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Fodder production under canopy of five species of the Tamaulipan thorn scrub in the northeast of Mexico

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woody species coverage, herbaceous biomass, fodder production, Tamaulipan thornscrub

A B S T R A C T

Much of the northeastern Mexican surface, especially the area physiographically called "the Northern Gulf Plain," is covered with vegetation consisting predominantly of shrub, composed of a wide variety of species, with diverse structures and associations, which gives to the landscape a toponymy known as "Tamaulipan thorn scrub". The main use is for extensive pastoral and forestry purposes, generally without a management plan. The quantitative determination of the vegetation coverage was important to establish strategies for optimal utilization of vegetation by livestock and wildlife. In a typical scrub of Linares, Nuevo León, Mexico, and experimental plantations of over 28 years with native species, an inventory was conducted with the aim of evaluating forage availability. Coverage by woody species and herbaceous biomass were determined. The results showed highly significant differences ($P<0.001$) between types of management by species, with maximum coverage value of 19.68 m^2 $tree^{-1}$of *Ebenopsisebano* and only 2.73 m^2 $tree^{-1}$ for *Acacia berlandieri* in their native area. As for biomass, *Acacia wrightii* in experimental condition and *Acacia berlandieri* in its habitat presented higher productions, with values of 0.83 and 0.79 kg ha^{-1}, respectively. *Ebenopsisebano* in its native area produced the lowest biomass (0.19 kg ha^{-1}) of the experiment.

Introduction

Scrubs are the most abundant plant communities of Mexico, covering almost 40% of its area, 800,000 km^2 (Rzedowski, 1978).In this type of ecosystem, large-scale extensive livestock has been practiced for the last 350 years (Foroughbakhch*et al.*, 2009), resulting in the loss of quality and number of forage species, followed by the reduction of the vegetation layers that cover and protect the soil (González *et al.*, 2004).

Since the soil is the basic component of an ecosystem by its influence in the productivity, any attribute of vegetation associated with the reduction of erosion and stability of the characteristics of the soil surface should be measured primarily. Vegetal coverage is an attribute of vegetation which is closely related to soil stability, because it offers protection to the interception and absorption of the impact of raindrops, promotes infiltration, reduces surface runoff of water and decreases soil drag(Branson *et al*., 1981; Gaither andBuckhouse, 1983; Thurow*et al.*, 1988; Simanton*et al*., 1991).The relevance of selecting plant coverage as an indicator of the impact of grazing or any improvement practice is because any change in it is the first symptom of changes in environmental processes, such as erosion, the amount of mulch on the ground and botanical composition (Wilson and Tupper, 1982).In addition, the coverage parameter indicatesthe occupied volume or soil surface covered by a species, better than the abundance or dominance parameters, (Huss *et al.*, 1986).

Woody plants, characteristical of scrubby natural ecosystems, play a dual role in the habitat. Apart from being the main source of food, they also have the function of serving as a means of coverage and soil protection from erosion (Villarreal, 1999; González andCantú, 2001).These scrubby woody plants are economically important for the rural population, as they are used as a source of fodder for animals (Von Maydel, 1996). But due to variations in coverage, particular aspects of the parts of those plants and the result of differences in the radiation load, the temperature of the tissue at any time varies widely (Alldredge*et al.*, 2002). The management of these resources must be based on the observation and interpretation of distinct ecological characteristics that allow one to estimate in the most accurate possible way, forage availability, defined as the amount of dry matter delivered daily to each animal.That is the starting point for a series of high-impact decisions on productive results in livestock systems based on forage, with the main objective to establish workable and adaptable strategies through changes according to the place and thus achieve optimal handling and use of vegetation and wild fauna.Therefore, the study and analysis of vegetation coverage should be the first step.

As a strategy in the management and use of Tamaulipan thornscrub species, the research focused on the vegetal coverage of woody species, to evaluate their ability to provide forage, based on the development of herbaceous species.

Material and methods

Site of study

The monitored area is located in the scrub-school of the Forestry Faculty of the Autonomous University of Nuevo Leon in the town of Linares (24°47' LN and 99°32' LW), near the Sierra Madre Oriental (Foroughbakhch, 1992).The data were recorded in autumn 2013, at 28 years after plantation.

