Cuban Journal of Forest Sciences

CFORES

Identification of tree species present in silvopastoral dairy production systems of the Villa Los Almácigos municipality, Dominican Republic

Identificación de especies arbóreas presentes en sistemas silvopastoriles de producción lechera del municipio Villa Los Almácigos, República Dominicana

Identificação de espécies arbóreas presentes em sistemas silvipastoris de produção leiteira do município de Vila Os Almácigos, República Dominicana

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ABSTRACT

The study of livestock systems in the Dominican Republic is a necessity to guide livestock farming towards sustainable alternatives such as silvopastoral systems. In this research, it was proposed to identify useful tree species in silvopastoral systems of milk production in the Villa Los Almácigos municipality, Santiago Rodríguez, Dominican Republic, through direct inspection and application of semi-structured interviews to selected livestock producers in the municipality. Dasometric variables: diameter ($D_{1,30}$) and total height were measured to characterize the tree species and descriptive statistics were applied to the data. It was evident that the most predominant silvopastoral system was scattered trees, then living fences and riparian forests. A total of 23 species were recorded, some of the main ones identified as multipurpose, including: *Gliricide sepium* Jacq., *Mangifera indica* L., *Callophyllum calaba* L., and *Persea Americana* Mill. *Pinus species patula* Schiede former Schltdl. and Cham., recorded the highest $D_{1,30}$ with 74.17 cm and commercial height with 0.84 m, key characteristics in a timber species. It is recommended to ranchers in the region to expand and manage the silvipasture Systems in grazing with tree species suitable for each farm and to train ranchers in their locative management. The study contributes to the promotion of dispersed trees of evergreen species on farms, because they provide shade and forage throughout the year, contributing to animal well-being.

Keywords: Height, dasometrics, diameter, multipurpose tree species, livestock, cattle, milk, silvopastoral.

RESUMEN

El estudio de los sistemas ganaderos en República Dominicana es una necesidad para orientar la ganadería hacia alternativas sostenibles como los sistemas silvopastoriles (SSP). En esta investigación se propuso identificar especies arbóreas útiles en sistemas silvopastoriles (SSP) de producción de leche del municipio Villa Los Almácigos, Santiago Rodríguez, República Dominicana, por medio de inspección directa y aplicación de entrevistas semiestructuradas a productores de ganado seleccionados del municipio. Se midieron variables dasométricas ($D_{1,30}$) diámetro, altura de pecho o DAP, altura total) para caracterizar las especies arbóreas y a los datos se les aplicó estadística descriptiva. Se evidenció que el sistema silvopastoril más predominante fue árboles dispersos, luego cercas vivas y bosques riparios. Se registraron en total 23 especies, algunas de las principales señaladas como multipropósitos, entre ellas: *Gliricida sepium* Jacq., *Mangifera indica* L., *Callophyllum calaba* L., y *Persea americana* Mill. La especie *Pinus patula* Schiede ex Schltdl. y Cham., registró el mayor $D_{1,30}$ con 74,17 cm y altura comercial con 0,84 m, características clave en una especie maderable. Se recomienda a los ganaderos de la región la ampliación y manejo de los SSP en pastoreo con especies arbóreas adecuadas para cada finca y la capacitación de los ganaderos en el manejo locativo de estos. El estudio aporta al fomento de árboles dispersos de especies perennifolias en las fincas, debido a que brindan sombra y forraje durante todo el año, contribuyendo al bienestar animal.

Palabras clave: Altura, dasométricas, diámetro, especies arbóreas multipropósito, ganadería, ganado bovino, leche, silvopastoriles.

