

## Impact of Shading of a Silvopastoral System on Microclimate and Botanical Composition of Polyphytic Pasture: A Preliminary Study in the Subtropics

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### ABSTRACT

The silvopasture system is an integrated system which has been widespread in tropical and sub-tropical climates. However, there is a lack of detailed studies regarding agroecological silvopasture systems. This study assessed whether the different levels of shading in an agroecological silvopastoral system influences the microclimate and botanical composition of polyphytic pasture. We used eight paddocks composed of a silvopastoral system in a subtropical climate, with different tree species arranged in simple lines with polyphytic pasture. In each paddock, we established three levels of visual shading (under the canopy, intermediate and full sun). The following microclimatic variables were recorded monthly during the daytime: illuminance, air temperature, air relative humidity, wind speed, and surface soil temperature. The samples of forages were separated into grasses, legumes and spontaneous, then fractionated into leaves, stems, and senescent material. We observed lower values of illuminance and surface soil temperature under the canopy, with differences between full sun and under the canopy at noon. Regarding the forage, the percentage of legumes was higher in full sun, and spontaneous species and leaves had high proportions under the canopy. Based on the results, the agroecological silvopastoral system changed the microclimatic characteristics and altered the plant composition of polyphytic pasture.

**Keywords:** integrated crop-livestock-forest systems, biometeorology, shading, polyphytic grassland

### INTRODUCTION

The livestock grazing has a large territorial extension in tropics and subtropics as a low-cost system for maintenance and implementation [Poppi et al., 2018]. However, approximately 33% of the world terrestrial surface have some degree of degradation [Wall and Six, 2015], resulting in reduced productivity and damage to soil

resources, such as erosion and leaching of soil nutrients. In this context, the adoption of practices that promote the sustainability and conservation of natural resources is necessary to mitigate degradation effects.

Ergo, agroecology is strengthened, focused on agronomic, ecological, and socio-economic studies in agricultural systems [Altieri, 2018]. According to the same author, the agroecology

associated with the production model that resembles natural ecosystems – such as agroforestry – is an alternative to achieve sustainability in agricultural production and pasture areas. The silvopastoral system is an agroforestry arrangement that integrates into the same area, simultaneously, the use of pastures, trees, and animals [Peri et al., 2016] to change microclimate conditions for the benefit of the environment and consequently for animal production [Vieira et al., 2020]. This system becomes essential for animal thermal comfort because the shade of the trees reduces the thermal load of the environment providing adequate conditions for grazing animals [Karvatte Jr. et al., 2021].

The trees support animal production and contribute to improvements in forage production if the vegetal species are introduced correctly. The mulch from the trees directly increases the production of soil biomass, which raise the level of soil organic matter [Murgueitio et al., 2014]. However, if this system is not correctly managed, the effects may be harmful.

The densification of trees can cause a high reduction of solar radiation above the forage canopy, which changes the illuminance and the temperature, impairing photosynthesis and leading to problems in animal production because the forage requires a suitable environment for growth and development [Feldhake, 2009]. Therefore, adequate criteria are necessary regarding the choice of tree species, the distance between individuals, and forest management to ensure the successful implementation of the silvopastoral system [Jose and Dollinger, 2019].

In this system, microclimatic differences may occur within the same site, which emphasizes the importance of characterizing such changes and quantifying them in the evaluated system. However, we found a lack of studies regarding the microclimatic variation in an agroecological silvopastoral system. Thus, it is essential to evaluate the microclimate provided by the composition of different trees and their influence on the quality and production of polyphytic pasture in a silvopastoral system managed in an agroecological design. It is necessary before introducing grazing animals, to understand the conditions of microclimate in different points, such as under the canopy and in full sun. It is also important to evaluate the effect on the botanical composition and morphologic characteristics of plants. Thus, we aimed to

assess whether the different levels of shading in an agroecological silvopastoral system influences the microclimate and botanical composition of polyphytic pasture.