The regional climate in the scheme of Köppen modified by García (2004) is defined as semiarid and subhumid [(A) C (Wo)] with two rainy seasons (summer and autumn) and a dry spell between November and April. Mean annual precipitation is 780 mm (Cavazos & Molina, 1992). The mean annual temperature is 22.3 ºC with a large difference between winter and summer (abs. min. 12° C, abs. max. 45°C) and even within the same month. Soils of the region mostly derive from rocks of the Upper Cretaceous rich in calcite and dolomite. The dominant soils are deep, dark grey, lime-clay vertisols which are the result of alluvial and colluvial processes (FAO-UNESCO, 1974; Navar, 2003) characterized by high clay and calcium carbonate content (pH 7.0 - 8.0) and low organic matter content. Analysis of major nutrients reveals phosphorus and nitrogen deficiencies. Underground water is hard, but non-saline (Woerner, 1991). Vegetation associated to the study area is described as dense (2.0–6.4 shrubs m^{-2}), shrubby (average height of 1.95–2.63 m) and diverse. Most plant species overlap vertically from 0.5 to 5.0 m (Manzano, 1997; De Soyza et al., 1997) and horizontally average distance between shrubby stems is 30 cm while mean crown radius is 47 cm, resulting in a mean overlapping radius of 17 cm. Average open space between shrub canopies is 10 cm. The altitude is 350 m above sea level.

Selection of woody species

The choice of the species to be studied was made only after careful consideration of their adaptability, their growth rate, and their potential use by local people as timber for construction and firewood. Furthermore, general utility species combine adequate shape with structural strength and durability. Thus, the five woody species selected in the experiment are native to arid and semi-arid zones in Mexico and the south USA: *Heliettaparvifolia* (Gray) Benth., *Ebenopsisebano* (Berl.) Barneby, *Acacia berlandieri* (Benth.), *Havardiapallens* (Benth.) Britton & Roseand *Acacia wrightii* (Benth.).

The sample consisted of 27 plots of 10 x 10 m at both conditions,15 plots in the experimental plantations with native species and 12 plots in native vegetation, with three plots per species in each area. There are 25 trees per plot of experimental plantations, while in plots of the native area, there is variability in number of trees.

The canopy coverage of woody species was determined by recording the perpendicular projections of the aerial part of each tree to the ground, according to the North-South and East-West directions (Fig. 1a). From the classic method to calculate the area of a circle, a method was developed, adapted to scrubs, to calculate the area occupied by each individual. From this, the total area occupied by each species and the relative area (percentage) in each plot and then per hectare was determined (Equation 1).

$$C = \pi\left(\frac{P1}{2}\right)\left(\frac{P2}{2}\right) \quad \text{(Equation 1)}$$

Where, C is the coverage of each tree (m^2 $tree^{-1}$);P_1 and P_2, the projections (m) in North-South and East-West directions.

Figure.1 Data recording: a) projection of crowns of trees and shrubs, b) characterization of herbaceous vegetation, c) harvesting, drying and weight for herbaceous biomass.

Herbaceous species

The study of herbaceous vegetation under eachwoody species at both sites was the key parameter to determine the forage production. Three sub-plots of 1 x 1 m were delimited by a wooden frame and randomly distributed in each plot. The recorded data to characterize the herbaceous species were those established by the method of interception points of Mueller-Dumbois and Ellenberg (1974), which consisted of noting the species found under the interception points of the wires of the grid formed by the wooden box, divided every 10 cm (Fig. 1b).

The biomass produced in each sub-plot of sampling of 1 m^2 was determined by the direct method of total plot cutting, which consisted of harvesting within the sub-plot of 1 x 1m, all the plant material cut at ground level. The harvested green biomass was dried to constant weight in an oven (65 ± 5 ° C for 48 to 72 hours), and the final weight was recorded as anhydrous biomass (Fig. 1c).

The frequency was determined per herbaceous species, based on its appearance in sub-plots of sampling (Equation 2); its density, according to the number of individuals in function at the area occupied (Equation3); its coverage, defined as the area of occupation (Equation4).Percentage values (%) of these parameters were calculated, and the results were used to obtain the importance value index (*IVI*), in order to check the type of herbaceous community under the Tamaulipan thornscrub (Equation 5).

$$F = \frac{Ps}{Pt} \quad \text{(Equation2)}$$

Where F is the frequency of a species, $P_s$the number of plots where this species was founded, and P_t the total number of plots sampled.

$$D = \frac{n}{a} \quad \text{(Equation3)}$$

Where D represents the density of a species, n the number of individuals of the species and a, the unit sampled area.

$$C = \frac{As}{At} \quad \text{(Equation4)}$$

Where C represents the herbaceous cover, A_s the area occupied by the species and A_t, the total sampled area.

$$IVI = \frac{F(\%) + D(\%) + C(\%)}{3} \quad \text{(Equation 5)}$$

Analysis of information

Data ofindividual coverage of the native woody species and the herbaceous biomass (forage available) produced under the coverage of the native species of the Tamaulipan thornscrub at both conditions were subjected to an analysis of variance. To determine the differences between the two conditions, the means were compared by applying Tukey test (Zar, 2010) with a significance level of 5%. The correlation tests between trees coverage and biomass production herbaceous were determined. All statistical analyses were performed using SPSS program version 21.0.