RESUMO

O estudo dos sistemas pecuários na República Dominicana é uma necessidade para orientar a pecuária em direção a alternativas sustentáveis, como os sistemas silvipastoris (SSP). Nesta pesquisa foi proposto identificar espécies arbóreas úteis em sistemas silvipastoris (SSP) de produção de leite no município de Villa Los Almácigos, Santiago Rodríguez, República Dominicana, através de inspeção direta e aplicação de entrevistas

semiestruturadas a produtores pecuários selecionados no município. Variáveis dasométricas (D$_{1,30}$ (diâmetro, altura do peito ou DAP, altura total) foram medidas para caracterizar as espécies arbóreas e estatística descritiva foi aplicada aos dados. Ficou evidente que o sistema silvipastoril mais predominante eram árvores dispersas, depois cercas vivas e matas ciliares. Foram registradas 23 espécies, algumas das principais identificadas como polivalentes, entre elas: Gliricida sepium Jacq., Mangifera indica L., Callophyllum calaba L. e Persea Americana Mill. A espécie Pinus patula Schiede ex Schltdl. e Cham., registraram o maior D$_{1,30}$ com 74,17 cm e altura comercial com 0,84 m, características chave em uma espécie madeireira. Recomenda-se aos pecuaristas da região ampliar e manejar os SSPs no pastoreio com espécies arbóreas adequadas para cada fazenda e capacitar os pecuaristas no seu manejo locativo. O estudo contribui para a promoção de árvores de espécies perenes dispersas nas explorações agrícolas, pois proporcionam sombra e forragem durante todo o ano, contribuindo para o bem-estar animal.

Palavras-chave: Altura, dasometria, diâmetro, espécies arbóreas multiuso, pecuária, bovinocultura leiteira, silvipastoril.

INTRODUCTION

The economy of the Santiago Rodríguez province, Dominican Republic, depends fundamentally on the production of dairy cattle and, to a lesser extent, on dual-purpose livestock farming, having a significant concentration of herds dedicated to milk production (approximately 14.5 % of the national territory at surface level) and is one of the main income-generating activities for families: it represents more than 70 % of their economy (MepyD, 2017). Grasses are the main source of food for cattle worldwide, the main genera being *Brachiaria*, *Cenchrus*, *Cynodon*, *Digitaria*, *Panicum* and *Pennisetum*, of which these genera are described and the main species/genus are listed (Sotomayor and Schank, 2000). According to Bacab -Pérez and Solorio-Sánchez (2011), there are also high percentages of land occupied by the native Haitian pajón grass (*Bothriochloa pertusa* L. ex A. Camus).

However, the dairy livestock subsector shows low farm productivity due to the lack of quality forage resources and poor management of the implemented systems. This, however, in combination with the adverse effects brought by climate change (CC), could cause low performance in the amount of milk produced by livestock (Carranza and Ledesma, 2009). In addition to this adverse effect, by observing the reality of the farms visited in the study, other impacts of CC have been identified in the area, although without quantification. These include: weight loss and animal deaths, low milk productivity, as well as low water availability, decreased availability of pastures, and less diversification on farms.

Therefore, the production of pastures and forage in the province is affected year after year by droughts. Its impacts are mainly manifested in the reduction of the availability and quality of the pastures on offer, and in a decrease in the performance of the animals (Wagner *et al.*, 2018). In this sense, Farias (2006) states that there is poor management and use of pastures, particularly in the control of animal overload, or undergrazing, weeding and a decrease in the persistence of the pasture with losses in production. and economic benefit. In the provinces of Montecristi, Santiago Rodríguez and Valverde, Wagner *et al.* (2018) report that the farms do not have defined management of soil and water resources; and they do not have a seasonal sustainable management program for their pastures. In contrast, pastures under trees with some arrangement in the paddocks present greater productive stability, both at the level of the pasture and the animals, according to the study by Santos-Gally and Boege (2022), which highlights the role of native trees in Neotropical pastures and how they are coupled to SSPs. These authors propose that the remnants of natural forests are immersed in grassland with low productivity, due to soil degradation and erosion, high temperature and low humidity (Santos-Gally and Boege, 2022), which also It is correlated with the CC. The inclusion of leguminous trees in pastures improves the chemical characteristics of the soil, thanks to a greater contribution of organic matter that results in greater nutritional quality of the grass and greater availability of consumable forage material (Mahecha *et al.*, 2000).