## METHODS

### Study area

A trial was carried out at the Centro Paranaense de Referência em Agroecologia (Paraná Center for Reference in Agroecology – CPRA), in the city of Pinhais, Paraná State, Brazil. The geographic coordinates were 25°23'06.21"S and 49°07'26.16"W, with an altitude of 893 meters above sea level. According to the Köppen classification, the climate of the region is Cfb, humid subtropical (Mesothermal), with an average temperature of 11 °C in the coldest month, sometimes reducing below 2 °C. During the summer, the average temperature is approximately 23 °C, and it can reach above 32 °C [Alvares et al., 2014].

The studied site was composed of an agroecological silvopastoral system, established over 10 years ago (Figure 1).

Pasture is polyphytic, composed of several species of grasses, such as *Axonopus compressus* (Sw.) P. Beauv., *Pennisetum clandestinum* Hochst. Ex. Chiov., spontaneous species, and by legumes, with a predominance of *Trifolium repens* L. and *Arachis pintoi* K. Regarding the trees, the species found in the experimental area was *Mimosa scabrella* Benth; Hook., *Lafoensia pacari* Saint-Hilaire, *Psidium cattleianum* Sabine, *Bastardiopsis densiflora* (Hooker & Arnott) Hassler, Fedde, *Taxodium distichum* (L.) Rich., *Liquidambar styraciflua* L., *Compomanesia cambessedeanana* Berg. and *Acer palmatum* Thunb. The following inventory is showed in Table 1.

The paddocks handling was carried out by the mob-grazing, in which grazing occurs with high stocking and grazing time is short, and the animals were used only for lowering the forage canopy. The lactating cows of this system are Jersey x Holstein crossbred (n=27), with age varying between 34 to 63 months, body weight average of 410 kg and days in milk average of 128.

The animals were moved when the forage was grazed down to a height of 6 to 8 cm. The mean grazing intervals were 28.9 days. Nine pasture samples per paddock were collected to determine



**Figure 1.** View from the experimental area

the dry matter, botanical composition, and structural constituents. These samples were collected in three levels of shade in the paddock (under the canopy, intermediate, and full sun).

The soil of the experimental area was classified as typical dystrophic Cambisol with humic horizon B. For a better understanding of the studied area, soil samples were collected for chemical analysis (Table 2).

The samples were collected in a zig-zag pattern, totaling 4 samples of 0–20 cm per paddock, totaling 24 samples. Chemical analyses were carried out at the Soil Laboratory of the “Luiz de Queiroz” College of Agriculture (ESALQ/USP).

As for soil analysis, the soil was generally presented with high organic matter with more than  $50 \text{ g dm}^{-3}$  and pH varying between average acidity and no acidity, but not compromising the soil. Base saturation was acceptable on all paddocks. The potassium content was high in all pickets, but phosphorus levels vary between low and very low.

## EXPERIMENTAL DESIGN

We used for the study eight paddocks with an average of  $898.75 \text{ m}^2$  of area. The system was composed of trees of different species, arranged in simple lines with an average spacing of 2.5 m between individuals.

For microclimatic recordings, we performed the measurements at three different times, the first time from 8:00 am to 10:00 am, the second time from 12:00 pm to 2:00 pm and the third time from 4:00 pm to 6:00 pm, with an interval of one hour for each observation.

With the paddocks established, the points of microclimatic data recordings within the paddocks were determined according to the level of visual shading provided by the silvopastoral system. We measured three points per level, inside each paddock. The levels were defined as follows:

- Level 1: under the canopy of the trees (the point that entirely remains the shade for most of the day);

**Table 1.** Forest inventory of the tree individuals on the studied paddocks

N° paddock	Number of trees	Average DBH	TH	HF	Average canopy rays	Shading area (m <sup>2</sup> )	Total paddock area
10	14	14.53	9.15	3.62	4.60	85.33	938.12
11	19	14.92	9.08	2.49	4.34	82.98	946.36
12	12	18.70	8.41	2.66	5.21	108.17	812.70
13	18	18.01	7.86	2.83	5.38	107.41	852.77
07	15	14.74	8.70	2.83	3.91	61.43	830.07
06	17	14.06	6.68	2.33	4.05	62.61	928.57
05	14	14.48	6.17	1.74	4.05	77.35	897.31
04	15	16.28	7.08	2.70	4.40	88.21	984.07