Result and Discussion

Coverage of the native woody species

Figure 2 shows the coverage mean per individual of each species at bothconditionsin the studied area.

Analysis of variance of the canopy coverage indicates highly significant differences ($P<0.001$) between sites, species and their interactions (Table 1). The Tukey test revealed the similar tree coverage (statistical group *a*) on the five species in the experimental plantation and two statistical groups in the native scrub,with *E. ebano* and*A. wrightii*in the group *a*,*H. parvifolia*, *A. berlandieri*and*H. pallens* in the group *b* (Fig. 2).Trees of the species *Ebenopsisebano* and *Acacia wrightii* showed the highest mean coverage values in native vegetation. The mean area of their crowns was 19.68 and 17.6 $m^2 tree^{-1}$ respectively. Trees of *Havardiapallens*, *Acacia berlandieri* and *Heliettaparvifolia* covered a larger area in the experimental plantation than in native vegetation. The lowest coverage (2.73 $m^2 tree^{-1}$) was presented by *A. berlandieri*, in its natural habitat.

Biomass production of herbaceous vegetation under canopy of woody species

Dry biomass production per unit area was done by weighing, presented in Figure 3. Analysis of variance (Table 2) indicates that there were no significant differences (P=0.358)in biomass production of herbaceous species at both conditions. However, highly significant differences (P<0.01) were presented in the biomass of herbaceous species under canopy of the woody species studied.Tukey test highlighted three statistical groups in plantations: group *aA. wrightii*, group *bH. parvifolia*, group *abE. ebano*, *A. berlandieri*, *H. pallens* and four statistical groups in the native scrub: group *aA. berlandieri*, group *abA. wrightii* and *H. parvifolia*, group *bcH. pallens* and group *cE. ebano* (Fig. 3).

The herbaceous biomass that developed under the canopy of *Acacia wrightii* species in the experimental condition and *Acacia berlandieri* in the native area presented higher biomass production values of 0.83 and 0.79 kg ha^{-1}, respectively. The herbage under canopy of *Ebenopsisebano* in the site with native vegetation produced the lowest biomass (0.19 $kgha^{-1}$) of the experiment.Plantations of *Ebenopsisebano*, *Acacia wrightii* and *Havardiapallens*trees have generated greater herbaceous biomass than in the native vegetation of these species.

Relationship between biomass production and canopy coverage of the woody species

The statistical analysis of correlation test between biomass production and coverage of woody species at both conditionsis summarized in Table 3.

There were no significant correlations (P>0.05) between the biomass production of herbaceous and the canopy coverage of woody species at both conditions. The correlation coefficient were irrelevant (R^2=0.122), so it can be considered that biomass is not necessarily dependent on the bearing of shrubs in which they are developed.This development can be influenced by the surrounding grasses. Indeed, the proximity of the plots planted with other uncontrolled ecosystems may be grounds for invasion by other grasses.

Characterization of herbaceous vegetation

Table 4 presents the constituent species of the herbaceous stratum, considered as a potential forage resource, depending on their importance per shrub and per condition.

The inventory of herbaceous vegetation at both conditions indicates that there are approximately 50 species of 15 different families. This inventory reveals that several herbs are under canopy of almost all shrubs of all species of Tamaulipan thorn scrub. *Lantana sp.* And stipagrass (*Stipalessingiana*) were the most common species. These two herbaceous species resulted to be of greater importance, demonstrating their high capacity to withstand the harsh conditions that may prevail under bushes.

In terms of species richness, *H. parvifolia* and *H.pallens*plantations resulted to be the richest in biodiversity (24 species), while the native vegetation of *A. berlandieri* was characterized by a marked poverty in terms of biodiversity in the low stratum, presenting only 5 different species.

Under every woody species, their individuals were found in the herbaceous vegetation, highlighting the ability of Tamaulipan thorn scrub to ensure their own regeneration from their seeds.

