($t_{(3)} = -1.1$; P = 0.15) and H ($t_{(3)} = 4.7$; P = 0.12) were not significant, whereas the other variables have evidenced strong spacing effect (r > 0.5) capable of explaining from 80% to 97% of the observed variation.

Spacing of 8 m x 2 m recorded the highest mean values for the variables shading ($t_{(5)}$=9.9; P < 0.001, r=0.97; R^2=0.95), litter accumulation in the soil ($t_{(10)}$=6.3; P < 0.001, r=0.89; R^2=0.80) and wood volume per hectare ($t_{(4)}$=9.7; P < 0.0003, r= 0.97; R^2=0.96). Conversely ,the lowest values were recorded for green cover ($t_{(10)}$ =-10.9; P < 0.001, r=0.96; R^2=0.92), dry matter production (GDM - $t_{(10)}$=-6.9; P < 0.001, r=0.91; R2=0.83; TDM - $t_{(10)}$= -6.7; P < 0.001, r=0.91; R^2=0.82) and DBH ($t_{(3)}$ = -2.8; P=0.03, r=0.85; R^2=0.72).

Table 1 - Mean values recorded for variables, such as shading (S%), bare soil (BS%) litter accumulation (LA), Green cover (GC%), Green forage dry matter (GDM), Dead forage dry matter (DDM), Total forage dry matter (TDM), diameter at breast height (DBH), height (H) and volume per hectare, based on the genetic material and spacing adopted for silvopastoral systems investigated in Bagé County (RS).

Genetic material	Spacing (m)	S%	BS%	GC%	LA Kg ha^{-1}	GDM Kg ha^{-1}	DDM Kg ha^{-1}	TDM Kg ha^{-1}	DBH cm	H m	Volume (m^3)
E. dunnii	8x2	96.1*	1.2	2.60*	8551.0*	31.8*	17.8*	49.5*	17.4*	15.2	96.7*
	16x2	66.4*	3.2	46.5*	3431.1*	222.3*	364.4*	586.7*	19.9*	14.6	49.5*
FSFA				95.2		453.3	326.7	780.0			
E. grandis	16x2	60.7*	6.2*	47.7	2841.5	373.3	337.7	690.3	14.7	12.3	26.0*
	24x2	46.4*	13.4*	58.8	3893.2	302.3	268.7	571.0	14.3	10.9	14.1*
FSFA				87.5		786.7	782.7	1569.4			

*Significant at 5% level in the T-Test. FSFA = Full-sun field area.

Evaluated spacings to *E. grandis* recorded significant differences for S% ($t_{(16)}$= 2.3; P = 0.01; r= 0.49, R^2= 0.24), BS% ($t_{(19)}$ = -1.8; P = 0.04, r= 0.38; R^2 = 0.14) and tree volume per hectare ($t_{(4)}$= 2.4; P = 0.03, r= 0 .77; R^2 = 0.59).

Natural grassland composition and biodiversity

The floristic composition comprised 54 species and 3 genera distributed in 14 families. Poaceae, Asteraceae and Ciperaceae were the most representative families. Natural grassland vegetation richness and similarity between spacing dimensions were higher in TRUs planted with *E. grandis* trees, which presented 16 species (ranging from 8 to 21), on average, and SI = 0.59 (Table 2).

There was statistically significant difference in natural grassland composition only among spacings evaluated to *E. dunnii*; the smallest spacing between tree rows has shown reduced species richness and diversity. The use of 625 trees per hectare led to reduced species richness ($t_{(10)}$= -8.6; P < 0.001, r= 0.93; R^2 = 0.88), grass rate ($t_{(10)}$ = -3.6; P < 0.001, r = 0.77; R^2 = 0.57), legume rate ($t_{(10)}$ = -3.3 , P = 0.0004, r = 0.75; R^2 = 0, 57), winter-growing species ($t_{(10)}$ = -4.0; P = 0.001, r = 0.78; R^2 = 0.51) and summer-growing species ($t_{(10)}$ = -2.5; P = 0.001 , r = 0.61; R^2 = 0.38).

Live vegetation cover in this spacing ranged from 0.33% to 8.3%; mean value recorded for this parameter reached 1.3% due to large litter accumulation in the soil - 8,5 tons per hectare (Figure 1A and Table 1). *Elephantopus mollis* (Rf =18.1%), *Hypoxis decumbens* (Rf =18.2%) and *Sida rhombifolia* (Rf = 17.7%) were the most frequent species.