DBH: diameter of breast height; TH: total height; HF: height of the first fork

**Table 2.** Forest inventory of the tree individuals on the studied paddocks

N° paddock	pH CaCl <sub>2</sub>	O.M. Col.	P	K	Ca	Mg	H +Al	Al	BS	CEC	V	m
		g dm <sup>-3</sup>	mg/dm <sup>3</sup>		cmol <sub>c</sub> /dm <sup>3</sup>						%	
10	4.7	58.1	7.8	104	5.8	2	14.2	1	8.1	22.3	36.3	10.99
11	4.8	58.4	4.3	129	6.5	2.4	13.7	0.7	9.2	22.9	40.2	7.07
12	5.1	57.8	7.1	154	7.8	4.5	11.2	0.1	12.7	23.9	53.1	0.78
13	4.9	57.5	17.3	172	6.7	2.8	11.6	0.3	9.9	21.5	46	2.94
04	5.4	56.5	10.7	205	12	4.2	7.5	0	16.7	24.2	69	0
05	5.6	50.4	5.2	175	12.8	4.3	6.5	0	17.5	24	72.9	0
06	6.5	55.5	5.4	162	12.9	5.7	3.2	0	19	22.2	85.6	0
07	5.2	55.9	6.5	212	10.9	2.8	8.9	0	14.2	23.1	61.5	0

pH CaCl<sub>2</sub>: hydrogen potential in calcium chloride; O.M. Col.: Organic matter by colorimetry; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; H +Al: potential acidity; Al: aluminum; BS: base saturation; CEC: cation exchange capability; V: base saturation; m: aluminum saturation.

- Level 2: intermediate (an area that remains in a transition place shade and sun during the day);
- Level 3: in full sun (the place that remains in full sun throughout the day).

## MICROCLIMATE ANALYSIS

All microclimatic measurements were undertaken once a month for 10 months (from December 2015 to September 2016). The illuminance (lux), air temperature (°C), air relative humidity (%), wind speed (m s<sup>-1</sup>) and soil surface temperature (°C) were evaluated. Except for soil surface temperature, all the measurements were taken 1.50 m above the soil. For air temperature, relative humidity, and wind speed, we used a thermo-hygro-anemometer ITAN 700 (Instrutemp, São Paulo, Brazil). Regarding the illuminance, we measured using a digital lux meter, model LDR-225 (Instrutherm, São Paulo, Brazil). The soil surface temperature was recorded with the use of an infrared thermometer, model TI-870 (Instrutherm, São Paulo, Brazil).

## Botanical composition

Within each paddock, nine forage samples were collected, referring to the points and ranges established in the experimental design.

The forage was collected with a metallic square with dimensions of 25 × 25 cm. This metallic square was randomly released at the points. The forage was cut as closest to the ground as possible with the aid of pruning shears and stored in previously identified paper bags. After collection, the samples were weighed to obtain the fresh

matter mass of the forage and then kept under refrigeration for subsequent separation of botany and structural constituents. The average height of the plant was measured with a graduated ruler at a point within the metallic square, considering the plants with observed average height.

As for botanical separation, the pasture sample collected was separated into the grass, legumes and spontaneous (species that were not intentionally established). After determining the proportion of each species (grass and legume) in the sample, it was divided into leaves (leaf blades), stems and senescent material (considering the material with more than 50% visibly senescent) and proceeded to dry in a forced-air oven at 55 °C for 72 hours to determine the dry matter of the structural constituents. The leaf/stem ratio was expressed as the ratio between kg ratio of leaf kg of stem<sup>-1</sup>.

## STATISTICAL ANALYSIS

The statistical analysis for climate variables was based on linear mixed models, assuming the following mathematical model:

$$y = \mu + \alpha + b + \tau + \psi + \tau\psi + \varepsilon \quad (1)$$

where:  $y$  is a 1944 × 1 response vector;

$\mu$  is a common effect vector to all observations;

$\alpha$  is the month effect, assuming the values  $\{1, \dots, 9\}$ ;

$b$  is the paddocks random effect vector, assuming  $b \sim N_8(0, \sigma_b^2 I)$ ;



