

## Potential of tree species for designing silvopastoral technologies in animal husbandry areas<sup>1</sup>

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### Abstract

**Objective:** To evaluate the potential of tree species for the development of silvopastoral technologies in animal husbandry areas in the Sibanicú municipality, Camagüey, Cuba.

**Materials and Methods:** The study was conducted between February and March, 2024, at the La Quintina farm. An inventory of trees present for silvopastoral purposes was carried out, and air temperature, soil moisture, and the Temperature-Humidity Index (THI) for livestock were determined.

**Results:** Nineteen trees belonging to nine species and nine botanical families were observed, with *Samanea saman* (Jacq.) Merr being the species that casts the most shade (between 300 and 568 m<sup>2</sup>). The air temperature ranged between 31,0 and 35,0 °C, always higher in areas under full sun (35 °C) than in shaded areas (31,0 °C). Both under the shade of the trees and in full sun, the THI was above 78.

**Conclusions:** The strategic integration of trees in livestock systems provides multiple benefits by reducing heat stress in cattle, improving soil moisture retention, and enhancing drought resilience.

**Keywords:** botanical composition, silvopastoral system, shade

### Introduction

Cuban animal husbandry faces a critical challenge: the low productive efficiency of dairy cattle, resulting from limitations in feeding, management, and, especially, adverse climate conditions. High temperatures and high relative humidity cause heat stress in animals, which negatively affects their reproduction, weight gain, milk production, and milk quality. Although traditional efforts have focused on improving breeds and pastures, a key factor has been neglected: animal welfare linked to the microclimate provided by tree vegetation in animal husbandry systems (Valdivia-Cruz *et al.*, 2021).

The performance of meteorological variables (temperature and humidity) causes stress conditions that affect the physiology and homeostasis of the animal and are reflected in a decrease in voluntary feed intake, milk production, and reproductive efficiency of cows under production conditions. Nguyen *et al.* (2016) consider dairy cattle to be particularly sensitive to heat stress due to the high metabolism of dairy cows during lactation.

The use of shade in animal husbandry areas has a major influence on preventing the incidence of direct and indirect solar radiation on animals. Natural shade is one of the most effective forms of shade, as it not only reduces the incidence of solar radiation, but also significantly lowers air temperature through the evaporation of water from the leaves. Trees also provide ecosystem services such as carbon sequestration, nitrogen fixation, improved soil fertility and moisture, animal feeding, among others (Loyola-Hernández *et al.*, 2024).

In this context, it is essential to characterize the tree species present in animal husbandry agroecosystems and evaluate their influence on animal comfort, soil conservation, and climate mitigation. The design of efficient silvopastoral systems could offer sustainable solutions to heat stress, thus optimizing livestock productivity. Therefore, this study focuses on evaluating the potential of tree species in animal husbandry areas in the Sibanicú municipality, Camagüey, Cuba.

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## Materials and Methods

**Study area.** The study was conducted between February and March, 2024, at the La Quintina farm, belonging to the CCS Antonino Roja in the Sibanicú municipality, Camagüey province, located at 21°16'07" North latitude and 77°33'02" West longitude. The farm covers 26,84 ha, with predominance of *Paspalum notatum* Flügge and a herd of 47 animals (36 LAU). The prevailing soils are Brown soils without Carbonates (MINAGRI, 2019).

**Inventory of tree species present for silvopastoral purposes.** In the sampling unit (enclosed pasture), all trees present were identified by common and scientific name; the diameter at 1,3 m above the ground, the total height (Ht), and the crown projection area were measured (Matteucci and Colma, 1982).

**Air temperature and soil moisture.** A total of 76 observations were made to evaluate these variables, and 38 observations were made to determine air temperature, one under each tree (19) and other 19 under full sun at random. A similar procedure with the same number of observations was used to measure soil moisture percentage. Soil moisture was determined by taking 1 kg at each point, identifying it properly, and drying it in the sun until it reached a constant weight. Then, the soil moisture percentage for each condition was determined by weight difference (Bohmanova *et al.*, 2007).

