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Importance and Function of Scattered Trees in Pastures in the Sierra Region of Tabasco, Mexico

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Abstract: Scattered Trees in Pastures (STP) are common in the Sierra Region of Tabasco (SRT) but currently are little known to researchers. The objective of this study was to identify and characterize STP of the SRT. In 23 selected pastures, all trees were inventoried and identified; their density, abundance and diversity were determined and Shannon and Simpson indexes were obtained. Also, diameter at Breast Height (DBH) and height were recorded for the trees and information was obtained regarding uses of the principal tree species. The 1600 STP recorded belonged to 31 botanical families and 75 species. Average density was 38 trees ha^{-1}, with a range of 12-146 trees ha^{-1}. Shannon and Simpson indexes were 2.8 and 0.09, respectively. The majority of individuals (1458) belonged to only 24 species. The most abundant species were *Cordia alliodora*, *Cedrela odorata*, *Tabebuia rosea*, *Zanthoxhyllum riedelianum* and *Blepharidium mexicanum*, all of which are used as timber, the principal use for most STP. Many species (51) showed a reduced number of individuals in the pastures; 28 of the species only appeared once or twice. A majority of the trees had heights of 5-10 m and DBH of 10-29 cm with an average height of 10.1 m and an average DBH of 27 cm.

Key words: Scattered trees in pastures, tropical silvopastoral systems, Sierra Region of Tabasco, *Blepharidium mexicanum*, *Tabebuia rosea*, Mexico

INTRODUCTION

During the past 50 years in the south-eastern Mexican state of Tabasco, an intense process of implementing cattle raising has occurred. In 1950, an estimated 25.6% of the surface area of the state was covered with grasses for livestock production and by 2000, this statistic reached 76.4%. As with many other agricultural activities in Tabasco, the expansion of livestock production has brought about the elimination or destruction of vegetation and the disappearance of many plant and animal species. Therefore, by 1980, as a result of agricultural development, approximately 90% of the original vegetation had been devastated, especially in the evergreen tropical rain forest (Lopez, 1980) and in 1992, only 8% of the surface area of Tabasco was covered with original vegetation, 18% of which was in a highly disturbed state (Flores and Gerez, 1994). Most animal production systems have been developed based on the extensive model, characterized by the cultivation of large grassy areas, ever increasing agro-chemical use and elevated use of other external inputs (Tudela, 1992).

Deforestation resulting from agricultural expansion, as well as implementation of the conventional extensive model in the majority of livestock production units has led to many adverse impacts on the environment and natural resources. With respect to soils, dramatic effects have been observed, such as diminishing organic matter and nutrients as well as accelerated soil erosion due to hydric erosion and mechanized cultivation (Larios and Hernandez, 1992). In the face of this situation, in the agricultural sector statewide and in animal production in particular, there is an urgent need to identify and evaluate practices, technologies and productive systems which allow for better resource use and management and which contribute to decreasing or reversing environmental impacts derived from agricultural activities. Silvopastoral Systems (SPS) represent one such alternative given that

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aside from increasing productivity and providing benefits to cattle ranchers and their animals such systems allow for recuperating soil fertility, microclimates and hydrological cycles similar to the original ones, as well as reestablishment of part of the surviving native flora and fauna (Harvey and Gonzalez, 2007). Such recuperation is very important in many environmentally degraded sites in the state of Tabasco. Currently, cattle ranchers of Tabasco practice several SPS with varied characteristics and levels of social, economic and environmental importance. Scattered Trees in Pastures (STP) are one of the main SPS`s and have a broad species distribution and composition. However, they have been studied very little and to date few studies which characterize STP have been carried out. Knowledge of STP is very important due to the great impact they have on productivity of cattle ranches, principally due to the valuable products and functions they provide, such as wood and shade, as well as animal feed (Harvey and Haber, 1999; Pinto *et al*., 2004). STP offer ecological benefits, such as contributing to conservation of habitat for animal species important to dispersing tree seeds so that natural regeneration may take place, as well as functioning as biological corridors (Harvey and Haber, 1999) and contributing to biodiversity conservation (Naranjo, 2003).

Woody species also may contribute to restoration of degraded pastures (Montagnini and Ugalde, 2001) and carbon storage (Botero, 2003; Ruiz *et al*., 2004) and are a strategic alternative for reducing pressure on forests (Kaimowitz and Angelsen, 2008). Aside from the fact that knowledge of STP will allow for understanding their importance and will generate useful information for design and improvement of regional silvopastoral systems, such information can also serve as a basis for evaluating the role of scattered trees in pastures in forest species conservation and habitat restoration.

Based on these considerations, this study analyzes the importance, characteristics and principal products obtained from Scattered Trees in Pastures (STP) in the Sierra Region of Tabasco, as well as density, diversity and dasometric variables.