$\tau$  is the daily hours period effect vector, assuming the values  $\{1, 2, 3\}$ ;  
 $\psi$  is the illuminance levels points effect vector, assuming the values  $\{1, 2, 3\}$ ;  
 $(\tau\psi)$  is the daily hour period/illuminance levels points interaction effect vector;  
 $\varepsilon$  is a random error term,  $\varepsilon \sim N(0, \sigma^2 I)$ .  
 The mathematical model for botanic variables follows:

$$y = \mu + \alpha + b + \psi + \alpha\psi + \varepsilon \quad (2)$$

where:  $y$  is a response vector;

$\mu$  is a common effect vector to all observations;

$\alpha$  is the month effect, assuming the values  $\{1, \dots, 9\}$ ;

$b$  is the paddocks random effect vector, assuming  $b \sim N_8(0, \sigma_b^2 I)$ ;

$\psi$  is the illuminance levels points effect vector, assuming the values  $\{1, 2, 3\}$ ;

$(\alpha\psi)$  is the month/illuminance levels points interaction effect vector;

$\varepsilon$  is a random error term,  $\varepsilon \sim N(0, \sigma^2 I)$ .

The inference over the fixed effects was based on likelihood ratio tests using the usual asymptotic large sample sampling distributions when the normal distribution assumption was adherent [Verbeke and Molenberghs, 2000]. In the cases where the error residuals were not normally distributed, randomized permutation tests (or Monte Carlo permutation tests) was adopted [Lee and Braun, 2011]. These tests are nonparametric tests, robust to nonnormality, heteroscedasticity or sample size restriction. The only strong assumption is the exchangeability of observations under the null hypothesis, which are guaranteed by the executed experimental planning. The drawback is the computer-intensive calculations, where for each test, it was set 9999 random permutations to generate the sampling distribution for test statistics, demanding some hours for all the calculations. Confidence intervals and p-values for multiple comparisons were based on Bonferroni adjustment to p-values, to control the Type-I errors. Residual diagnostics supported the choice when to adopt the normal-based likelihood tests or Monte Carlo permutation tests. All statistical procedures were performed through the R software [R Development Core Team, 2019].

## RESULTS

### Microclimate

We observed an interaction between daily hours vs points ( $P < 0.001$ ) for illuminance (Table 3). In the full sun, the illuminance was lower at 16:00 to 18:00 when compared to the other periods. Under the canopy, the higher illuminance was recorded from 12:00 to 14:00, followed by 08:00 to 10:00. Comparing the shading levels, the lowest illuminance was obtained under the canopy during all daily periods, as described in Table 1. However, at 08:00 to 10:00 and 16:00 to 18:00, the mean value of illuminance obtained in the full sun was similar to the intermediate point.

Regarding the average variation of soil surface temperature, there was an interaction between hours vs points ( $P < 0.001$ ) (Table 4). The higher soil surface temperatures were obtained in the intermediate level and full sun for 12:00 to 14:00. Also, we found higher values under the canopy and in the intermediate point at 16:00 to 18:00. According to each shading level, the higher soil surface temperature in the silvopastoral system was obtained from 12:00 to 14:00. Our results demonstrated the effect of shading by trees in an agroecological system to maintain the soil surface temperature lower along the day. This effect is important to increase soil microbial activity, which results in benefits to soil and rhizosphere.

Considering the air temperature, our results showed that there was no interaction between hours vs shading levels ( $P = 0.8866$ ). However, daily hours had a significant effect ( $P < 0.001$ ). As expected, for the assessed time intervals, the air temperature was higher at noon, and the lowest mean temperature was found under the canopy (Table 5).

The amplitude of values between 8:00 to 10:00 and 12:00 to 14:00 was higher, with 5.8 °C. Between 12:00 to 14:00 and 16:00 to 18:00, we found an amplitude of 4.4 °C. The higher amplitude between the first intervals is due to the linear increasing of air temperature with solar radiation.

There was no interaction between hours vs points for relative humidity ( $P = 0.9771$ ) and wind speed ( $P = 0.5305$ ). However, the significant effect was obtained for time intervals ( $P < 0.001$ ). Concerning the air relative humidity, the lowest average was recorded at 12:00 to 14:00, and the

**Table 3.** Illuminance values (lux) according to different distances from the canopy of the silvopastoral system and times of the day

Points	Hours		
	8:00–10:00	12:00–14:00	16:00–18:00
Under the canopy	13.083.0 Bb <sup>1</sup>	15.267.1 Ca	5.766.5 Bc
Intermediate	25.764.5 Ab	36.900.7 Ba	10.421.0 Ac
Full sun	32.807.5 Ab	58.015.7 Aa	13.197.3 Ac

<sup>1</sup>Means followed by the same upper-case letters on the columns and lower-case letters in the lines did not differ in the Bonferroni test, at 5% probability.