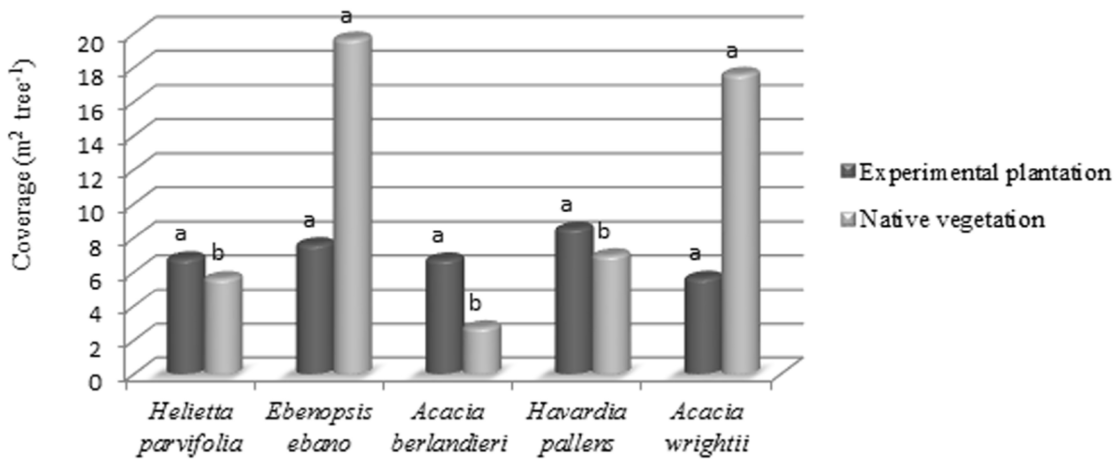

Figure.2 Coverage mean of each speciesat both conditions. Means followed by same letter in a sitedo not differ at 5% probability by Tukey test

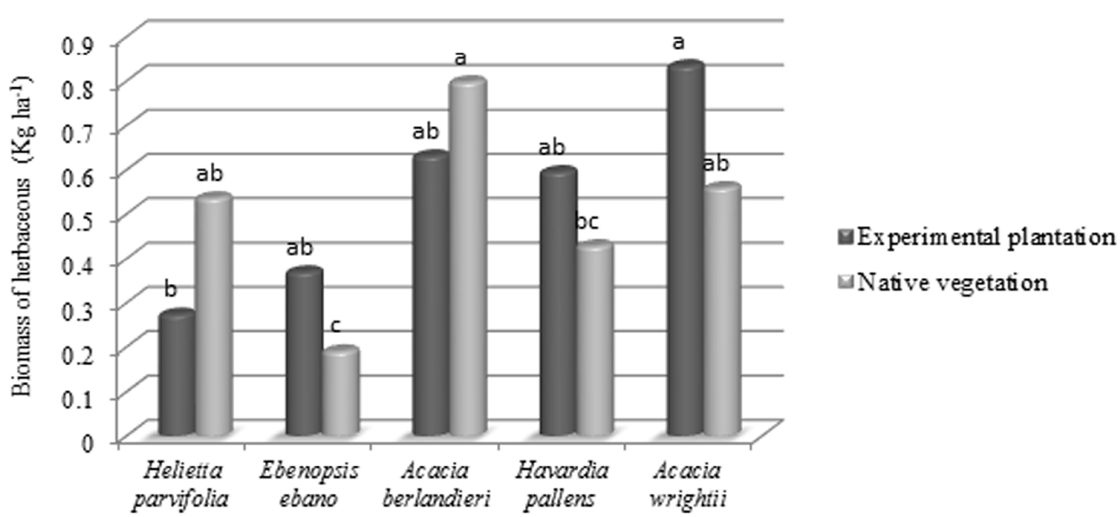

Figure.3 Biomass production of herbaceous under canopy of woody species at both conditions. Means followed by same letter in a site do not differ at 5% probability by Tukey test

Table.1 Analysis of variance of woody species coverage per site.

Source of variation	Sum of squares	df	Meansquare	F value	P
Intersection	21215.746	1	21215.746	542.555	.000
Site	1307.468	1	1307.468	33.436	.000
Species	3798.215	4	949.554	24.283	.000
Site * Species	4237.175	4	1059.294	27.090	.000

Table.2 Analysis of variance of herbaceous biomass produced under the canopy of woody speciesat both conditions

Source of variation	Sum of squares	df	Meansquare	F value	P
Intersection	1.542	1	1.542	291.856	.000
Site	.005	1	.005	.856	.358
Species	.160	4	.040	7.559	.000
Site * Species	.085	4	.021	4.017	.005

Table.3 Analysis of variance of correlation test between biomass production and coverage[a].