Bromus auleticus, commonly reported in natives forest edge areas, *Piptochaetium montevidense*, commonly found in quite poor grasslands undergoing degradation process, and *Piptochaetium stipoides* were observed among winter-growing grass species. Conversely, *Paspalum urvillei*, *Axonopus affinis* and *Desmodium incanum*, summer-growing leguminous plant also found in shrubby fields, "capoeiras" and in the edges of natural forests (NABINGER & DALL'AGNOL, 2019) were observed among summer-growing species.

Live vegetation cover increased after tree density was reduced to 312 trees per hectare; it ranged from 36.7% to 59.3%, and mean uncovered soil value reached 3.2%. *Desmodium incanum* (Rf = 18.2%), *Paspalum notatum* (Rf = 15.1) and

Table 2 - Mean values recorded for variables, such as Grass rate (G%), legumes rate (L%), winter-growing species rate (WGS%), summer-growing species rate (SGS%), species richness (SN) and Sorensen Index (SI), based on the genetic material and spacing adopted for silvopastoral systems investigated in Bagé County (RS).

Genetic material	Spacing (m)	G%	L%	WGS%	SGS%	SN	SI
E. dunnii	8x2	16.3*	2.4*	9.3*	9.3*	9*	0.37
	16x2	40.0*	11.4*	29.4*	22.1*	17*	
E. grandis	16x2	45.7	18.3	18.3	32.0	16	0.59
	24x2	39.4	12.1	12.1	29.6	16	

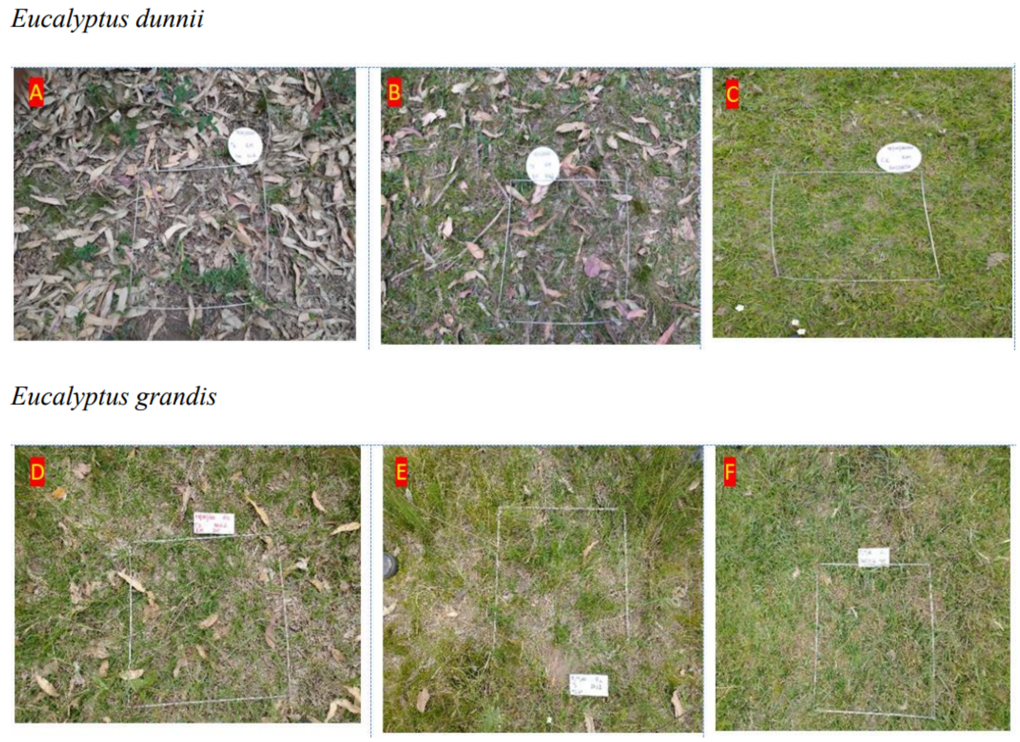

Figure 1 - Detail of samples collected in silvopastoral systems and in full-sun field area (C, F), as well as in silvopastoral system planted with *E.dunnii* at 8 m x 2 m (A) and 16 m x 2 m (B) and with *E. grandis* at 16 m x 2 m (D) and 24 m x 2 m (E) spacing dimensions.