**Table 4.** Soil surface temperature values (°C) according to different distances from the canopy of the silvopastoral system and times of the day

Points	Hours		
	8:00–10:00	12:00–14:00	16:00–18:00
Under the canopy	17.7 Bc <sup>1</sup>	21.2 Ca	19.8 Ab
Intermediate	19.3 Ac	24.0 Ba	20.4 ABb
Full sun	19.6 Ac	26.1 Aa	21.0 Bb

<sup>1</sup>Means followed by the same upper-case letters on the columns and lower-case letters in the lines did not differ in the Bonferroni test, at 5% probability.

higher was found during 8:00 to 10:00. There was a 17% reduction in the humidity value from 12:00 to 14:00 and 10% from 16:00 to 18:00. The wind speed was lower in the first hours, from 8:00 to 10:00, and at dusk, from 16:00 to 18:00, compared to the time of highest peak solar radiation and temperature, 12:00 to 14:00. At 12:00 to 14:00, an average of 0.5 m s<sup>-1</sup> was registered, with an increase of 0.3 m s<sup>-1</sup> compared with other intervals (Table 5).

### Botanical composition

We found differences between the shading levels regarding the proportions of legumes and spontaneous species (Table 6).

The proportion of legumes was lower under the canopy than the other shading levels. This could be caused by the lowest illuminance (Table 3) and soil surface temperature (Table 2), which influence the plant metabolism and soil microbial activity. For the botanical components, we observed difference between shading levels, mainly for the proportions of grass leaf and leaf/stem ratio (Table 7).

For leaf proportions and leaf/stem ratio of grass, the mean value was higher under the canopy when compared with other shading levels.

The legumes plant did not show the same morphological answer (Table 6) due to the preference for growth in the condition of the lowest illuminance (Table 3 and 7).

**Table 5.** Descriptive statistics (mean ± standard deviation, minimum median and maximum) for the variables of microclimate during selected hours.

Variables	Hours	Mean	Minimum	Median	Maximum
Temperature (°C)	8:00–10:00	23.6±7.1 c <sup>1</sup>	14.2	28.8	39.0
	12:00–14:00	29.4±6.7 a	18.5	28.9	42.0
	16:00–18:00	25.0±6.1 b	14.1	24.7	38.9
Relative humidity (%)	8:00–10:00	66±16 a	32	69	89
	12:00–14:00	49±16 c	20	49	89
	16:00–18:00	59±11 b	30	62	79
Wind speed (m s <sup>-1</sup> )	8:00–10:00	0.2±0.4 b	0	0.0	3.7
	12:00–14:00	0.5±1.0 a	0	0.1	5.7
	16:00–18:00	0.2±0.6 b	0	0.0	4.7

<sup>1</sup> Means followed by the same lower-case letters in the columns, for each variable, did not differ in the Bonferroni test, at 5% probability.

**Table 6.** Average values (mean  $\pm$  standard deviation) of height (cm) of forages and proportions (%) of grasses, legumes, senescent material and spontaneous in the different measure points.

Points	Height	Grass	Legumes	Senescent	Spontaneous
Under canopy	11.3 $\pm$ 5.4	23.8 $\pm$ 14.8	2.4 $\pm$ 7.3 b <sup>1</sup>	18.4 $\pm$ 16.2	55.6 $\pm$ 21.3 a
Intermediate	13.2 $\pm$ 6.1	32.0 $\pm$ 18.2	7.9 $\pm$ 12.8 a	20.1 $\pm$ 15.2	40.4 $\pm$ 23.5 b
Full sun	12.9 $\pm$ 6.1	28.9 $\pm$ 16.9	9.0 $\pm$ 14.2 a	21.7 $\pm$ 15.4	40.3 $\pm$ 22.3 b

<sup>1</sup>Means followed by the same lower-case letters in the columns, for each variable, did not differ in the Bonferroni test, at 5% probability.