MATERIALS AND METHODS

Location and characteristics of the study region: This study was carried out in the Sierra Region of Tabasco (SRT), a southeastern state of Mexico with a surface of 2.4 million ha which comprises 1.3% of Mexico's total surface area. The SRT includes four municipalities (Jalapa, Tacotalpa, Macuspana and Teapa) and comprises a surface area of 435,135 ha or 17.7% of the total surface area of the state (STCSG, 2008). The SRT has a warm humid tropical climate with annual rainfall of 3500-4000 mm and an average annual temperature of 26°C. Regional altitudes are no >800 masl (STCSG, 2008) and original vegetation was evergreen tropical rain forest. Principal agricultural activities of the zone are cultivation of tropical crops such as sugar cane, coffee, cocoa, bananas and rubber, as well as cattle production in extensive pasturing with native and introduced grasses, typically under silvopastoral management.

Evaluation of scattered trees in pastures: In order to evaluate scattered trees, 23 pastures under grazing were selected in which the presence of trees was immediately evident in a homogenous distribution. In the selected pastures, all scattered trees with a Diameter at Breast Height (DBH) >10 cm were inventoried and identified. Trees were identified in the field with the help of a local guide.

For each tree, DBH and total height were recorded. DBH was measured with a diametric tape, while height was obtained using a Bushnell electronic laser distance measuring device with a sensitivity of +/-1 m for measurements of 1500 feet. This device was also used to measure the perimeter of the pastures from which total surface area was obtained.

Additionally, information was collected regarding common uses of the zone's principal tree species. Possible decrease in forage production due to tree presence was determined based on the percentage of trees in the pastures in which diminished growth of grass below the canopies or near the trees was observed. Four levels of interference were established: very low, low, moderate or great when 0-10, 11-20, 21-30 or 31-40% of all trees, respectively showed this condition. During pasture evaluations, other indicators which could eventually interfere with growth of grass were also recorded for the trees (e.g., age, size and crown form).

Characterization of production systems: Through field visits and interviews with producers (40 interviews), additional information was obtained regarding scattered tree species in pastures and characteristics of regional silvopastoral systems.

The information was obtained through direct observations in the cattle ranches and through a questionnaire applied to ranchers using the semi structured informal interview technique (Vela, 2001).

Data analysis: Inventory and measurement data for the trees was analyzed with a descriptive statistical approach using Excel. With the information obtained, density and frequency of STP were calculated. In order to identify the diversity of scattered trees in the pastures, Shannon and Simpson diversity indexes were calculated. These two indexes were obtained separately as well as for the group of 23 pastures studied. The Shannon index (H') was obtained using the formula:

$$H' = \sum\left(\frac{ni}{N}\right)\left(LN\frac{ni}{N}\right)$$

Where:

n_i = The total number of individuals of species i
N = The total number of individuals of all species
n_i/N = The proportion of individuals of species i in relation to the total number of individuals (that is the relative abundance of species i)
LN n_i/N = The natural logarithm of the value of the relative abundance of species i (Moreno, 2001)

The Simpson index (D) was calculated using the formula:

$$D = \sum\left(\frac{ni(ni-1)}{N(N-1)}\right)$$

Where:

n_i = The total number of individuals of species I
N = The total number of individuals of all species (Moreno, 2001)

RESULTS

Density and diversity of tree species: Table 1 shows location, numbers of individuals and species, density and indexes of diversity (H' and D) of scattered trees for each pasture evaluated.

The 23 pastures had a total surface area of 41.7 ha. The surface area of the smallest pasture measured 0.3 ha, while the largest measured 4 ha. Seven pastures (30.4%) had surface areas <1 ha, another seven (30.4%) from 1-2 ha and nine (39.2%) were >2 ha. Average surface area for all pastures was 1.8 ha. The least number of trees (25) was found in the smallest pasture (0.3 ha) while an intermediate sized pasture (1.4 ha) had the greatest quantity (193) of individuals.

A total of 1600 scattered trees were present in the 41.7 ha making up the 23 pastures. A small pasture of 0.8 ha and another of 2.9 ha contained the fewest species (4) while the greatest number (36 species) was found in a 4 ha pasture.

Eleven pastures (47.8%) had <10 tree species and the remaining 12 (57.2%) contained 10 or more. A total of 75 species were recorded among all pastures (Table 2) with an average of 3 species per pasture and 1.8 species ha^{-1} trees with the greatest frequencies (found in seven or more pastures) were *Cedrela odorata*, *Zanthoxyllum riedelianum*, *Cordia alliodora*, *Tabebuia rosea*, *Citrus sinensis*, *Citrus reticulata* and *Cupania glabra*. Those which had the greatest numbers of individuals (nine or more) were these 7 species as well as *Blepharidium*

Table 1: Location, number, density and indexes of diversity for scattered trees in pastures in the Sierra Region of Tabasco