Dichondra macrocalyx (Rf = 12.1) were the species mostly observed at this tree density.

Larger number of forage species was observed in areas planted with summer-growing cespitose grass species, such as *Chizachyrium tenerum*, *Setaria parviflora*, *Axonopus argentinus*; as well as summer-growing prostrate grass species, such as *Axonopus affinis*, *Stipa filiculmes*, *Piptochaetium stipoides*, *Paspalum lepton* and *Melica sarmentosa*; summer-growing grass species, such as *Piptochaetium montevidense*; *Chascolytrum subaristatum* , Vulpia australis; as well as summer-growing legume species, such as *Desmodium incanum* , and winter-growing legume species, such as *Trifolium polymorphum*. Only 5 species were often observed in the investigated phytophysiognomies, on average; 13 species were only found in the widest spacing; consequently, there was lower similarity between vegetation types.

Lower shading was observed in the spacing dimensions adopted for *E. grandis* (Table 1), and it led to little change in the floristic composition of the field between the two assessed spacing. There was larger number of species common to the investigated phytophysiognomies (15, on average; they ranged from 12 to 19 species) than the number of exclusive species (10, on average; they ranged from 5 to 13 species), and it resulted in greater floristic similarity.

Paspalum notatum (Rf =17.7%) and *Mnesithea selloana* (Rf = 12.8) were the most frequent forage grass species. *Piptochaetium montevidense* recorded the highest frequency (Rf =12.8%) in tree-planting rows, a fact that indicated its high tolerance to shading.

DISCUSSION

Results have shown that eucalyptus tree planting affected herbaceous extract production and biodiversity in natural grasslands; this finding corroborated studies conducted by NORDENSTAHL et al. (2011), FEDRIGO et al. (2019) and SCHINATO et al. (2023). The bidirectional behavior of interactions mentioned by VARELA et al. (2019), according to which, favoring one variable can decrease the development of another, was observed. In other words, increased tree density has favored wood production; on the other hand, it has reduced pasture supply for animals.

Green cover and green dry matter production at tree density of 625 trees ha^{-1} were 97% and 92.9% lower than values recorded for the full-sun area. These indicators improved when tree density dropped to 312 trees ha^{-1} (48.8% and 50.9%, respectively).

With respect to *E. grandis*, mean reduction recorded for GC and GDM reached 60.8% and 42.9%, respectively. These values can be considered high in comparison to those recorded by SCHINATO et al. (2023), who observed reduction by 20% when they compared dry matter produced in a full-sun area to that of a silvopastoral system planted with *E. grandis* at 18-meter spacing between rows (427 trees ha^{-1}), in natural grassland, in the Uruguayan Pampa. However, unlike the current study, the aforementioned authors only took into consideration pasture dry matter in the central region between tree rows and disregarded the region under the canopy.

Conversely, NORDENSTAHL et al. (2011) observed reduction by 52.6% in TDM, on average, compared 25-year-old *Populus deltoids* plantations at tree densities of 625 and 1,111 trees ha^{-1} to full-sun areas of prevalent Argentine Pampa natural grassland. The fact that this species loses all its leaves in winter may explain the smaller reduction in forage supply.

It is worth emphasizing that the herein collected data reflect reductions in dry matter production in summer, which is the season when most forage production takes place. Production losses may be even higher in winter, as pinpointed by SCHINATO et al. (2023), and it can be critical for the system, since low primary yield during winter often sets the limit for animal-carrying capacity in Pampa grasslands (NORDENSTAHL et al., 2011).

Shading and litter accumulation at tree density of 625 trees ha^{-1} can be associated with reduced number of species and herbaceous extract dry matter production. Shading, which ranged from 46.4% to 96.1%, can be considered excessive to maintain forage species growth in all spacing evaluated, since shading levels higher than 40% can affect the growth of most tropical grass species (PACIULLO et al., 2007), whereas maximum shading level at 50% can be applied as parameter for using winter-growing species in silvopastoral systems (VARELA et al., 2008).