**Temperature-Humidity Index (THI) for dairy cattle.** To determine the THI for dairy cattle, the following formula was used:

$$THI = (1,8 \times Ta + 32) - (0,55 - 0,55 \times Hr/100) \times (1,8 \times Ta - 26)$$

Where:

Ta= Ambient temperature

Hr= Relative humidity

Ambient temperature ( $T_a$  °C) and relative humidity (Hr %) measurements were taken at a height of 1,20 m. Stress in cattle, according to the THI, was classified according to the following scale:

THI <72: Normal (no stress for animal health); THI = 72-79: Alert (moderate heat stress); THI = 80-89: Danger (moderate to severe heat stress)

**Statistical analysis.** The descriptive statistics mean and standard deviation (SD) were determined for the studied variables. The analyses were performed using the statistical package StatGraphics Centurion XV Version 15.2.06 (2007).

## Results and Discussion

Nineteen tree individuals belonging to nine species and nine botanical families were observed in the area (table 1). The most common species is *Mangifera indica* L., which is closely related to the soil conditions of the region, where *M. indica* is very common and propagates naturally through animals that eat its fruit, such as bats or livestock, which are also widely kept in the area. In addition, there is a long-standing tradition among farmers of planting this species near their homes as a source of fruit, shade, and for cooling the environment.

According to the results in table 2, tree cover has a positive effect on the following variables: air temperature, soil temperature, relative humidity, and soil moisture. This impact is directly related to: (i) the shade cast by each individual tree, (ii) tree height, (iii) canopy density, (iv) foliage type, and (v) leaf litter deposition on the ground.

During the studied period (February and March, 2024), the air temperature ranged between 31 and 35 °C, always higher in areas under full sun (35 °C), unlike shaded areas (31 °C) at the base of the trees, and around 32 °C in areas of transition between shade and sun, with an average difference

Table 1. Species found as scattered trees in enclosed pastures.

Common name	Scientific name	Family
Copperwood	<i>Bursera simaruba</i> (L.) Sarg.	Burseraceae
Spanish lime	<i>Melicoccus bijugatus</i> Jacq.	Sapindaceae
Rain tree	<i>Samanea saman</i> (Jacq.) Merr.	Fabaceae
Royal palm	<i>Roystonea regia</i> (Kunth) O. F. Cook	Arecaceae
Calabash tree	<i>Crescentia cujete</i> L.	Bignoniaceae
Red cedar	<i>Trichilia hirta</i> L.	Meliaceae
Clammy cherry	<i>Cordia collococca</i> L.	Boraginaceae
Mango	<i>Mangifera indica</i> L.	Anacardiaceae
West Indian elm	<i>Guazuma ulmifolia</i> Lam.	Byttneriaceae

Table 2. Average temperature variation under the canopy of scattered trees in pastures, temperature outside the canopy, and soil moisture percentage.

