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Dynamics of forage mass, air temperature and animal performance in a silvopastoral system of Uruguay

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Abstract This work studies the effects of forestation on forage mass and its chemical composition, as well as mean air temperature and their impact on beef cattle performance and grazing behaviour when compared to a natural grassland system. The systems comprised 100% natural grassland from the *Campos* biome (NG) and forested land (FL) 60% 6 y.o. *Pinus taeda* (500 trees per hectare) and 40% of natural grassland. We found that the crude protein composition of the pasture growing under the trees was higher, while mean air temperature was lower during the hot season. This changed the grazing pattern of the cattle, and was associated with higher average daily gain of the animals grazing in FL. We conclude that the introduction of trees in natural grasslands changed the environmental conditions, providing a better thermic and nutritive situation for growing grazing cattle that ultimately results in an increase in their productivity.

Keywords Forest · Natural grassland · Animal behavior · Productivity

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Introduction

Since 1987, the legal system stimulated the introduction of forestry in Uruguay, especially on soils where meat and wool production were limited (MGAP/CNFR 2012). Under this new paradigm, silvopastoral systems (SPS) evolved by the conversion of grazing lands to forest plantations in just a few decades (Cubbage et al. 2012). The importance of SPS for economic, ecological and social sustainability has been recognized in several regions around the world (Moreno et al. 2014). The introduction of trees in natural grasslands can decrease forage productivity (Peri et al. 2003) due to alterations in the quantity and quality of light in the environment, but mean leaf protein content may increase, improving photosynthetic efficiency in forage plants (Cruz 1997). Because of this, when associated with adequate forage mass, the quality increase in SPS may provide an opportunity for livestock farmers to improve daily weight gain of heifers.

Environmental conditions during the summer, even in temperate zones, can have a negative impact on beef

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cattle performance and behavior (i.e. reduction in dry matter intake) (Davis et al. 2003; Renaudeau et al. 2012). A way to mitigate the heat stress impact on animal welfare is the provision of artificial or natural shade, trees being the most effective source of shade (Armstrong 1994). In Uruguay, the provision of shade for 55 days during the summer decreased the respiratory rate on steers grazing under extensive conditions, although it had no impact on grazing period and average daily weight gain (Rovira y Velazco 2010). On the other hand, information on the effect of cold stress on productivity is less consistent, but the association of low temperature with moisture and wind can cause discomfort and increase energy expenditure in ruminants (Young 1983).

Although SPS are extremely common in Uruguay, and are practiced on most of the lands with forested plantations, information on animal behavior and performance in these systems for the whole year is still very limited (Cubbage et al. 2012). These systems may represent an opportunity to improve daily weight gain during the rearing phase of heifers, an important component of the productivity of the beef herd. The hypothesis of this study rests on the microclimate created by the introduction of trees, and the improvements in pasture quality and animal welfare brought by it, stimulates a greater growth on heifers grazing under these conditions, particularly during the hottest months of the year. Therefore, the objective of this study was to compare air temperature, forage mass and its bromatological composition with grazing behavior and performance of Hereford heifers in a forested versus a non-forested Campos grassland during their rearing phase.

Materials and methods

Experimental area and treatments

The experiment was carried out between June 2009 and October 2010 in a private forest company located in the department of Tacuarembó, Uruguay, a region of the *Campos* grasslands (Allen et al. 2011). The experiment was a randomized block design with two replications and the treatments were: 1) Forested land (FL), comprising 110 ha covered by *Pinus taeda* (60%) and by natural grassland (40%); and 2) Non-forested land (NFL) – composed of 74 ha of natural grassland. The seedlings were transplanted in July/August 2003 at a density of 1000 trees/ha, with a first thinning in 2006 to a density of 670 trees/ha and to 500 trees/ha in 2008 followed by pruning of 50% of the tree canopy. Both experimental units included natural waterways and were similar in topography and hydrography.

Herd management

The animals were transported to the experimental site at weaning, from eight different farms, located in the Basaltic region of the country, characterized by the absence of large forested areas. The experimental animals were all Hereford (*Bos taurus taurus*) heifers of 169 ± 2.0 kg of live weight, and were blocked by origin and live weight. Heifers grazed continuously and the stocking rate was adjusted to 0.5 livestock units/ha. Live weight measurements were performed in the morning, every 45 days, without previous fasting.