Currently, according to Hernández *et al.* (2022), animal production systems require intensifying food production processes, through different production systems, but without deteriorating the existing ecosystems on our planet. In this sense, it is important to apply a series of actions to increase sustainable productivity and water resources in the soil, the recovery of the vegetation cover and the improvement of livestock management practices (Galván *et al.,* 2018). Therefore, the application of agroecological principles and practices is required for the transition towards sustainable cattle farming (Angel-Lozano *et al.,* 2023), with the purpose of changing traditional systems. To achieve this, it is necessary to understand the interactions that occur in the tree-grass-soil-animal relationship (Mordelet and Roux, 2006). These report the interactions of these four components, as well as their implications with the environment and other components in positive and negative terms (Mordelet and Roux, 2006), like Muñoz-Guerrero, Navia, and Solarte Guerrero (2018), who they report these interactions in detail. However, bad livestock practices combined with the effects of CC, represent serious risks for the continuity of the productivity of grassland ecosystems, mainly in arid and semi-arid areas (Ortega, 2012), coinciding with the actions recommended by Galván *et al.* (2018). The changes to be implied have the objective that the rancher applies management that guarantees efficient and environmentally friendly systems, as recommended by Hernández. *et al.* (2022), Galván *et al.* (2018) and Wagner *et al.* (2018).

Consequently, progress must be made in the implementation, generation of information and dissemination of sustainable animal production systems, in order to guarantee greater productivity and competitiveness of the livestock sector. Due to the above, there is a need to modify current monoculture grass systems and adopt silvopastoral systems (SSP) to improve animal welfare, production, biodiversity and environmental sustainability (Galván *et al.,* 2018; Wagner *et al.,* 2018). The generation of information in the livestock systems of the municipality of Villa de Los Almácigos, Santiago Rodríguez is a necessity for the efficiency of its productive units. Given the importance of these systems in the livestock area, through this research we seek to identify tree species in silvopastoral systems in the dairy livestock sector of the Villa Los Almácigos municipality, Province of Santiago Rodríguez, Dominican Republic, with the purpose of contributing to its sustainability.

MATERIALS AND METHODS

Study zone

The Villa Los Almácigos municipality, Santiago Rodríguez, RD, is located between 19°24'30" N and 71⁰19'59.98" E (Municipal Planning and Programming Office Villa de Los Almácigos City Council, 2021). The province has a variable altitude from 159 meters above sea level to more than 2000 meters above sea level, with a humid tropical, dry subtropical and semi-humid tropical climate (Betancourt Fernández and Lamelas, 2010). It has an average annual precipitation of 150 mm (Betancourt Fernández and Lamelas, 2010), with two rainy seasons per year, May-June and September-October, with May being the rainiest month. The average maximum temperature is 31 °C and minimum 19°C (ONE, 2019).

Population and sample size

A population of 100 dairy cattle producers registered in the municipality of Villa Los Almácigos was used; the formula for finite populations defined by Fisher *et al.* (1941) for a random sample was calculated Equation 1:

$$n = \frac{Z^2 N p q}{(N-1) e^2 + Z^2 p q} \quad (1)$$

Where: N = Universe (100); Z = 1.28 (80 % confidence level); p = Probability of success (0.50); q = Probability of failure (0.50); e = Estimation error (0.10), and n = sample (30).

Variables analyzed

The common name of the species was determined by direct observation in the field, diameter ($D_{1,30}$) was measured (Figure 1a), and the total height of the plants expressed in meters, with a clinometer. In addition, the type and number of arrangements were determined through direct observation. Subsequently, the scientific names of the species initially identified by the common ones were identified (Figures 1b). Tables and taxonomic lists of species were used throughout the process. Figures 1c and 1d show the typical landscape of the study region, the SSP of scattered trees of fruit species.