Common name	Scientific name	Under canopy		Outside canopy (sun)		Difference	
		t °C	% H soil	t °C	% H soil	t °C	% H soil
Copperwood	<i>B. simaruba</i>	35,0	50,0	35,0	41,9	0	-8,1
Spanish lime	<i>M. bijugatus</i>	34,0	50,0	34,5	41,8	+0,5	-8,2
Rain tree	<i>S. saman</i>	33,0	50,9	35,0	41,8	+2	-9,1
Royal palm	<i>R. regia</i>	35,0	49,6	35,0	41,8	0	-7,8
Calabash tree	<i>C. cujete</i>	32,0	50,3	35,0	41,2	+3	-9,1
Red cedar	<i>T. hirta</i>	35,0	50,3	35,0	41,8	0	-85
Clammy cherry	<i>C. collococca</i>	32,0	49,8	35,0	41,7	+3	-8,1
Mango	<i>M. indica</i>	31,5	50,3	35,0	42,1	+3,5	-8,2
Royal palm	<i>R. regia</i>	35,0	49,3	35,0	42,0	0	-7,3
Mango	<i>M. indica</i>	31,0	50,1	35,0	41,5	+4	-8,6
Mango	<i>M. indica</i>	31,0	49,6	35,0	41,8	+4	-7,8
Mango	<i>M. indica</i>	31,0	50,3	35,0	41,8	+4	-8,5
Mango	<i>M. indica</i>	31,0	50,3	35,0	41,8	+4	-8,5
Mango	<i>M. indica</i>	31,0	49,8	35,0	41,2	+4	-8,6
Mango	<i>M. indica</i>	32,0	50,3	35,0	41,8	+3	-8,5
Spanish lime	<i>M. bijugatus</i>	33,0	50,0	35,0	41,7	+2	-8,3
West Indian elm	<i>G. ulmifolia</i>	33,0	50,0	35,0	42,1	+2	-7,9
West Indian elm	<i>G. ulmifolia</i>	31,0	50,9	35,0	42,0	+4	-8,9
Rain tree	<i>S. saman</i>	31,0	49,6	35,0	41,5	+4	-8,1
Mean		32,5	50,07	34,97	41,75	+2,47	-8,32
Standard deviation ±		1,5899	0,4027	0,1147	0,2475		

of 4 °C. There were also differences in relative humidity, which ranged from 28,2 to 34,3 % in the sun and in the shade of the canopy, respectively. Poveda *et al.* (2021) found a decrease of 3 to 4 °C in temperature and an increase of 3 to 10 % in relative humidity between areas with and without vegetation, respectively. These authors assert that, in addition to the decrease in temperature, the increase in relative humidity also contributes to the microclimate improvement of the ecosystem.

In terms of soil temperature, it was observed that under the canopy shade the average was 32,5 °C, with a range between 31,0 °C in species such as *M. indica* and *G. ulmifolia* and 35,0 °C in *B. simaruba*, *R. regia*, and *T. hirta*. In contrast, in sunny areas, the temperature was consistently higher, with an average of 34,9 °C, reaching 35,0 °C in almost all cases. The greatest differences were recorded under the canopy of *M. indica* and *G. ulmifolia*, where the temperature was up to 4 °C lower than in exposed areas; while species such as *B. simaruba* and *R. regia* showed no cooling effect under their canopy.

In terms of soil moisture, values under the canopy were significantly higher (50,1 % on average) than in sunny areas (41,8 %). The average difference was -8,32 %, indicating a significant loss of moisture in unshaded areas. The species with the greatest capacity to retain moisture were *C. cujete* and *S. saman*, with differences of up to -9,1 %; while *R. regia* showed the smallest difference (-7,3 %). These results suggest that certain trees, such as *M. indica* and *G. ulmifolia*, not only reduce the temperature under their shade, but also help maintain higher levels of moisture in the soil, which once again corroborates the positive effect of afforestation on the soil and, consequently, on its microclimate, benefiting edaphic fauna and, with it, the decomposition of organic matter (Loyola *et al.*, 2024).

Pastures that grow under the shade of trees have a higher nutritional value compared with those that grow in the open (full sun), even more so if these trees are legumes such as *S. saman*. These results are similar to those obtained by Olaya-Montes *et al.* (2021), who report that temperature reductions

between 2 and 9 °C have been found under the canopy of trees compared with open grasslands. These results are corroborated in this study, where temperature reductions were also between 2 and 4,0 °C.

Detailed analysis of the temperature variable shows a close relationship with the morphological characteristics of each plant. It was observed that the height of each plant and its shade projection area, in this case the most pleasant microclimates, with temperatures of 31 °C, generally corresponded to the species *M. indica*. For individuals of this species, their heights varied between 5 and 7 m and the shade area between 76 and 176 m<sup>2</sup>, unlike other species with very broad crowns, such as one of the *S. saman* specimens, whose crown measures 568,3 m<sup>2</sup>, but whose height is 15,0 m.