Locality	Municipality	Total number of trees/pasture	No. of species/pasture	Density of trees ha^{-1}	Shannon index H'	Simpson index D
Ejido Caparroso 2ª	Macuspana	99	7.0	146.0	0.58	0.75
Rancho Julio Meza	Teapa	193	10.0	135.0	1.42	0.30
Rancho San Agustín	Teapa	113	15.0	113.0	1.34	0.40
Pedro C. Colorado 1ª	Macuspana	69	7.0	92.0	1.54	0.24
Ejido Palomas	Macuspana	25	6.0	83.0	1.28	0.36
Ejido Nueva Reforma	Tacotalpa	62	10.0	81.0	1.51	0.34
Ejido Melchor Ocampo	Macuspana	91	9.0	71.0	1.82	0.20
Ejido Buenavista Apasco	Macuspana	104	13.0	50.0	1.90	0.20
Ejido Lázaro Cárdenas	Tacotalpa	36	4.0	45.0	0.59	0.70
Nicolás Bravo 1ª	Teapa	45	10.0	44.0	1.35	0.43
Ejido Emiliano Zapata	Jalapa	29	8.0	40.0	1.58	0.30
Ejido Lázaro Cárdenas	Tacotalpa	39	6.0	39.0	1.04	0.44
Nicolás Bravo 1ª	Teapa	32	14.0	37.0	2.43	0.10
Ejido San Manuel	Tacotalpa	71	7.0	37.0	1.43	0.29
Ejido Reforma	Tacotalpa	120	16.0	30.0	1.63	0.32
Ejido Palomas	Macuspana	71	12.0	28.0	1.59	0.32
Madrigal 4ª Sección	Tacotalpa	103	36.0	26.0	3.04	0.08
Ejido Emiliano Zapata	Jalapa	38	8.0	22.0	1.66	0.26
Santa Rosa Poaná	Tacotalpa	43	16.0	21.0	2.36	0.13
Rancho Ángel Martínez	Tacotalpa	56	4.0	19.0	0.97	0.43
Pedro C. Colorado	Macuspana	76	11.0	18.0	1.20	0.49
Ranchería El Progreso	Jalapa	51	12.0	17.0	1.62	0.31
Ejido Caridad Guerrero	Tacotalpa	34	9.0	12.0	1.79	0.21
	Total	1600	75.0	-	2.80	0.09
	Means	69	3.2	38.2	-	-

Table 2: Summary of all tree species found in pastures in the Sierra Region of Tabasco

Family and species	Common names	Habitat*	Total
Anacardiaceae			
Mangifera indica	Mango	C	17
Spondias mombin	Jobo	P	35
Annonaceae			
Annona muricata	Guanábana	C	2
Annona reticulata	Anona	C	1
Arecaceae			
Bactris gasipaes	Palma' Pejibaye	S	10
Cocus nucifera	Palma de coco	C	3
Roystonea regia	Palma Real	P	4
Scheelea liebmannii	Palma de corozo	P	1
Bignoniaceae			
Parmentiera edulis	Cuajilote	S	10
Tabebuia rosea	Macuilís	P	220
Bombacaceae			
Ceiba pentandra	Ceiba	P	5
Pachira aquatica	Zapote de agua	P	5
Boraginaceae			
Cordia alliodora	Bojón	S	290
Burseraceae			
Bursera simaruba	Mulato	P	10
Capparidaceae			
Crataeva tapia	Coscorrón	P	1
Cecropiaceae			
Cecropia obtusifolia	Guarumo	S	1
Elaeocarpaceae			
Muntingia calabura	Capulín	P	2
Euphorbiaceae			
Hevea brasiliensis	Hule	C	4
Fagaceae			
Quercus oleoides	Encino, Roble	P	3
Flacourtiaceae			
Casearia nitida	Botoncillo	P	1
Icacinaceae			
Oecopetalum mexicanum	Cacaté	P	1
Lauraceae			
Nectandra sanguinea	Laurel	P	8
Persea americana	Aguacate	P	5
Persea schiedeana	Chinín	P	4
Leguminosae			
Andira galeottiana	Macayo	P	1
Diphysa robinioides	Pichilcoi, Chipilcoíte, Chipilco	P	26
Enterolobium cyclocarpum	Guanacastle	P	23
Erythrina sp.	Madre	P	5
Gliricidia sepium	Cocoíte	S	23
Haematoxylum campechianum	Tinto	P	20
Inga jinicuil	Jinicuil	P	12
Inga vera	Chelele	P	4
Leucaena leucocephala	Leucaena	S	1
Lonchocarpus hondurensis	Gusano	P	2
Lysiloma bahamensis	Pinolillo, Tzalam	P	4
Pithecellobium saman	Samán	P	3
Sweetia panamensis	Chakté	P	11
Platymiscium yucatanum	Cachimbo	P	7
Tamarindus indica	Tamarindo	C	2
Vatairea lundellii	Tinco	P	1
Malpighiaceae			
Byrsonima crassifolia	Nanche	P	9
Melastomataceae			
Miconia argentea	Cenizo, hoja de lata	P	1
Meliaceae			
Cedrela odorata	Cedro	P	245
Guarea glabra	Cascarillo	P	1
Moraceae			
Arctocarpus altilis	Pan de sopa	S	3
Castilla elastica	Hule criollo	P	4