Litter accumulation was strongly associated with *E. dunnii* tree density. The accumulation difference between the smallest (625 trees ha^{-1}) and the largest (312 trees ha^{-1}) spacing was 5, 2 tons ha^{-1}. Decrease in litter accumulated on the soil was followed by increase in green cover and dry matter production in the herbaceous stratum.

In total, 99.4% biomass under the ground was composed of litter at the density of 625 trees ha^{-1}; however, this rate dropped to 82.6% when tree density was reduced by 50% (312 trees ha^{-1}), and it increased TDM rate from 0.6% to 17.4% (i.e., increase by 191.5 kg ha^{-1}). This factor explains the low uncovered soil rate, despite the low soil cover by herbaceous extract species, observed for *E. dunni* in the smallest spacing.

Litter accumulation on the soil in eucalyptus plantations is often high and takes place due to low decomposition rates resulting from low nutritional quality, mainly with respect to nutrients such as Nitrogen and Phosphorus (PINTO et al., 2016). However, non-excessive litter accumulation can contribute to the nutrient cycle, increase organic matter contents in the soil and protect vulnerable areas from water and wind erosion events (BRUN et al., 2013).

Significant changes in natural grassland composition were observed at 625 trees ha^{-1}, namely: smaller number of species, as well as prevalence of shade-tolerant and winter-growing species found in areas bordering the forests, shrubby fields and fields undergoing degradation process. However, no significant increase in the number of winter-growing plants wasobserved, based on spacing and shading levels. On the other hand, CLAVIJO et al. (2005), BERNARDI et al. (2016) and NORDENSTAHL et al. (2011) investigated the effect of afforestation on natural grasslands in the Uruguayan and Argentinean Pampas and reported that shading has favored the growth of C3-metabolism plants.

Although, the grassland produced less dry matter than FSA at tree density ranging from 204 to 312 trees ha^{-1}, it proved to be rich in species and capable of maintaining significant number of grass and legume species of forage value. The non-observation of significant differences in dry matter production and species composition in the herbaceous extract between the two aforementioned spacings indicate that up to 85 months of planting, for this planting arrangement, at the evaluated age, there was little influence of trees from 16 meters of distance between tree lines.

Increase in spacing dimension had significant effect on forest yield, which is directly linked to the number of trees per hectare; however, trees grown in systems featured by lower tree density are expected to show greater diameter growth and individual volume due to less competition for production factors, such as nutrients, water and light (RIBEIRO et al., 2020).

The non-significance between mean DBH and H recorded for *E. grandis* has indicated that, up to the assessed age, competition in the planting row (which has the same spacing between treatments - 2 m) had greater influence on competition between trees than spacing between rows. The same finding was not observed for the spacing applied to *E. dunnii*, and it indicated that the 8-m distance has influenced growth and reduced individual growth.

Therefore, if one makes the option for densities close to 208 or 312 trees ha^{-1}, one should take into account that even if there is no significant difference in dry matter production in the herbaceous stratum, in species richness and in forage species incidence, there will be difference in the area occupied by the forestry component (in this case, 8.3% and 12.5%, respectively); consequently, it will result in lower wood volume production. This reduction in forest yield can be offset by increase in grazing area and stocking rate, depending on producers' goals.

Results have also indicated that, in order to reconcile forest and animal production to the preservation of natural grassland species throughout the forestry component cycle, it is necessary to continuously monitor the field and to apply silvicultural treatments, such as thinning and pruning, to enable light to enter the system; to adopt natural grassland management and improvement techniques, such as planting winter-growing species, fertilization and forage supply control, as well as low grazing intensities. These findings corroborated some recommendations by LUCAS et al. (2015).

CONCLUSION

Tree density was highly correlated to forest and forage production, as well as to natural grassland composition and diversity. Higher tree density promoted increase in forest yield; however, it reduced green cover, herbaceous extract dry matter production and species richness, mainly in grass and legume species with higher forage potential. It is possible combining forest and animal production to natural grassland species preservation at low tree densities. Tree densities ranging from 204 to 312 trees ha^{-1} were the most suitable for this purpose. It is so because;although,the field was less productive than the full-sun pasture, it remained diverse due to the maintenance of a significant number of grass and legume species of forage value.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors have equally contributed to the study design and manuscript writing. All authors have critically revised the manuscript and approved its final version.

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