In the interview, the following variables were evaluated: farm area (ha), heads of cattle (unit), cows in production (unit), average milk production (liters day^{-1} animal^{-1}), breeds and type of dairy system. Additionally, the perception of livestock producers in the region regarding the SSP and management recommendations was determined.

Figure 1. *- T- ome of dasometric variables and livestock landscapes: a) DAP measurement; b) Measurement and identification of species; c) Livestock landscape in the municipality of Villa Los Almácigos; and d) Silvopastoral system of scattered trees of fruit species.*

Information collection

The research was carried out in three phases: 1. Planning of field work and preparation of protocol, 2. Field activities, and 3. Office phase with data analysis and writing. The three phases were carried out during the period September 2020 to December 2022. For the base characterization of the study area, semi-structured interviews were applied to the sample of 30 producers from the municipality of Villa Los Almacigos. The interview included a form with open and closed questions related to general information such as climate, family members, farm data, paddocks, arrangements, field measurements, producers' perception,

advantages and disadvantages of SSPs. In parallel, a visual inspection was carried out on all the farms to recognize the types of SSP arrangements in accordance with the methodology defined by Villanueva *et al.* (2006), which helps identify each type of SSP arrangement found. In each one, a plot between 250-1000 m² was established, where species identification and dasometric variables were measured: diameter and height.

Analysis of data

The field information related to the species and arrangements, as well as that obtained in the interviews with the livestock producers, was tabulated in Microsoft office, in the Excel spreadsheet and the analyzes were carried out with the InfoStat software, using descriptive statistics.

RESULTS AND DISCUSSION

Livestock context of Villa Los Almácigos, Santiago Rodríguez

The average area of the farms expressed by the producers in the semi-structured interview is approximately 13 ha; the majority for livestock production (Table 1). On these farms, the dual-purpose production modality predominates, found in 29 farms (96.67 %) and only one is dedicated to specialized dairying, which agrees with what is described by the FAO (2015, 2018), which records that the country's milk production relies on the dual-purpose system. Likewise, 27 farms (90 %) keep the animals in a semi-stable mode. According to Mohan and Ramachandran (2011), this may be due to the absence of quality pastures. In general, the low quality of the pasture, associated with the CC and the water deficit, could be the reason for livestock farmers to resort to cutting grasses, which are supplied to the animal in the pens, as suggested by Angel -Lozano *et al. to the.* (2023) and Ortega (2012). In that sense, some producers stated that they use commercial concentrates, which increase production costs; however, no investigation was made about these products, prices and quantity used per animal, according to weight.

Table 1. - *Main characteristics of the livestock systems in Villa Los Almácigos, Santiago Rodríguez, Dominican Republic*

Variable	Mean
Total farm area (ha)	13.12
Number of cattle	45.77
Cows in production	12.83
Average milk production (liters day^{-1})/animal group	101.70
Type of dairy production system	
Dual purpose (farms)	29
Specialized dairy (farms)	1
Grazing system mode	
Semi-stabled (%)	27
Permanent grazing (%)	3

The average milk production is equivalent to 8.5 L of animal day^{-1}, which shows that production is below what is expected for Holstein breeds, which is between 15 and 20 L of animal day^{-1} (Cañas *et al.*, 2009). predominant in the majority of the farms (93 %). There is also the presence of other races or crosses such as: Hostein-Zebu, Holstein-Swiss Brown, these in order to look for certain favorable characteristics of each breed, whether better adaptation to the edaphoclimatic conditions of the area, typical of Zebu and Swiss brown, complementing the high milk productivity of the Holstein breed. In only one farm was the Jersey breed mentioned, being the least common in the region. On livestock farms in Nariño, Colombia (Bucheli *et al.*, 2020), it is reported that on more than 200 farms, the recurring cattle are the Holstein and Criollo breeds for dairy production. These results are similar to those obtained on the farms of Villa Los Almacigos.