Table 2: Continued

Family and species	Common names	Habitat*	Total
Ficus oerstediana	Amate	P	1
Ficus padifolia	Pogón; mata palo	P	69
Ficus sp.	Ficus	S	2
Trophis racemosa	Ramoncillo	P	1
Myrtaceae			
Eugenia capuli	Escobillo	P	1
Psidium guajava	Guayaba	C	9
Pimenta dioica	Pimienta gorda, Pimienta Tabasco	P	4
Piperaceae			
Piper nigrum	Pimienta	C	2
Rhamnaceae			
Colubrina arborescens	Tatuán	P	3
Rubiaceae			
Blepharidium mexicanum	Popistle	P	102
Calycophyllum candidissimun	Canelo	P	2
Genipa americana	Jagua	S	9
Rutaceae			
Citrus sinensis	Naranja	C	61
Citrus reticulata	Mandarina	C	13
Citrus limon	Limón	C	4
Citrus maxima	Toronja	C	4
Zanthoxyllum riedelianum	Cola de lagarto	P	191
Salicaceae			
Salix chilensis	Sauce	P	8
Sapindaceae			
Cupania glabra	Quebrache	P	19
Sapindus saponaria	Jaboncillo	P	2
Talisia olivaeformis	Guaya	P	2
Sapotaceae			
Chrysophyllum cainito	Caimito, Cimarrón	P	1
Manilkara zapota	Chicozapote	P	2
Pouteria sapota	Mamey	P	3
Sterculiaceae			
Guazuma ulmifolia	Guácimo	S	24
Sterculia mexicana	Bellota	P	1
Theobroma cacao	Cacao	C	6
Tiliaceae			
Belotia mexicana	Patastillo	S	1
Verbenaceae			
Vitex gaumeri	Nancillo	P	2
Total			1600

*C = Cultivated; P = Primary vegetation; S = Secondary vegetation

mexicanum, *Ficus padifolia*, *Spondias mombin*, *Diphysa robinioides*, *Guazuma ulmifolia*, *Gliricidia sepium*, *Enterolobium cyclocarpum*, *Haematoxylum campechianum*, *Mangifera indica*, *Inga jinicuil*, *Sweetia panamensis*, *Parmentiera edulis*, *Bursera simaruba*, *Bactris gasipaes*, *Psidium guajava*, *Genipa americana* and *Byrsonima crassifolia* (Table 3).

Scattered tree densities varied greatly among pastures, while one pasture had only 12 trees ha^{-1}, another contained 146 trees ha^{-1}. In the great majority of pastures (19 = 82.6%), densities were >20 trees ha^{-1} and in a large number of pastures (9 pastures = 39.1%), 20-40 trees were recorded per hectare. Average tree density for all pastures was 38 trees ha^{-1}. Despite the densities mentioned, levels of interference with growth of grass were very low.

Table 3: Species of the most frequent scattered trees and their abundances in the Sierra Region of Tabasco

Species	Family	Abundance N	Abundance (%)	Accumulated (%)	Frecuency in the pastures N	Frecuency in the pastures (%)	Principal uses
Cordia alliodora	Boraginaceae	290	18.1	18.1	12	52.1	Timber
Cedrela odorata	Meliaceae	245	15.3	33.4	21	91.3	Timber
Tabebuia rosea	Bignoniaceae	220	13.8	47.2	12	52.1	Timber
Zanthoxyllum riedelianum	Rutaceae	191	11.9	59.1	16	69.5	Timber
Blepharidium mexicanum	Rubiaceae	102	6.4	65.5	4	17.3	Timber
Ficus padifolia	Moraceae	69	4.3	69.8	3	13.0	Shadow
Citrus sinensis	Rutaceae	61	3.8	73.6	10	43.4	Fruits
Spondias Bombin	Anacardiaceae	35	2.2	75.8	6	26.0	Fruits
Diphysa robinioides	Leguminosae	26	1.6	77.4	4	17.3	Timber, firewood, posts, medicinal, live fence
Guazuma ulmifolia	Sterculiaceae	24	1.5	78.9	7	30.4	Timber, firewood, fodder, medicinal
Gliricidia sepium	Leguminosae	23	1.4	80.3	6	26.0	Live fence, firewood, shadow
Enterolobium cyclocarpum	Leguminosae	23	1.4	81.7	4	17.3	Shadow
Haematoxylum campechianum	Leguminosae	20	1.2	82.9	4	17.3	Posts
Cupania glabra	Sapindaceae	19	1.2	84.1	7	30.4	Timber, medicinal, honey production
Mangifera indica	Anacardiaceae	17	1.1	85.2	5	21.7	Fruits, shadow
Citrus reticulate	Rutaceae	13	0.8	86.0	7	30.4	Fruits
Inga jinicuil	Leguminosae	12	0.8	86.8	2	8.6	Fruits
Sweetia panamensis	Leguminosae	11	0.7	87.5	1	4.3	Timber, posts
Parmentiera edulis	Bignoniaceae	10	0.6	88.1	2	8.6	Fruits
Bursera simaruba	Burseraceae	10	0.6	88.7	6	26.0	Timber, firewood, medicinal
Bactris gasipaes	Arecaceae	10	0.6	89.3	1	4.3	Timber, Fruits
Psidium guajava	Myrtaceae	9	0.6	89.9	6	26.0	Fruits
Genipa americana	Rubiaceae	9	0.6	90.5	5	21.7	Timber, firewood, medicinal
Byrsonima crassifolia	Malpighiaceae	9	0.6	91.1	6	26.0	Fruits
	Sub-total	1458	-	91.1	-	-	
Other species (51)	Various	142	8.9	100.0	-	-	Various
	Total	1600	-	-	-	-	

