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Microclimate in an agro-ecological silvopastoral system with bamboo at different tree-shade projection distances: a case study in Southern Brazil

Microclima em sistema silvipastoril agroecológico com bambu em diferentes distâncias de projeção de sombra: um estudo de caso no Sul do Brasil

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ABSTRACT

The aim of the present study was to evaluate the ability of an agro-ecological silvopastoral system, composed of bamboo and tree species, to promote microclimatic alterations at different projection distances from the canopy of trees. A total of 16 paddocks in an agro-ecological silvopastoral system were evaluated. The paddocks were divided into four separate groups (silvopastoral treatments): a) *Bambusa vulgaris L.* and planted trees, b) only bamboo, c) only trees, and d) open grassland system. The following microclimate parameters were studied: air temperature, relative humidity, grass temperature and wind speed. All parameters were measured at a height of 20 cm above the soil. The measurements were recorded by different time intervals, in order to examine the effect of three factors: time of day, silvopasture treatment and distance to the row of trees. The results show that there was an increase in relative humidity and a reduction in wind speed close to the tree line. The agro-ecological silvopastoral system acts therefore as a windbreaker and retains humidity close to the trees. Thus, it can be concluded that regardless of the presence of bamboo, due to the limited canopy area at young stage of *B. vulgaris*, the agro-ecological silvopastoral system promoted microclimatic alterations to the environment, indicating the potential of this integrated system to reduce the heat load for livestock and plants.

KEYWORDS: agroecology, biometeorology, integrated production systems.

RESUMO

O objetivo do presente estudo foi avaliar a capacidade de um sistema silvipastoril agroecológico, composto por espécies de bambu e árvores, em promover alterações microclimáticas a diferentes distâncias de projeção a partir do dossel das árvores. Um total de 16 piquetes em um sistema silvipastoril agroecológico foram avaliados. Os piquetes foram divididos em quatro grupos separados (tratamentos silvipastoris): a) *Bambusa vulgaris* L. e árvores plantadas, b) somente bambu, c) somente árvores, e d) sistema de pastagem aberta. Os seguintes parâmetros do microclima foram estudados: temperatura do ar, umidade relativa do ar, temperatura da grama e velocidade do vento. Todos os parâmetros foram medidos a uma altura de 20 cm acima do solo. As medidas foram registradas por diferentes intervalos de tempo, a fim de examinar o efeito de três fatores: horário do dia, tratamento da silvipastoril e distância até a fileira de árvores. Os resultados mostram que houve aumento na umidade relativa e uma redução na velocidade do vento próximo à linha de árvores. O sistema silvipastoril agroecológico age, portanto, como um quebra-vento e retém a umidade perto das árvores. Assim, pode-se concluir que, independente da presença de bambu, devido à limitada área de copa em estágio jovem de *B. vulgaris*, o sistema silvipastoril agroecológico promoveu alterações microclimáticas ao ambiente, indicando o potencial deste sistema integrado de reduzir a carga de calor para gado e plantas.

PALAVRAS-CHAVE: agroecologia, biometeorologia, sistemas de produção integrada.

Conventional agriculture has increased food production; however, this advancement had caused a process of environmental degradation due to the poor use of natural resources. Because of this, recent governmental initiatives demonstrated interest in producing commodities with sustainability (RASMUSSEN et al. 2017). In this regard, agroecology reflects the possibility of sustainable production and protection of biodiversity through governmental, private and agricultural actions (ALTIERI & NICHOLLS 2010). In association with the concept of sustainability being intrinsic to agroecological practices, promotion of the dissemination of agroecosystems has been growing in recent years.

Currently, the use of agroforestry systems (AFS), such as silvopastoral systems (SPS), demonstrated improved exploitation of natural resources since it increases production diversity of rural properties. SPS's are natural associations, either planned or consortium from pastures using tree species (NEPOMUCENO & SILVA 2009). One of the principal characteristics of these systems is the modification of the microclimate, enabling mitigation of the incidence of solar radiation on forage and animals. Other characteristics of AFS are the decrease in air temperature, increased soil humidity and increase in microbiological activity of the soil, resulting in greater mineralization of nutrients. These characteristics are similar with that of AFS (BERNARDINO & GARCIA 2009, HAILE et al. 2010). However, the choice of wood species is fundamental, as it is necessary to aim for balance between the microclimate, soil fertility and water use since it is gaining economic benefit from the wood and other by-products.

One of the most promising species with this objective is bamboo, which is characterized as a monocotyledone family of grasses originating from Asia, possessing approximately 50 genres and 130 species spread across the tropics as far as temperate regions (ZHANG & CLARK 2000). Due to its high vegetative growth, it produces a considerable volume of biomass, which results in higher CO_2 fixation and acts on the physical-chemical structure of soils (MAOYI & BANIK 1995). Scientific research is scarce for the composition of a silvopastoral system with bamboo in an agroecological environment, especially in a subtropical climate. In this light, we evaluated whether an agroecological silvopastoral system composed of bamboo and tree species promotes microclimatic alterations at different projection distances from the tree canopy.