Model	Sumof squares	df	Meansquare	F value	P
Regresion	.019	1	.019	3.876	.059[b]
Residual	.137	28	.005		
Total	.156	29			

a. Dependent variable: Biomasa (Kg ha^{-1})
b. Predict Variables: (Constant), Coverage ($m^2 tree^{-1}$)

Evaluating harvestable timber of the main species of Tamaulipan thorn scrub, Maginot *et al*. (2014) presented *H. parvifolia*, *A. berlandieri* and *H. pallens* as species that produce more shoots in plantations, compared to native scrubs.This could justify the higher surface occupied by individuals of these species in plantations as a result of a great competition between them.Moreover, *E. ebano* and *A. wrightii* occupied more surfacesin the native area, in which they had less number of individuals, but wider spacing.In all cases, shrub species with more canopy projection presented a denser bearing than those with low canopy.

Consequently, shrubs with a denser bearing are of closerconformation, and those with non-dense bearing (low area of occupancy) are of open conformation. Thus, *A. berlandieri*that covered the lower groundarea is presented as the shrub under which more herbaceous vegetation developed.This can be explained by their small leaves (Texas A & M System, 2013), and the fall of these leaves in autumn – the latter allowing for the provision of more organic matter and nutrients to the associated herbaceous species; also, higher exposure to sunlight, which promote their photosynthetic activities.In contrast, trees of the species*E. ebano* which had more coverage, led to a relatively lower biomass production of herbaceous species.

Tracy (2014), finding similar results in the coverage of *E. ebano*, concluded that it presents a dense canopy. In addition, the same author mentioned that it is a slow-growing species, with multiple branches extending in zigzag, and it needs a large space to mature.These branches in zigzag are the origin of the impoverishment of the herbaceous layer and consequently a low dry matter production.

Table.4 Importancevalue index of the herbaceous and semi-shrubby vegetation of the Tamaulipanthorn scrub in plantation and native areas

Species	Importance Value Index (%)									
	H. parvifolia		***E. ebano***		***A. berlandieri***		***H. pallens***		***A. wrightii***	
	P	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**	**N**
Lantana sp. (Verbenaceae)	18.23	23.74	15.18	10.36	18.78	19.02	19.57	18.54	16.18	12.94
Stipalessingiana(Poaceae)	9.60	2.59	5.51	2.84	4.20	3.12	6.81	4.30	5.13	21.88
Malpighiaglabra (Malpighiaceae)	5.23		5.48	2.84	13.08		6.35	1.99	24.28	1.82
Meximalvafilipes (Malvaceae)	3.95						2.49			
Croton cortesianus (Euphorbiaceae)	3.72	9.32	9.78	4.73	3.03		4.03	6.73	8.64	4.66
Justiciapilosella (Acanthaceae)	3.69		1.18				2.55			
Partheniumfruticosum (Asteraceae)	3.61		2.43	5.06			5.75			
Ruelliaoccidentalis (Acanthaceae)	3.57		1.80	4.95	3.03		4.15			
Karwinskiahumboldtiana(Rhamnaceae)	3.57	3.83	5.16		2.71	2.94		1.36		2.65
Evolvulusalsinoides (Convolvulaceae)	3.52		13.02				1.12			
Eysenhardtiapolystachya (Fabaceae)	3.44	2.20			1.35		4.47	1.36	1.15	1.26
Forestieraangustifolia (Oleaceae)	3.19							1.36		1.26
Hisbiscuscardiophyllus(Malvaceae)	2.84				3.39		2.40			
Sennagreggii (Fabaceae)	2.75						1.12			
Acacia berlandieri (Fabaceae)	2.46				8.07	3.74	1.76	1.36	1.15	
Acacia rigidula (Fabaceae)	1.70						1.12			
Scuttellaria sp. (Lamiaceae)	1.23	4.59		3.15			5.75			
Urvilleaulmacea (Sapindaceae)	1.70	1.49		2.26	3.39		3.18			
Cyphomerisgypsophiloides (Nyctaginaceae)	1.23						4.31			
Havardiapallens(Fabaceae)	1.47						1.91			1.82
Zexmeniahispida(Asteraceae)	1.23						5.11			
Elytrariabromoides (Acanthanceae)	1.99		4.54				3.34			
Leucaenasp. (Fabaceae)	1.23								1.15	
Heliettaparvifolia (Rutaceae)	1.23	3.69							1.67	
Randiarhagocarpa (Rubiaceae)		2.20	1.18	2.22				3.67	1.15	2.65
Lantana velutina (Verbenaceae)		6.10								
Salvia ballotiflora (Lamiaceae)		6.89						1.36	1.15	
Fraxinusgreggii (Oleaceae)		1.49		2.30						
Phyllantuspolygonoides (Euphorbiaceae)		4.21		1.36						
Diospyrostexana (Ebenaceae)		3.05							1.15	4.07
Caesalpiniamexicana (Fabaceae)			1.18	1.36						
Zanthoxylumfagara (Rutaceae)			1.18	2.26	4.56		2.86	1.36	2.70	1.26
Ebenopsisebano (Fabaceae)			1.18							
Ibervilleatenuisecta (Cucurbitaceae)			1.18		1.35	2.12				
Bernardiamyricifolia (Euphorbiaceae)				3.58				1.36		1.26
Bastardiaviscosa (Malvaceae)				4.28						
Amyristexana (Rutaceae)				2.26						1.26
Mimosa malacophylla(Fabaceae)				1.36						1.26
Porlieriaangustifolia (Zygophyllaceae)				1.36						
Justiciaturneri (Acanthaceae)				4.99						
Ipomoea sp.(Convolvulaceae)				1.36				2.61		
Aloysialycioides (Verbenaceae)				2.26						
Solanumtriquetrum(Solanaceae)				3.11						
Viguierastenoloba (Asteraceae)							4.15			
Cynanchumbarbigerum (Asclepiadaceae)							1.12			
Cissusincise (Vitaceae)							2.40			
Capsicum annum (Solanaceae)									1.67	
Chromolaenaodorata (Asteraceae)									1.15	
Celtispillida (Ulmaceae)									1.15	
Acacia wrightii(Fabaceae)									2.18	
Total low vegetation / shrubs	**24**	**14**	**16**	**22**	**12**	**5**	**24**	**13**	**16**	**14**