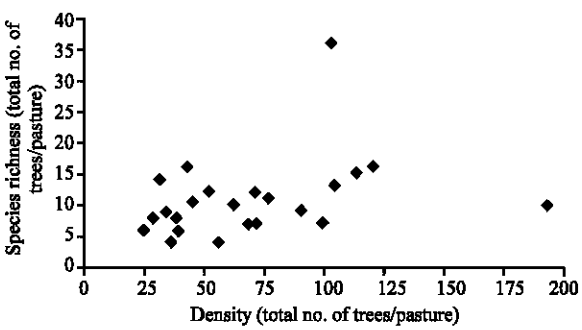

Fig. 1: Density and richness of tree species in 23 pastures in the Sierra Region of Tabasco. Each point represents a pasture

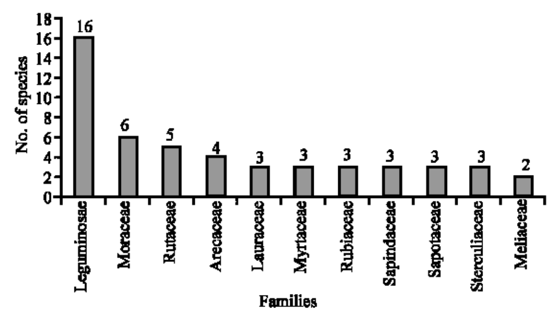

Fig. 2: Number of species in the principal families of scattered trees

The Shannon index for individual pastures varied from 0.5-3.0 and the great majority were 1-2. The Simpson index was 0.08-0.75 with values of 0.3 or less in the majority of pastures. The Shannon index for global tree diversity of the 23 pastures was 2.8 while the Simpson index was 0.09. Density and richness of tree species varied greatly among pastures with the presence of greater numbers of species in pastures with the highest tree densities (Fig. 1).

Species composition: The scattered tree individuals and species found belonged to 31 botanical families (Table 2). Figure 2 shows the 11 principal families, based on number of species. Two thirds of all species of the STP belonged to these families (51 species = 68%), with Leguminosae, Moraceae and Rutaceae having the greatest numbers of species. With respect to number of individuals, the most common families were Boraginaceae (290 individuals), Rutaceae (273), Meliaceae (246), Bignoniaceae (230), Leguminosae (145) and Rubiaceae (113) which totaled 1297 individuals and represented 81% of all trees in the pastures. A great majority of STP (1458 individuals = 91.1%) belonged to 24 species (32% of all species), while the remaining 51 species (68%) included only 142 individuals or 8.9% of the total number of trees in the pastures (Table 3). The five most abundant trees were bojon (*C. alliodora*) (Boraginaceae), cedro (*C. odorata*)

(Meliaceae), macuilis (*T. rosea*) (Bignoniaceae), cola de lagarto (*Z. riedelianum*) (Rutaceae) and popistle (*B. mexicanum*) (Rubiaceae). Bojon was the most numerous species with 290 individuals or 18% of all trees, followed by cedro with 245 individuals (15%) and macuilis with 220 individuals (14%).

Z. riedelianum showed 191 individuals and *B. mexicanum* 102 or 12 and 6% of the total number of trees, respectively. Jointly, these five species included a majority of STP (1048 individuals or 65.5% of the total), all of which are used as timber, a use shared by half of the 24 principal species in the pastures (Table 3).

Among the pastures, there is an evident pattern of a small group of very abundant species and a large number of species with low abundances; upon graphing the number of individuals per species (Fig. 3) (in order of abundance) beginning with the most abundant species, the number of species rapidly descends, demonstrating this pattern.

The 24 principal tree species showed nine or more individuals in the pastures while the remaining 51 species (the great majority) showed eight individuals or less. Of the 51 species mentioned, 11 (15%) showed 2 individuals and 17 (22%) only one, meaning that a large number of species (28 = 37% of total) showed only 1 or 2 individuals in the pastures (Fig. 4).