Types of silvopastoral systems present on the farms studied

Five types of silvopastoral systems were found (Figure 2) on the selected farms. The predominant arrangement was scattered trees, present in 29 farms (96.67 %), followed by live fences in 25 farms (83.33 %). Those with the least presence were: forest patch and trees on boundaries, reported in two farms. It should be noted that the number of silvopastoral arrangements (80) is greater than the total number of sampled farms (30), which indicates that some farms have more than one silvopastoral arrangement, this is a good indication of the diversity existing in the area. study. Portilla *et al.* (2015) obtained similar results, highlighting that arrangements of dispersed trees and live fences are the most used in the SSPs of Central America. According to Murgueitio *et al.* (2011), report the woody and herbaceous species adapted to the area, these can be used in livestock systems for cutting and carrying, because they have good development when planted in high densities to feed the animals, trying to guarantee the contribution of protein, energy and fiber for ruminants throughout the year, making production systems more resilient.
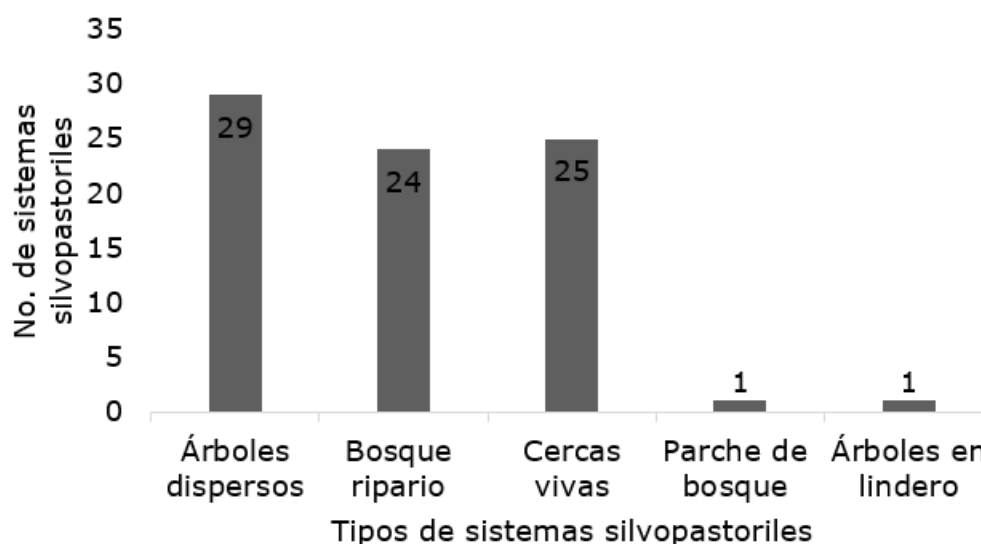
Figure 2. - Types and quantity of silvopastoral systems present on livestock farms in Villa Los Almácigos, Santiago Rodríguez, Dominican Republic

444 individuals and 23 tree species were identified. Of the total species, four reached more than 30 individuals (Table 2). Among the registered species, *Gliricida* stands out. *sepium* Jacq., *Mangifera indica* L., *Calophyllum calaba* L., *Persea Americana* Mill., which represent 75 % of the individuals found. However, the goods and services of the species were not determined, although the various uses of these by the livestock producers interviewed were observed in the field.