This study was carried out at the Centro Paranaense de Referência em Agroecologia – CPRA – (Paraná Centre of Reference in Agroecology), city of Pinhais (Paraná State, Brazil) between the period of December 2015 and March 2016. The central coordinates are 25°23'03.43 S and 49°07'30.18 W, with an average altitude of 910 m. The local climate is Cfb (humid subtropical with mild summer), with an average temperature of 11 °C in the coldest month, and a mean summer temperature of 23 °C (ALVARES et al. 2013). Polyphite pasture was used, with a predominance of *Cynodon nlemfuensis* Vanderyst (african star), *Pennisetum purpureum* Schum. (napier), *Paspalum notatum* (bahiagrass), *Axonopus affinis* Chase (carpet grass), *Trifolium repens* (white clover) and *Arachis pintoi* (pinto peanut).

Initially, a forest inventory was conducted to determine the integration of the silvopastoral system already consolidated with species of bamboo. Afterwards, a census was performed taking into account the following parameters: diameter at breast height (DBH, cm), canopy area (m²), total height (m) and the number of bamboo shoots. The chosen species were defined according to the edaphoclimatic characteristics of the region and adaptation of the species to these conditions. The species were *Bambusa vulgaris vulgaris*, *B. oldhamii* and *B. tuldoides*.

Using the forest inventory of the experimental area, it was observed that there was no difference between the DBH, canopy area and total height means (p>0.05). Therefore, the only criterion for the choice of which species to study was the number of shoots, in which the *B. vulgaris vulgaris* stood out. Thus, only this species, which remained with the highest number of shoots, was chosen for evaluation (Table 1). Sixteen paddocks were evaluated, divided into four separate groups (silvopastoral treatments): 1) composed of *B. vulgaris vulgaris* and trees, 2) only bamboo, 3) only trees, and 4) without any tree specimens.

Table 1. Mean values of the variables of the forest inventory carried out in the experimental area.

Species	No. of shoots	DBH (cm)	Canopy area (m²)	Total height (m)
Bambusa vulgaris vulgaris	40a	8.1a	2.1a	1.3a
B. oldhamii	25b	7.1a	1.7a	1.2a
B. tuldoides	5c	7.0a	1.5a	1.3a

Means followed by distinct letters in the column differ between each other using the Duncan test, at 5% probability. DBH: diameter at breast height.

The microclimate data of air temperature (ºC), relative humidity (%), grass temperature (ºC) and wind speed (m s^{-1}), measured at a height of 20 cm above the soil were registered. To determine the twomicroclimate measurement points, the total distance from the paddock line to where the tree components are found was measured and it divided by three. The first measurement location of each point, corresponding to 0 m, it being found in front of the tree line of the paddock. The second location corresponds to five meters distance from the first. The microclimate measurements at each point and at each location, within each paddock were taken at 08:00, 12:00 and 16:00 hour's local time.

In order to analyse the microclimate, the experiment was carried out in a split-plots design in order to examine the effect of three factors: A = time of day; B = silvopastoral treatment; and C = distance between the rows of trees. The experiment was divided into d = 4 measurement dates. On every single date, the measurements were taken at a = 3 distinct periods of time, considering the main plot (pp). Each principal plot was divided into four subplots (sp), where b = 4 silvopastoral treatments were selected through a draw.

Each subplot was then divided into c = 2 distances in relation to the row of trees of the paddock, thus defining the sub-subplot (ssp). Each subplot had r = 4 repetitions in the experiment. The climatic variables were measured and analysed in each of the 384 sub-subplots ($d \times a \times b \times c \times r = 4 \times 3 \times 4 \times 2 \times 4$). After the assumptions of normality and homogeneity of variance had been checked for the microclimatic variables, it was only necessary to transform the data for relative humidity and grass temperature using Box-Cox transformation. When the effects were significant, the means were compared using the Duncan test (α=0.05). The models were adjusted for each of the climate variables using R software and the lme4 package (BATES et al. 2015, R DEVELOPMENT CORE TEAM 2016).There was a distance effect for relative humidity and wind speed, and a time effect for air temperature, wind speed, grass temperature and relative humidity (Tables 2 and 3). There was no effect for the silvopastoral treatments of the experiment ($p>0.05$), which may be justified by the invasion of dairy cows into the bamboo plantation lines trampling its shoots. This occurred as result of a lack of maintenance of the electric fence and a power cut in the month after plant of the bamboo species. Therefore, the bamboo specimens had a reduced canopy area, affecting shade projection. However, the agroecological silvopastoral system remained with the trees intact, to which the microclimatic influences can be attributed in the present study.