Evaluations

The behavior of the heifers was analyzed using the scan sampling method (Martin and Bateson 1993) during one day (daylight hours) for each season (Winter, Spring, Summer and Fall). Instantaneous activities (grazing, watering, ruminating, walking, lying or standing) were recorded every 10 min. To facilitate the measurement of activities we defined a representative smaller plot (delimited with electric fences) for each experimental unit, with ten allocated heifers each. The plots in the FL were defined to include an area with and without trees. Four trained persons were in charge of recording activities in each plot, rotating every fourth of a daylight in all groups.

The determination of forage availability was performed at the beginning, and then every 45 days, until the end of the experiment. Twelve cuts per experimental unit were performed at ground level in 0.25 m^2 frames, selected according to topography, botanical composition and location. For the FL, 6 cuts were performed under the trees and 6 in area of natural grassland without trees. The forage samples were weighted at both fresh and dry; dry after being placed in an air oven at 60 °C for 48 h, to determine the percentage of dry matter and analyze the relative contents of crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF).

Air temperature was measured in different locations under the trees in FL (n = 5) and in NFL (n = 3) using thermometers equipped with dataloggers that recorded the information during the whole day with a frequency lower than every half an hour.

Data analysis

Univariate analyses were performed on all variables to identify possible outliers and inconsistencies, as well as to verify the normality of residuals. Continuous data with repeated measurements (observations) such as air temperature, body weight and average daily gain were compared by analysis of variance using the mixed procedure available in SAS (SAS 9.0, SAS Institute Inc., Cary, NC, USA 2002). The model included the fixed effects of treatment, observation and their interactions. For the animal variables, the heifer were considered a random effect. The covariance structure was selected on the basis of the Akaike information criterion. Behavior was analyzed using the GLIMMIX SAS procedure by evaluating the time that the group of animals were observed performing each predetermined activity (grazing, rumination, water consumption, others) for each treatment and each observation expressed as a percentage of total time. When significant differences between treatments were found, averages were compared by the Tukey test ($P < 0.05$). The figures describing the evolution of forage mass and green forage mass, air temperature by season, and the proportion of animals grazing during the day were all created using JMP (JMP v.13.1.0, SAS Institute Inc., Cary, NC, USA 2017).

Results

FL without trees showed higher values of total forage mass in the first evaluation; elevated contents of the different fractions of cell wall (expressed as NDF and ADF), as well as a lower crude protein during all the evaluated seasons, when compared to the NFL treatment. For the area of FL with trees, total forage mass remained lower than 800 kg/ha and showed higher contents of crude protein, along with lower NDF and ADF (Fig. 1 and Table 1).

Mean air temperatures differed significantly ($P < 0.05$) between treatments in all seasons of the year (Fig. 2). Higher temperatures were verified in the absence of trees during the day, during summer and fall (Fig. 2b and c). During the night the temperature was higher in the presence of trees during all seasons (Fig. 2).

Grazing activity was significantly influenced by treatments and the moment of the day (Fig. 3). The heifers in NFL grazed mainly in the early morning and late afternoon, showing a significant reduction of activity around noon ($P < 0.05$). However, the number of heifers grazing in FL was relatively stable during the day, with approximately 55% of the herd performing this activity at any one time.

Both groups of heifers started with a similar body weight (Fig. 4), which decreased in the first winter and recovered during spring and summer. In the first winter, heifers grazing FL had a greater daily weight loss than those grazing on NFL. In summer, weight gain was greater ($P < 0.05$) in FL (December = 0.633 ± 0.036 kg/day and February = 0.410 ± 0.029 kg/day) than in NFL heifers (December = 0.553 ± 0.030 kg/day and February = 0.220 ± 0.033 kg/day). This translated into a greater ($P < 0.05$) body weight at the end of the summer in FL (208.2 ± 2.9 kg) than NFL (199.1 ± 3.2 kg) heifers. In the second winter, there was a new body weight-loss period, which was greater ($P < 0.05$) in NFL (− 0.158 ± 0.039 kg/day) than in FL (− 0.033 ± 0.030 kg/day) heifers. Consequently, heifers from the FL group continued being heavier (234 ± 3.0 kg) that those from the NFL group (223 ± 3.4 kg; $P < 0.05$) and the difference between groups was greater than in the previous period (9 kg vs 11 kg, for summer and fall; respectively).