Table 2. - *Tree species found on the farms according to dasometric variables, Villa Los Almácigos, Santiago Rodríguez, Dominican Republic*

Species	Scientific name	N	$D_{1.30}$ (cm)	Commercial height (m)	Total height (m)
Pinion	*Gliricidia sepium* Jacq .	168	12.48	0.38	2.07
Mango	*Mangifera indica* L.	103	45.31	0.57	4.78
Mara	*Calophyllum calaba* L.	33	22.82	0.81	3.95
Avocado	*Persea Americana* Mill.	30	39.94	0.78	4.47
Knob	*Syzygium jambos* (L.) Alston	21	23.77	0.69	3.98
Orange	*Citrus aurantium* L.	14	17.55	0.51	2.44
Wow	*Comocladia dentata* Jacq .	9	11.21	0.43	3.04
Candelon	*Acacia skleroxyla* Tuss .	8	29.17	0.74	4.26
Gina	*Pithecellobium dulce* Martin	7	23.19	0.43	3.11
Cashew	*Anacardium western* L.	7	23.83	0.74	3.13
Jobo	*Spondias mombin* L.	6	32.84	0.90	3.79
Guácimo	*Guazuma ulmifolia* Lam.	6	45.15	0.61	4.87
Saman	*Samanea saman* Jacq.	5	49.34	0.71	4.44
Soursop	*Annona muricata* L.	5	15.41	0.72	2.34
Guama	*Inga Vera* Willd	5	33.11	0.45	4.45
Caimito	*Chrysophyllum cainito* L.	4	14.4	0.46	5.87
almácigo	*Bursera simaruba* (L.) Sarg	3	13.58	0.29	1.27

Layer	*Spirothecoma rubriflora* (Leon) Alain	3	38.52	1.20	3.95
John first	*Simarouba glauca* DC.	3	24.30	1.14	4.30
Carob tree	*Ceratonia siliqua* L.	2	31.19	0.79	4.54
Grayumbo	*Cecropia schreberiana* Miq. .	1	28.01	1.84	3.95
Pine pine	*pine patula* Schiede former Schltdl. and Cham.	1	74.17	0.84	7.96
Total		**444**	-	-	-

The highest $D_{1.30}$ values corresponded to *Pinus patula*, *Samanea saman* and *Mangifera indica*. *P. patula*, *Chrysophyllum cainito* and *Guazuma ulmifolia* They were the ones that reached greater total heights. Besides, the species *G. sepium* corresponds to a multipurpose species, according to the information provided by ranchers.

The Cuban pine nut (*G. sepium*) and the jobo (*Spondias mombin*), stand out in the production of posts for the establishment or repair of live and dead fences. Araque *et al.* (2006) determined the protein contribution of these legumes (G. *sepium* and *S. mombin*) in times of low and high rainfall is between 20.8 and 25.7 %, whose study was in edaphoclimatic conditions similar to the present research, which demonstrates that this tree legume offers high nutritional quality for the feeding ruminants and can be used as a protein source to enrich diets for these animals. Espinoza (2006) obtained a height of 2.3 meters in Cuban piñon live fences established 10 years ago, similar to the height recorded in the present study. Ramirez *et al. (2008), in a G. sepium* protein bank and at a soil depth of 0 to 100 cm, recorded the sequestration of 91.1 t ha^{-1} of carbon (in 3 years) in this species, under the conditions of the CC and livestock production, according to the review published by Cheng, Mccarl and Fei (2022) and Rojas-Downing *et al.* (2017).

Muñoz-Guerrero, Navia and Solarte Guerrero (2018), in milk-producing livestock farms in Nariño, Colombia, recorded the same tree species, highlighting *Bacharis* sp. (forage), *Weinmania pubescens* (firewood), *Miconia theacens*, *Acacia decurrens* (firewood), *Alnus acuminata* and *Eucalyptus globulus as* dead posts; In addition, natural and improved pastures managed in a mixed way were found, represented by *Holcus lanatus* , *Pennisetum clandestinum* and *Lolium multiflorum* (traditional pastures). In this research, they make a

detailed report on the species of live fences, medicinal uses, dead and live posts, timber, firewood, among other uses (Muñoz-Guerrero, Navia and Solarte Guerrero, 2018).