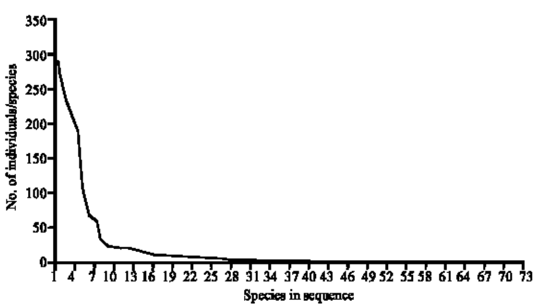

Fig. 3: Curve of abundance for tree species in the pastures studied

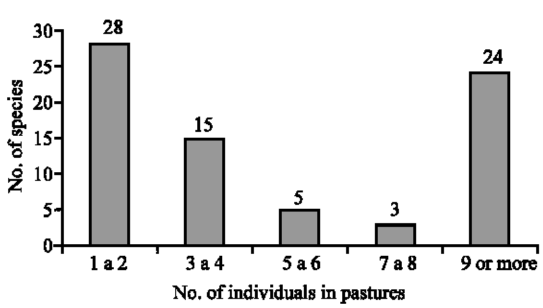

Fig. 4: Number of species and abundance of individuals in pastures

Primary vs. secondary tree species: Of the 1600 scattered trees, a majority (1098 individuals = 69%) were characteristic of the primary vegetation of the zone's evergreen tropical rain forest, 374 (23%) were characteristic of secondary vegetation and only 128 (8%) were cultivated species (for example, *M. indica*, *Annona* sp., *Cocus nucifera*, *Hevea brasiliensis*, *Tamarindus indica*, *P. guajava*, *Piper nigrum*, *Citrus* sp. and *Theobroma cacao*). The abundance of primary vegetation trees varied greatly among pastures. In five pastures, 90% of all trees belonged to such vegetation while in two pastures, fewer than 20% of trees corresponded to primary vegetation. Average tree density for primary vegetation was 26 trees ha^{-1}, varying from 6-135 trees ha^{-1} (Table 2).

With respect to primary and secondary species of the 75 tree species, a majority (51 = 68%) were characteristic of primary vegetation, 11 (15%) were characteristic of secondary vegetation and 13 (17%) were domesticated species (Table 2). The presence of primary vegetation species also varied greatly with a range of 3-25 species per pasture.

Height and DBH of scattered trees: A large number of the trees (761 individuals = 47%) had heights of 5-10 m. The next greatest proportion had heights of 10-15 m (506 individuals = 32%), followed by those with heights of 2-5 m (218 individuals = 14%). This means that the height of the great majority of scattered trees (1267 individuals = 79%) was 5-15 m (Fig. 5). Very few individuals (5) were taller than 25 m. The average height of all trees >5 m (n = 1513) in the pastures was de 10.1 m.

The tallest species (>10 m) were saman (*Pithecellobium saman*), tamarind (*T. indica*), amate (*Ficus oerstediana*), patastillo (*Belotia mexicana*), palma real (*Roystonea regia*), cacate (*Oecopetalum mexicanum*), pan de sopa (*Arctocarpus altilis*), palma de coco (*Cocus nucifera*), chicozapote (*Manilkara zapota*), guanacastle (*E. cyclocarpum*), ramoncillo (*Trophis racemosa*), botoncillo (*Casearia nitida*), palma de corozo (*Scheelea liebmannii*), pogon (*F. padifolia*), escobillo (*Eugenia capuli*), chinin (*Persea schiedeana*), hule criollo (*Castilla elastica*), capulin (*Muntingia calabura*), bojon (*C. alliodora*) and popistle (*B. mexicanum*). Young trees with a DBH of 10-20 cm (many of which had regenerated naturally) were the most numerous in the pastures (634 individuals or 39.6% of all trees found), followed by those with a DBH of 21-30 cm (506 individuals = 31.6%) and those with a DBH of 31-40 cm (258 individuals = 16.1%). This shows that in the pastures, young trees with DBH <30 cm predominated (71.2%) and the DBH of almost half of the trees (764 = 47.7%) was 21-40 cm. Large trees (DBH

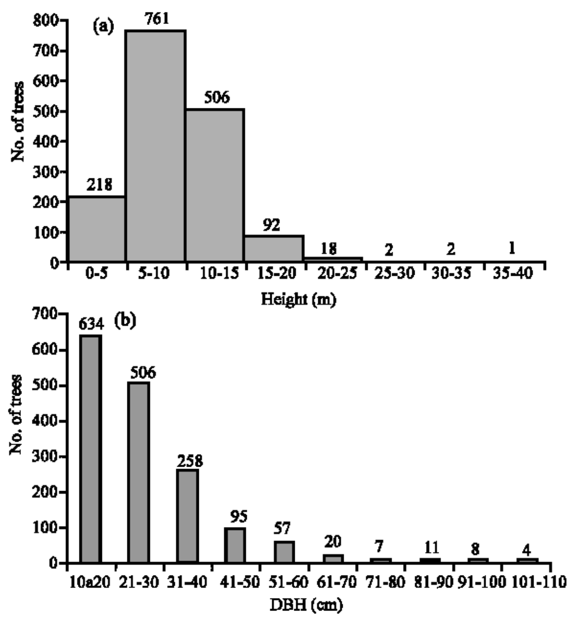

Fig. 5: Distribution of (a) heights and (b) diameters of all scattered trees found in pastures in the Sierra Region of Tabasco (n = 1600 individuals)