P. Experimental plantation, N. Native area

Regarding the availability of forage, the stipagass was one of the most important forage species in the study area.This condition was noted by Saldivar (1998), stating that in the area devoted to livestock exploitation (approximately 1'063,000 ha), over 35% are irrigation and temporary pasture occupied by this species.Moreover, this species has good adaptation to different ecosystems in northeastern Mexico, as well as good forage attributes such as protein content (7.5% of crude protein on a dry basis) and a high level of consumption by animals (3 kg day^{-1} of green grass). These and other attributes determine that this grass is highly preferred by many livestock producers not only in the state but also in the northeast of the country.

The specific richness in herbaceous stratum of the shrubs *H. parvifolia* and *H. pallens* shows their tolerance to the installation of other species, while the specific poverty of*A. berlandieri*in herbaceous shows that it is not tolerant to this installation. The rich biodiversity of the low stratum can provide a good diet for livestock, and so ensure, according to Moreno and Molina (2007), an excellent production of meat and milk.

Conclusion

The canopy coverage estimationof the main species of Tamaulipan thorn scrub was used to evaluate its effect on forage production of the herbaceous species developed under them, including the characterization and description of the herbaceous vegetation.This capability contributes to ensure a nutritious diet for livestock, according to the protective influence of shrubs on herbaceous development.

According to the results, it can be concluded that there is no necessarily influence of the shrubs conformation on the development of the herbaceous layer.However, the main species of Tamaulipan thorn scrub offered different availabilities of herbaceous biomass.In this way,*Acacia berlandieri* and*Acacia wrightii* were presented as the species with the best potential, by favoring the notable development of *Lantana sp.*and stipagrass which have good forage attributes.The management of this offer should be directed toward controlling the shrubs, avoiding them from closing in excess, thus limiting the increased risk of fire, loss of grazing resources and herbaceous diversity.This approach lends to the determination of long-term trends for producers.In this way,it is recommended increasing the space between individuals of *Heliettaparvifolia* when planting, due to their very close conformation.The same should happen with *Ebenopsisebano,*which requires much space to grow in good conditions.

H. parvifolia and *H. pallens* have presented a tolerance to the installation of herbaceous species, for their high specific richness. Finally, all woody species studied have demonstrated an appreciable regenerative capacity.

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