M. indica and *P. Americana* was recorded, agreeing this result with the findings of Marinidou and Jiménez (2010), in a study in the tropics. These provide various goods and services, such as forage, wood and fruits, which translate into an increase in the productivity of the system through self-consumption (Montiel-Aguirre *et al.*, 2006).

Perception of livestock producers in the region and recommendations on SSP

It was evident that there are some negative aspects of tree species in livestock systems, such as invasive (53.33 %), with thorns (10 %), for 63.33% of the producers interviewed (Table 3). This may be because some are easy to spread and can be spread by different means such as wind or different animal species. In the case of some fruit trees such as mango (*Mangifera indica*), avocado (*Persea americana*), cashew (*Anacardium occidentale)* and in some cases citrus trees, have an easy spread because their fruits fall directly on the pastures and a new plant is generated, or they are also spread by birds and animals. In this case, it is recommended to carry out selective management of the natural regeneration of the tree species present in the pastures (100% of those surveyed), to obtain greater diversity of species, with high potential for use in silvopastoral systems (Esquivel *et al.,* 2009). In contrast, 11 producers (36.67%) indicated that tree species do not have negative aspects, as long as adequate management is carried out.

On the other hand, several producers indicated that trees limit the growth of pasture (53.33 %). This is because if adequate pruning is not carried out on some species, the light interference with the tree crown is high and therefore the pastures do not adequately carry out the photosynthesis process and their production is not the same as in full sun. As pointed out by Alonso *et al.* (2011), they report a lower forage production in the treatment where there were a greater number of trees. The quality and quantity of solar radiation was, apparently, the fundamental limiting factor in grass growth. For this reason, pruning or, in some cases where the coverage is very dense, thinning is recommended.

Table 3. - *Perception of livestock producers from Villa Los Almácigos on silvopastoral systems and tree species*

Aspects related to SSP	Number of producers (n = 30)	Percentages (%)
1. Negative aspects of the species	eleven	36.67
2. The species are considered invasive	16	53.33
3. Presence of spines in some species and negative effects	3	10
4. Interest of producers to expand tree coverage	30	100
5. They want to plant fruit and forage species in pastures	30	100
6. They want to plant *G. sepium* in systems such as live fences and trees on boundaries	30	100
7. Provision to conserve and protect tree species on livestock farms	30	100
8. They consider that management of tree species on farms should be carried out, especially natural regeneration	30	100
9. They view tree species as key elements within the livestock system	30	100

All the producers interviewed stated that among their future plans is to expand tree cover and continue planting forage species such as the Cuban pine nut (G. *sepium*), as part of the living fences. The above was due to the fact that it fulfills several functions and services such as delimiting the farm, providing quality forage and providing shade for the animals, improving the landscape and increasing the flora and fauna of the area, functions that make it a potential species. to adapt to the effects of CC under the conditions of this study. Finally, for livestock farmers in the municipality of Villa Los Almácigos, the establishment of dispersed trees of evergreen species on their farms should be promoted, because they provide shade and forage throughout the year, thereby contributing to animal well-being.

CONCLUSIONS

The main multipurpose tree species found in the region were: *Gliricidia sepium*, *Mangifera indica*, *Persea americana* and *Calophyllum calaba.*

The most dominant SSP is a scattered tree, followed by live fences made up mostly of *Gliricidia sepium* useful for providing permanent forage, and the timber species *Pinus patula.* which was the one with the greatest height and $D_{1.30}$.

The study contributes to the promotion of dispersed trees of evergreen species on farms, because they provide shade and forage throughout the year, contributing to animal well-being. Based on the interviews, it was evident that the tree species present in livestock systems have negative aspects such as invasive, have thorns and rapid growth, which limits their use in the study area.

Finally, selective management of the natural regeneration of tree species present in the pastures will serve to increase diversity and better use of them in Villa Los Almácigos, Santiago Rodríguez.

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Conflict of interests:

The authors declare not to have any interest conflicts.

Authors' contribution:

The authors have participated in the writing of the work and analysis of the documents.