## DISCUSSION

This work demonstrated that the different microclimate conditions, according to the shading effect, influenced species distribution in the area, based on the leaf morphological characteristics. This is a preliminary result, characterized by a short-term study, due to the limitations regarding the periodicity of microclimate and forage sampling. However, even with a limited data, we found significant differences and important results which lead us to further confirmations. Our findings are particularly important because it is necessary to know what species might be suitable in the silvopastoral system, mainly considering agroecological handling. Many farmers introduced this system in their area, but they neglect that the tree provides shade, and if the pasture did not adapt to this condition, the result might be an area without pasture coverage.

### Microclimate

Regarding the illuminance, our findings were similar to Gao et al. [2013], who evaluated the photosynthetically active radiation in an agroforestry system with *Malus pumila* M. (apple) associated with *Glycine max* L. Merr. (soybean) and *Arachis hypogaea* L. (peanut) at different distances from the trees. The authors verified that the radiation peak occurred at 13:00 and the minimum value at 17:00. In the same research, they found lower values of photosynthetically active

radiation with a reduction of 17.9% in 0.5 m and 10.4% in 1.5 m for the system with apple and soybean and, 17.8% in 0.5 m and 5.4% in 1.5 m for the system with apple and peanut compared to the control treatment. Karki and Goodman [2010] found that solar radiation was lower under the canopy at dawn and late afternoon compared to the peak hours observed (11:00 to 14:00) in the silvopastoral system composed of *Pinus taeda* L.

Based on these results, we observed that the canopy architecture in an agroecological system intercepts solar radiation more efficiently under higher radiation peak during the day, that is, acting as filters or reflective material providing a higher level of shading. This result might explain the results obtained with illuminance demonstrated in Table 3.

From 8:00 to 10:00, we registered lower soil surface temperature under the canopy at 17.7 °C. In this daily period, the solar radiation is less intense, and the difference between under the canopy and the full sun inside the paddock was 1.9 °C. For the intermediate level, there was no difference when compared with under the canopy, which indicated the effect of the canopy in providing lower surface temperatures in a shaded area.

Throughout the year, there were changes in the maximum height of the sun, which generates spatial variation in the availability of solar radiation [Monteith and Unsworth, 2013]. This factor may have caused heterogeneity in the samples. The range from 12:00 to 14:00 was in the time interval when the sun is at its highest

**Table 7.** Average values (mean  $\pm$  standard deviation) of proportions (%) of leaf, stem, senescent material and leaf/stem (l/s) ratio of grasses and legumes in different measure points.

Points	Grass				Legumes			
	Leaf	Stem	Senescent	l/s	Leaf	Stem	Senescent	l/s
Under canopy	39.5 $\pm$ 19.4 a <sup>1</sup>	21.5 $\pm$ 14.5	38.6 $\pm$ 23.8	4.4 $\pm$ 11.4 a	11.5 $\pm$ 23.4	14.4 $\pm$ 27.1	2.3 $\pm$ 10.2	0.2 $\pm$ 0.5
Intermediate	36.4 $\pm$ 17.2 b	20.0 $\pm$ 14.0	34.5 $\pm$ 21.8	3.5 $\pm$ 8.0 b	17.5 $\pm$ 23.2	26.4 $\pm$ 31.1	3.1 $\pm$ 10.4	0.3 $\pm$ 0.4
Full sun	32.5 $\pm$ 16.0 b	20.7 $\pm$ 15.0	37.7 $\pm$ 24.0	3.8 $\pm$ 7.8 b	18.5 $\pm$ 23.1	26.0 $\pm$ 30.3	2.5 $\pm$ 8.8	0.3 $\pm$ 0.5

<sup>1</sup>Means followed by the same lower-case letters in the columns, for each variable, did not differ in the Bonferroni test, at 5% probability.

point, which influences average soil surface temperatures. However, the point under the canopy showed a lower temperature when compared with others, whose range of values between this and the intermediate collection point was 2.8 °C. The amplitude (4.9 °C) was evident between the point under the canopy and the full sun.