Discussion

The hypothesis that the microclimate created by the introduction of trees would improve the quality of pasture and animal welfare, stimulating a greater growth of heifers grazing under these conditions, was accepted. The merger of milder temperatures during the day in the hottest months of the year, the greater crude protein content of the forage under the trees, and the changes in the grazing pattern probably promoted a positive energy balance in heifers grazing FL

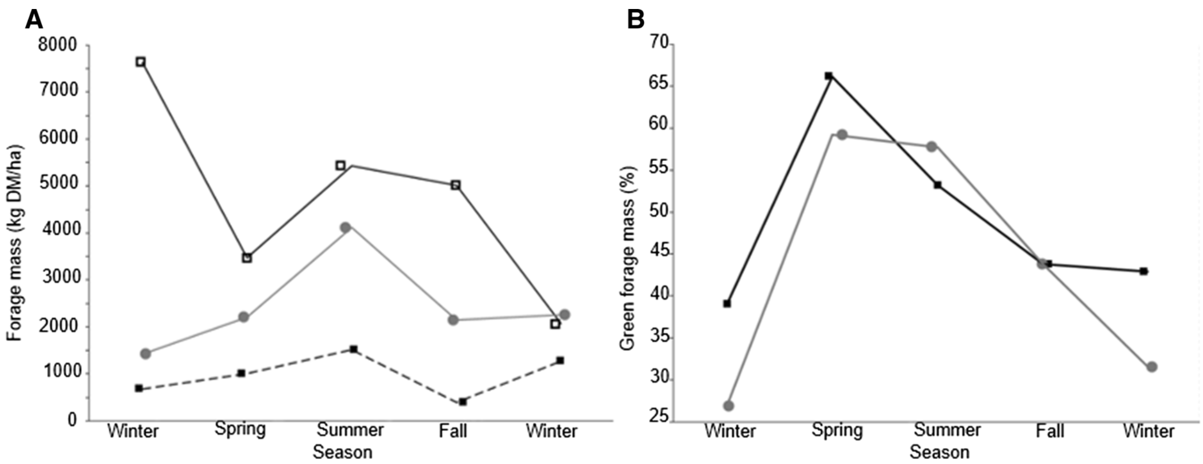


Fig. 1 Forage mass (kg DM/ha) (**a**) and green forage mass (%) (**b**) measured at different seasons. Forage mass was measured at non-forested land (continuous gray line), forested land with trees (dashed black line) and forested land without trees (continuous black line). Green forage mass was measured at non-forested land (continuous gray line) and a mean value for the forested land with and without trees was calculated (continuous black line)

Table 1 Brotamological composition of the forage

Seasons	Non forested land			Forested land					
				With tress			Without trees		
	CP	NDF	ADF	CP	NDF	ADF	CP	NDF	ADF
Winter 2009	5	73.8	46	3	77.1	50.3	9	73.2	45.5
Spring 2009	8	66.2	42.1	4.7	74.7	47	11	68.1	39.9
Summer 2010	5.6	70.8	45.6	4.9	73.2	47.3	8.6	73.5	44.7
Fall 2010	7.6	72.2	48.3	4	74.6	52.8	5.9	67.4	46.5
Winter 2010	7.8	68.3	44.3	5.5	69.2	47.4	8.8	70.6	46.1

Percentages of crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to different seasons in a non-forested land and forested land (with and without trees)

throughout the summer, that resulted in a greater daily weight gain and body weight. Moreover, heifers grazing FL lost less body weight during the second winter (but not the first), an aspect most probably related to a less negative energy balance. The greater weight loss in the first winter is probably related with forage, environment and animals factors (Roguet et al. 1998).