#### *Temperature-humidity index for dairy cattle.*

During the study period, both in the shade of the trees and in full sun, the THI was above 78,7 (table 3), so it is considered that the animals were under stress due to high temperatures and low humidity. In the case of the THI in the shade, it was 78,7, considered moderate, so an alert was issued to the farmer. In the case of the THI in the sun, it was 80,3, assessed as moderate to severe, which is already considered a dangerous condition for the animals (Ghiano *et al.*, 2014; Habeeb *et al.*, 2018).

Table 3. Temperature-humidity index (THI) for dairy cattle.

	Sun	Shade under canopy
THI	80,3	78,7
Standard error ±	0,0379	0,2252

In the study area, there are structural and non-structural vulnerabilities that can affect the comfort of the animals and accentuate the effect of high THI values. Among these, the lack of shade trees stands out (Lemaire *et al.*, 2019; Enríquez-Regalado and Álvarez-Adán, 2020), which, despite the existence of 19 trees in this area, only occupy 2 619,01 m<sup>2</sup> (0,26 ha), 5,2 % of the 5 ha of enclosed pasture studied.

Heat stress in livestock begins at THI values of 70 units in the animals and suggests that, in Cuba, 26 °C is the temperature at which heat stress begins, which is above the desired level with values ranging from 72 to 78 THI units, showing mild to moderate stress (Rodríguez-Silva and Regino-Arroyo, 2019). When the THI exceeds 73, the conception rate can

decrease by up to 12 %, depending on the time before mounting or insemination (Schüller *et al.*, 2014).

Heat stress reduces milk production by 10 % at temperatures between 27 and 32 °C and 50 to 90 % RH; up to more than 25 % RH at temperatures between 32 and 38 °C with the same ambient humidity (González, 2017). High-yield dairy cows are the most affected due to their high metabolic rate and high feed intake (Guerra-Montenegro *et al.*, 2019).

It can be said that, in general terms, adult cattle can withstand temperature ranges from 0 to 25 °C without major complications (Enríquez-Regalado *et al.*, 2020). Studies conducted by Claros-Hernández *et al.* (2010) show that each point increase in the THI above 18 °C means, in dairy cattle, a decrease of 0,26 kg of milk per day, a decrease in intake of 0,23 kg of forage per day, and an increase of 0,12 °C in the cow's body temperature. These aspects show the need to use tree species as an economically viable alternative to reduce heat stress in livestock, with the subsequent impact on production.

## Conclusions

Nineteen individuals belonging to nine species and nine botanical families were identified, with *M. indica* being the most common species. This predominance is associated with the soil conditions of the area and its cultural and economic value in local animal husbandry systems.

The trees showed a significant cooling effect, reducing the air temperature by up to 4 °C under their canopy compared with areas exposed to the sun. In addition, greater soil moisture retention was observed in these shaded areas, suggesting their key role in mitigating drought and heat stress.

Temperature-humidity index values exceeded 78, indicating that the animals were exposed to moderate-severe heat stress during the study. This is attributed to high ambient temperatures and low relative humidity, factors that negatively affect livestock welfare, production, and reproduction.

The results support the strategic incorporation of trees (especially species such as *M. indica*) into animal husbandry systems, as they reduce heat stress in livestock, improve soil moisture, and increase resilience to drought.

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### Conflict of interests

The authors declare that there is no conflict of interests.

### Authors' contribution

- Oscar Loyola-Hernández. Conception and design of the research; analysis and interpretation of the data and writing of the paper.
- Isael Pérez-Cabrera. Research conception and design; writing of the paper.
- Delmy Triana-González. Research conception and design; data analysis and interpretation, and writing of the paper.
- Elenia Díaz-Hernández. Research conception and design; writing of the paper.

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