Table 2. Mean values of the microclimate variables in relation to different distances from the silvopastoral system.

Distance (m)	RH (%)	WS (m s^{-1})	Air T (°C)	Grass T (°C)
0	80a	1.8b	26.3a	23.7a
5	79b	2.1a	26.4a	23.6a

Means followed by distinct letters in the column differ between each other using the Duncan test, at 5% probability. RH: relative humidity. WS: Wind speed. Air T: air temperature. Grass T: Grass temperature. Distance: measured from the tree lines to the centre of the paddock.

Table 3. Mean values of the microclimate variables in relation to different times in the silvopastoral system.

Time (h)*	RH (%)	WS (m s^{-1})	Air T (°C)	Grass T (°C)
8	85a	2.0ab	23.8c	20.8b
12	74b	2.5a	28.7a	26.5a
16	79ab	1.3b	26.5b	23.7ab

Means followed by distinct letters in the column differ between each other using the Duncan test, at 5% probability. RH: relative humidity. WS: Wind speed. Air T: air temperature. Grass T: Grass temperature. * local time.

Relative humidity was higher close to the trees than at 5 meters, which may be explained by the presence of the forest component. It can be perceived that at 0 meters, where the highest expected reduction in wind speed occurred due to the trees being denser in the agroecological system, the relative humidity was higher and the wind speed lower, with the inverse situation at 5 m. Furthermore, modifications to the microclimate promoted by the presence of tree specimens increase the humidity available to the plants beneath the treetops, as a result of the evapotranspiration (BALISCEI et al. 2013). In relation to solar radiation, the presence of trees together with forage reduces the flow of long wave radiation during the night and this lessens the cooling of the space between the tree canopy and the forage (SINGH et al. 2012). The immediate consequence of this phenomenon is to increase air humidity, reduce the rate of evapotranspiration by the forage and increase the humidity of the soil (PACIULLO et al. 2008, BERNARDINO & GARCIA 2009).

The wind speed results showed a reduction of 14% between the distances of 0 and 5 m, with higher speeds for 5 m. The effect of a decrease in wind speed for the plants is a reduction in transpiration, non-closure of the stomata, and maintenance of high rates of photosynthesis. Moreover, the reduction in wind speed protects the vegetables against breakages, lodging and tissue rupture, maintaining a larger photosynthetically active leaf area and, consequently, higher vegetal production (CLEUGH 1998). The wind speed occurring in the paddocks did not represent a threat of damage to the vegetal components of the system, as it did not pass 6 m·s^{1}, which is the mean taken to be capable of injuring plant tissue and reducing production (GREGORY 1995).

The air temperature beneath the tree canopy can be 2 to 3 ºC lower than that observed in full sun, as there is interference from the leaves in the passage of solar radiation (MORAES JÚNIOR et al. 2010). However, in the present study there was no difference between the distances in the silvopastoral system ($p>0.05$). Even so, it can be noted that the highest air temperature found in this study was at 12:00 (28.7 °C). It can be observed that for the forage, the air temperature at different times did not pass 32 ºC, which may accelerate ripening of individual forage (PEZO & IBRAHIM 1998). In a study conducted in the city of Parnaíba (PI), temperatures of 26.7, 32.9 and 29 °C for the times of 08:00, 12:00 and 16:00, respectively, were observed within the SSP, with average differences of -3.5 °C between the silvopastoral system and open pasture (SOUZA 2009).

Grass temperature behaved similarly to air temperature at the different times, albeit with lower values. This fact may be justified by the greater presence of forage species on the surface than at 20 cm, because as previously highlighted, the greater the presence of vegetation, the higher the reflectivity of short wave radiation. As an agroecological system with polyphite pasture, this rate of reflectivity may tend to be different to a conventional system. Furthermore, during nights of intense radiation, the air and grass temperatures may differ as much as 5 ºC (BOOSTMA 1976). The differences between these temperatures may be related to various factors, such as atmospheric conditions, topography and surface characteristics. SILVA et al. (2006) stated that direct planting maintains the soil and air temperature lower through the constant presence of vegetal residue covering the soil. Therefore, the greater presence of vegetal coverage and higher exposition of the soil contribute to the increase in soil temperature and in neighbouring regions through higher long wave radiation emission (SILVA 1999).

Thus, it can be concluded that regardless of the presence of bamboo, due to the limited canopy area at young stage of *B. vulgaris*, the agro-ecological silvopastoral system promoted microclimatic alterations to the environment, indicating the potential of this integrated system to reduce the heat load for livestock and plants. There was an increase in relative humidity and a reduction in wind speed close to the tree line. It showed that this system acts as a windbreaker and retains humidity close to the trees. Regarding the use of bamboo in this arrangement, further studies are still necessary to elucidate the microclimatic changes performed by this specie during its adult stage. This specie shows both economical and sustainable potential in agro-ecological integrated systems in Southern Brazil.

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