In this work, we verified that the forage parameters at the beginning of the experiment were comparable to the situation typical of high-density tree cultivation present in Uruguay: high amounts of forage mass were available in the FL without trees (low-lands, firebreak paths), outlined by the grazing exclusion enacted to protect seedlings over the early stages of development (Cubbage et al. 2012). Consequently, the bromatological composition of the forage present showed high concentrations of NDF and ADF, as well as a low crude protein percentages. Although short-term grazing deferments are considered as an alternative to restore the productivity and botanical composition of a degraded natural grasslands (Fedrigo et al. 2018), the forage structure after more than one year of grazing exclusion is highly modified towards a higher proportion of stems, fibrous, and less palatable biomass. Despite lower nutritional value, the reduction in the proportion of high-quality forage "parts" (i.e. grass leaves) due to the increase in structural foraging deterrents (stems) can limit the forage intake in relation to the time spent in the process of grasping

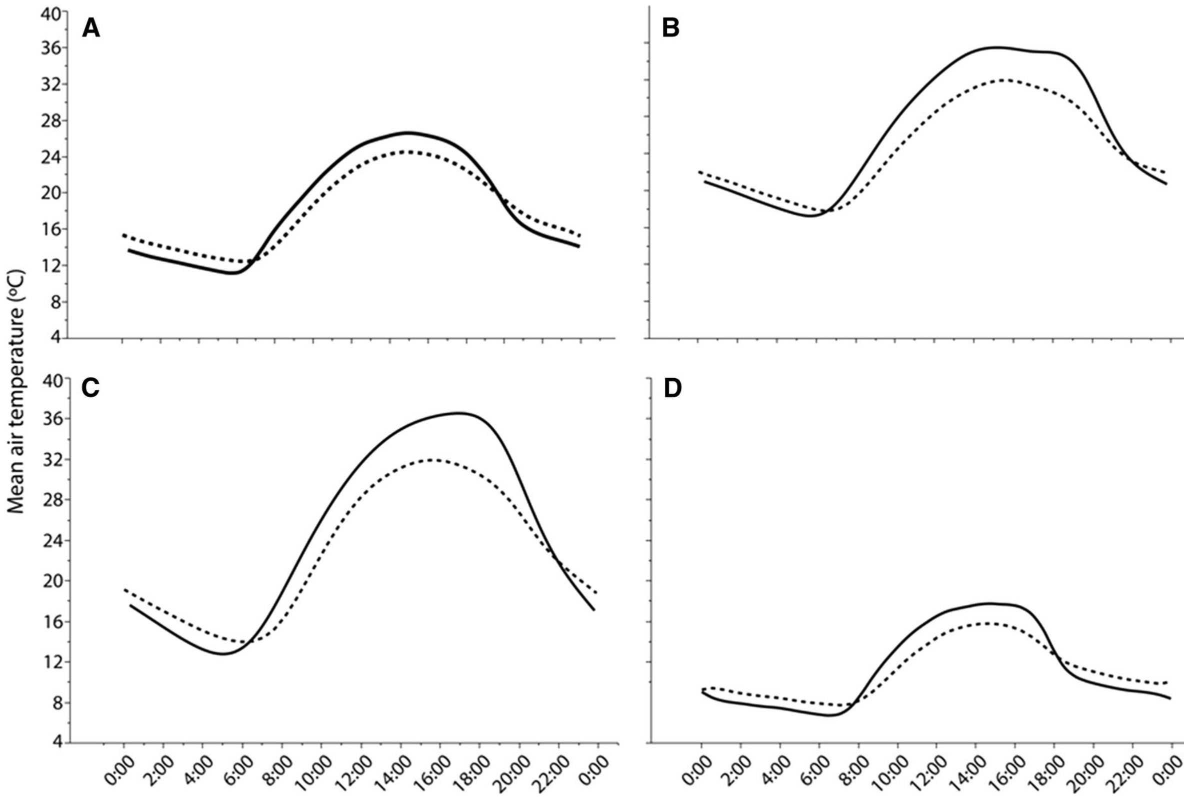
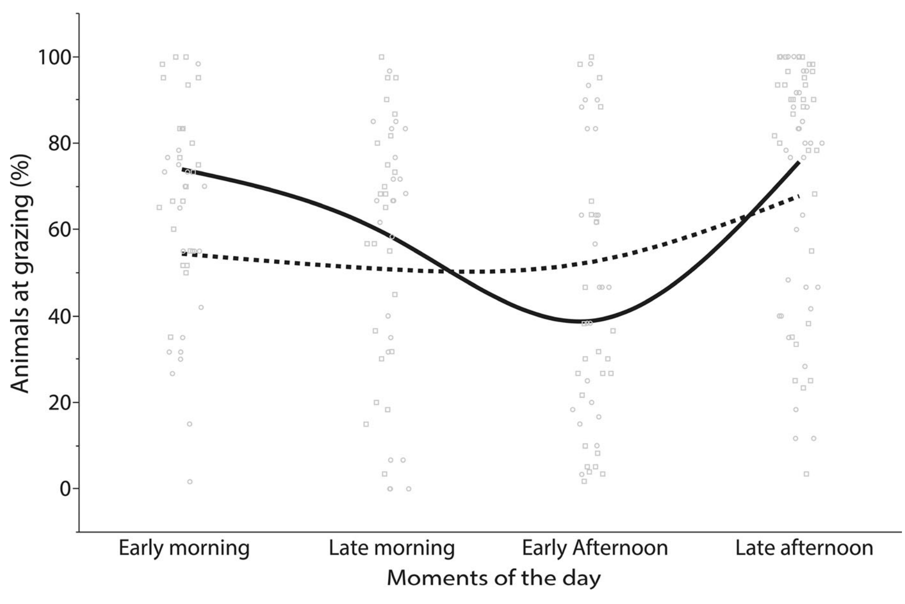