>41 cm) were the least common category found in pastures and very few (only 4) had diameters exceeding 100 cm (Fig. 5). Average DBH of all trees was 27 cm. The species with the greatest DBH were saman (*P. saman*), tinco (*V. lundellii*), cimarron (*Chrysophyllum cainito*), mango (*M. indica*), ceiba (*Ceiba pentandra*), mulato (*B. simaruba*), tamarind (*T. indica*), amate (*F. oerstediana*) and patastillo (*B. mexicana*).

DISCUSSION

Importance, functions and products obtained from STP: The great majority of STP (1098 individuals = 69% or 51 species = 68% of the total) are components of the zone's original vegetation and therefore are well adapted to predominant environmental conditions, they are well known by local producers who are familiar with their processes of propagation and establishment.

Some trees (for example mature, leafy individuals such as *C. pentandra*, *P. saman* and *E. cyclocarpum*) are especially appreciated by local producers due to the shade they provide for cattle. Ranchers also benefit from the adaptation of several trees to environmental conditions particular to the region. Such is the case of *H. campechianum*, *Pachira aquatica* and *T. rosea*, common in flooded pastures due to their great resistance to flooded soils, a frequent condition in the zone. Many of the STP found are multi-purpose species with a variety of particularities, functions and levels of social, economic and environmental importance. Number of individuals, species diversity and characteristics of the scattered trees in the pastures varied greatly with significant differences among pastures studied, although tree abundance and diversity were relatively high compared with findings of other studies carried out in similar tropical regions. Densities >20 trees ha^{-1} found in a great number of pastures (19 pastures = 82.6%) contrast with those found in the dry tropic of Costa Rica where densities of the great majority of pastures (92%) were lesser than this number (Esquivel *et al*., 2003). The average density of all pastures, 38 trees ha^{-1} is high, exceeding that of other studies in tropical regions in which averages of 3-33 trees ha^{-1} have been reported (Guevara *et al*., 1994, 1998; Harvey and Haber, 1999; Harvey *et al*., 2007; Souza *et al*., 2000; Esquivel *et al*., 2003; Villacis *et al*., 2003; Villanueva *et al*., 2004). It is noteworthy that despite tree densities found in this study, no significant interference in growth of grass was found in any of the pastures. Tree densities of a majority of pastures (almost 70%) are similar to those of 10-50 trees ha^{-1} reported in tree-grass associations in Cuba (Renda *et al*., 1999). In the region of study, pastures with scattered adult tree densities of 25-40 trees ha^{-1} are common (11 pastures = 47.8%). This density represents a shade level of 20-30% and such levels are recommended in order to not affect growth of grasses in tropical pastures (Casasola *et al*., 2005). This could explain why in pastures with the tree densities mentioned, adverse effects were not observed in growth of grass. It should be noted that in pastures with greater numbers of trees, aside from distribution, density and diversity, ranchers also manage other tree and grass characteristics in order to assure forage production. In the case of trees, they manage aspects such as age, size and tree canopy form (characteristics which are reinforced by the great abundance of young trees found in pastures) while with respect to grasses, they manage their response or tolerance to shade, as some studies have demonstrated (Wong, 1990; Costa *et al*., 1999). The combination of these aspects mentioned allowed for finding pastures with densities >100 trees ha^{-1} in which no significant interference with forage availability was detected.

The total number of tree species in pastures (75) is similar to the 72 species reported in a ranch landscape in Rivas, Nicaragua (Harvey *et al*., 2007) and both are >57 species found in pastures in the region of Los Tuxtlas, Veracruz, Mexico (Guevara *et al*., 1994) or the 55 species in farms in Guanarito, Venezuela (Solorzano *et al*., 2006) and numbers reported in highly technified farms in the humid tropic of Costa Rica (Villacís *et al*., 2003). All cases greatly surpass the 21 species found in native grasslands with high tree densities in Matagalpa, Nicaragua (Perez *et al*., 2006), the 20 species on the Coast of Chiapas, Mexico (Otero-Arnaiz *et al*.,1999) and the 16 species in pastures of three livestock systems in La Fortuna de San Carlos, Costa Rica (Souza *et al*., 2000).

The species quantities mentioned are greatly inferior to the 98 species reported by another study in pastures in the region of Los Tuxtlas in Mexico (Guevara *et al*., 1998), the 96 species on farms with low levels of technification in the humid tropic of Costa Rica (Villacis *et al*., 2003) and the 101, 101 and 106 species of three livestock landscapes in Costa Rica and Nicaragua (Harvey *et al*., 2007). All of these contrast with the tree diversity in pastures in the zone of Monteverde, Costa Rica in which the considerably elevated number of 190 species was reported (Harvey and Haber, 1999).