Ehret et al. [2018] assessed an agroforestry system, composed of different tree species, one meter away from the tree rows and in full sun and, they found temperatures of 15.8 °C at 5 cm depth in the soil, while the full sun was 16.2 °C. They observed that in the sub-forest, the photon flux density was lower compared to full sun, which decreases the soil temperature, evidencing the results found in the present study.

About the air temperature variation, the temperature on the Earth's surface is determined by the amount of radiant energy it receives from the sun (short waves) and terrestrial radiation (long waves). Therefore, this fact may explain the increase in temperature between 12:00 to 14:00, with 29.4 °C and reduction between 16:00 to 18:00, with 25.0 °C. Lopes et al. [2016] assessed the air temperature in two periods of the day (morning and afternoon) under the canopy, inside the paddock in full sun and among the rows in a silvopastoral system composed of *Eucalyptus* ssp intercropped with *Brachiaria brizantha* cv BRS Piatã and in adjacent pasture composed of the same forage species. The authors found averages of 30.8 °C (morning) and 34.7 °C (afternoon) under the canopy and values of 33.9 °C (morning) and 37.6 °C (afternoon) in the full sun inside the paddock. The values obtained by the authors follow the same variability found in our study, mainly during morning and noon.

The variability in relative humidity had a direct relationship with the air temperature throughout the day. Air humidity is an essential factor for plant growth since it allows the stomata to remain open longer, allowing the necessary gas exchange, mainly for photosynthesis activity as well as for transpiration, essential for the absorption of water and nutrients by the roots. The wind speed found for the time 12:00 to 14:00 can be explained by the difference between the shaded areas and the full sun – which they can create a horizontal temperature gradient that causes distinct heating between shade and sun, generating locally advective breezes – and to the possible

centralization of the wind by the tree rows [Bosi et al., 2020].

### Botanical composition

The condition of the lowest illuminance reduces the nutrients, water absorption and carbohydrate production in the plant, which is important to survival and growth. Andrade et al. [2004], assessing different levels of shade on the production of two genotypes of *Arachis pintoi* K., observed that at the highest level of shading (70%), legumes showed deficient growth, although the period evaluated is the dry season in which their performance is usually lower. The higher proportion of legumes in the full sun might be associated with the forage consumption of animals. This result was influenced by factors related to the structure of the forage canopy, mainly the ease of seizure and harvesting of forage during grazing [Oliveira et al., 2021]. *Arachis pintoi* K. and *Trifolium* ssp, with a low-growth habit, where the main legume species which were easily found in the experimental area.

The proportion of spontaneous species was higher under the canopy than in the full sun (Table 5). Ferreira [2012] evaluated the tree species of *Mimosa scabrella* Benth in the same experimental area of this study and found a lower frequency of spontaneous in full sun, with 5.13%, than under shading of trees with 21.39%.

Regarding the leaf proportions and leaf/stem ratio of grass, the light deficiency in plants can inhibit the growth and development [Choi et al., 2014; Scafidi et al., 2013; Wu et al., 2018] and change many physiological and biochemical characteristics as well as the changes in leaf morphological features as increasing the leaf area [Branco et al., 2017]. According to Wu et al. [2017], the shaded condition promotes the stimulus for multiplication and differentiation of cells, making the leaves more significant than for other parts.

The higher leaf area and leaf/stem ratio under the canopy were the physiological features used by grass to compensate for the lower illuminance avoiding a reduction in photosynthesis. These answers are according to the observations made by Pilau et al. [2015], with the proportion increase of ryegrass leaves under shade conditions provided by the *Anadenanthera colubrina* (Vell.) Brenan in the silvopastoral system.



## CONCLUSION

The different shading levels in an agroecological silvopastoral system affected the microclimate and botanical composition of polyphytic pasture. We registered lower illuminance and soil surface temperature under the canopy, especially in the hottest hours of the day. The air temperature was modified both by the level of shading and the assessed time intervals, and air humidity and wind speed were different in the measured hours. The levels of shading provided by the canopy influenced the proportions of legumes and spontaneous species in the area. Higher proportions of spontaneous species were observed under the canopy, which indicates the higher adaptability of these species to the shaded environment. The interception of radiation caused by the canopy influenced the botanical composition of the grass. Higher leaf proportions and higher leaf/stem ratio were obtained under shading.

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