Fig. 2 Evolution of the temperature along the day in a non-forested land (continuous line) and in a forested land under the canopy (dashed line) in spring (**a**), summer (**b**), fall (**c**) and winter (**d**)

Fig. 3 Animals grazing (%) in forested land (dashed line) and non-forested land (continuous line) at different moments of the day: early morning (6–9 AM), late morning (10–12 AM), early afternoon (12–15 h PM) and late afternoon (16–18 PM)



of leaves and selecting the better quality forage biomass (Drescher et al. 2006). Forage characteristics at the beginning of the experiment can partially explain the lower performance of heifers grazing FL

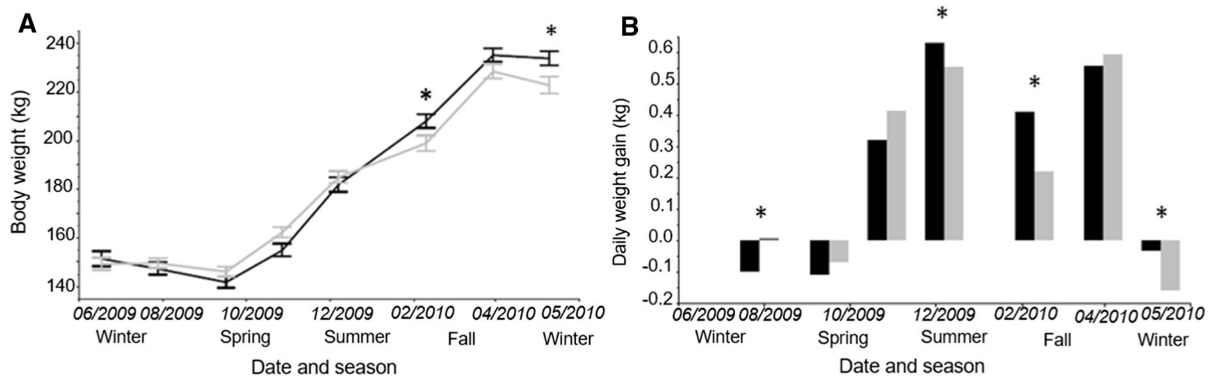


Fig. 4 Evolution of body weight (**a**) and daily weight gain (**b**) in Forested land (black line and black bar) and non-forested land (grey line and grey bar). Asterisk shows statically differences in that observation between groups ($P < 0.05$)

compared to those grazing NFL during their first winter, adding to this the stress of weaning and the exposure to a new environment and herd (Davis and Stamps 2004; Enríquez et al. 2011).

Forage growing under tree canopy had a better bromatological composition despite its lower availability (> 800 kg/ha). This is explained by the reduced quantity and quality of photosynthetically active radiation reaching the vegetation growing in the understory environment, which limits carbon accumulation rate, and consequently, forage production (Feldhake and Belesky 2009). In addition to the minor dilution effect of nitrogen in the biomass (due to low biomass) (Gastal and Lemaire 2002), the improvement of plant crude protein content is explained by nitrogen transference from roots and stems to leaf blades in order to increase their chloroplast concentration, in an attempt to enhance their photosynthetic efficiency (Cruz 1997). Despite the lower amount of forage available under tree canopy, its better bromatological composition may constitute an attractive feeding site for the herd (Roguet et al. 1998). Cattle can supply their requirements by selecting forage with higher crude protein and energy content (lower ADF and NDF; (Buxton et al. 1995)). Forage decisions can be interpreted as an overall objective in maximizing the net rate of energy gain (Roguet et al. 1998). Looked at from this point, grazing at the understory pasture may represent an adaptive strategy that complements the greater forage mass, but with low quality, present in FL without trees. This result is supported by previous studies and is relevant considering the ruminant selective capacity, since there is a "protein bank" like situation available to build up a better quality diet (Kyriazopoulos et al. 2012). However, heifers grazing NFL had access to forage mass with intermediate average contents of crude protein, ADF and NDF, when compared to FL heifers. Although they could also select a better diet from the available forage, NFL herds did not have access to sites where the forage had extremes in quality to build up their diet, as did those grazing FL (Roguet et al. 1998). This is very convenient for animals grazing FL, since foraging skills are a learning process in young animals (Ortega-Reyes and Provenza 1993), which could explain the differences in the daily weight loss in the first and second winters for these heifers (naive vs experienced animals in the same environment, after one year). It's important to reinforce the concept that the body weight loss experienced by growing cattle during winter, although ameliorated in FL, still prevails in animals grazing natural grassland (Guggeri et al. 2014). The relevance of the protein source provided by forage growing under the canopy on heifer's performance needs to be interpreted with appropriate experimental projects, such as the study of the composition of the diet ingested by animals in different grazing situations, as well as the temporal and spatial decisions taken by cattle during their grazing process.

Trees provided an environment with lower temperature during the hottest hours of the day over the summer and fall. Moreover, trees may reduce the temperature variations during a 24hs period, as previously noted (Garnier and Roy 1988), which also had an impact on animal behavior. Despite the similar time dedicated to grazing in both treatments, the patterns were significantly influenced by their treatments. In NFL, two grazing events were recorded, mainly after dawn and before dusk, as previously mentioned (Hodgson 1990). The reduction of heifers grazing in the hottest hours is a natural attempt to reduce heat production and absorption in order to keep body temperatures at an appropriate physiologic level (Savsani et al. 2015). By contrast, in FL the heifers didn't show any defined grazing period: despite animal alternating their own activity into periods of grazing, ruminating, watering or rest, about 55% of the heifers herds remained at grazing. These undefined grazing periods could be attributed to the free access to natural shade, which plays an important role in animal welfare due the lower mean air temperature (Lopes et al. 2016).

In summer, heifers grazing FL had a greater daily weight gain, and were thus heavier by the end of the season when compared to heifers grazing NFL. This is probably explained by the better thermic environment provided by trees. Metabolic alterations associated with heat stress have an energetic cost that can increase nutrient requirements. This, associated to changes in grazing behavior can cause a reduction in animal productive performance (Arias et al. 2008). Our results reinforce the relevance of animal welfare to improve productivity.

This work suggests that some alternatives to control the initial forage canopy structure (mowing, controlled grazing by mobile fences) needs to be evaluated in order to avoid the excessive production of low quality grass that had a negative impact on the productivity of growing cattle. It also helped in understanding the importance of shade for animal grazing behavior during the day, but some aspects have not been made quite clear yet. In order to produce management recommendations to better optimize synergic interactions among the components of the system, more studies are necessary.

Conclusion

We conclude that the introduction of trees in natural grassland changes the environment, providing a better thermic and nutritive setting for growing cattle, resulting in an increase in their productivity.

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