The 75 tree species reported in this study represent a large part of the 100-120 tree species that according to a conservative estimate should be present in pastures of the region. These numbers in turn constitute a significant percentage of the 250 or more tree species which according to Cowan (1983), Lopez (1994), Magaña (1995), Guadarrama and Ortiz (2000) and Ochoa and De La Cruz (2002) exist in the state of Tabasco. Presence in the pastures of a small group of very abundant tree species and a large proportion of species with low abundances is a common pattern in systems of this type, as has been demonstrated in pastures in the dry tropic of Costa Rica and Nicaragua in which 10 species made up 70% of all individuals (Villanueva *et al*., 2003a, 2004) or in Guanacaste, Costa Rica, where 6 species made up >60% of sampled individuals (Esquivel *et al*., 2003) and in pastures in the dry tropic of Guanarito, Venezuela in which the 15 most abundant species comprised 84% of all trees (Solorzano *et al*., 2006). Similar findings were also reported in SPS of Matagalpa, Nicaragua, in which 5 species constituted the majority of individuals and a single species represented 18% of the total number of trees (Perez *et al*., 2006) and in those of the humid tropic of Rio Frio, Costa Rica, in which 6 species made up 63.5% of the total number of trees found (Villacis, 2008).

This confirms results of several studies which demonstrate that livestock farms in Latin America generally have a high diversity of tree species, though many species are found in low densities (Guevara *et al*., 1998; Harvey and Haber, 1999; Otero-Arnaiz *et al*., 1999; Cajas and Sinclair, 2001). The great variability in tree coverage in pastures has been explained by a diversity of factors, such as topography, soil characteristics, principal products of the ranch, pasture location, stocking rate and producer preferences in relation to woody species. In the case of SRT pastures, ranchers have an evident marked interest in maintaining selected tree species in their pastures based on personal preferences or due to possible benefits which they see and the ranchers of this study focused on timber species. This confirms the importance of producer decisions which affect tree coverage in livestock farms, among which making use of the trees is one of the most important (Villanueva *et al*., 2003b).

The predominance of young trees (DBH <30 cm) (71.2%) could be partially explained by the natural regeneration encouraged in pastures in order to cover the demand of tree products, principally firewood, lumber and/or fenceposts. The DBH of 20-40 cm of a large percentage of individuals in pastures studied in the region (47.7%) contrasts with DBH >40 cm of a similar percentage of scattered trees (48%) found in the dry tropic of Cañas, Costa Rica (Villanueva *et al*., 2004). Both cases indicate producer management which encourages the presence of young trees with such DBH`s in pastures. The Shannon (2.8) and Simpson (0.09) diversity indexes obtained indicate relatively elevated tree diversity in the 23 pastures. The Shannon index surpasses the values of 1.5-2.1 reported for scattered trees in native and improved grasslands of high and low tree densities in Matagalpa, Nicaragua (Perez *et al*., 2006.), those of 0.7-0.82 in livestock production systems with trees in the dry tropic of Cañas, Costa Rica (Villanueva *et al*., 2003a) and also those of the STP of livestock farms in the humid tropic in Rio Frio, Costa Rica (0.8-0.9) (Villacis, 2008). The Simpson index was lower than the values of 0.1-0.18 obtained in livestock production systems with trees in the dry tropic of Costa Rica (Villanueva *et al*., 2003a) and those of 0.19-0.29 in STP of livestock farms in the humid tropic in Rio Frio, Costa Rica (Villacis, 2008). These data show that tree diversity in the SRT pastures was greater than levels of diversity found in other studies carried out in tropical zones. The five most abundant species in the pastures (*C. alliodora*, *C. odorata*, *T. rosea*, *Z. riedelianum* and *B. mexicanum*) possess characteristics which facilitate natural regeneration and consequently, an increase in tree coverage. These few dominant species in the pastures are very promising and contribute to the increase in tree coverage of SPS of the zone, as they include the majority of individuals found.

Four of the most abundant species (*C. alliodora*, *C. odorata*, *T. rosea* and *Z. riedelianum*) have valuable attributes such as rapid growth, abundant seed production, a high capability of seed dispersion by wind and good germination rates (which for *Zanthoxylum,* notably improve with a simple pre-treatment). Furthermore, the first three species offer advantages such as capability of vegetative reproduction. The seeds of *B. mexicanum*, the fifth most numerous species are winged and easily mobilized by wind. The majority presence of timber trees (particularly in the case of the five most abundant species) coincides with results of other studies carried out in tropical zones (Muñoz *et al*., 2003; Esquivel *et al*., 2003; Villanueva *et al*., 2003b) in that producers were found to greatly prefer these species. Of those timber trees traditionally used and appreciated by regional producers, it was significant that not a single individual of *Swietenia macrophylla* was found in any of the pastures.

Based on these findings, it is evident that scattered trees represent a valuable resource for wood supply in the zone. Three of the most abundant timber trees found in the pastures (*C. odorata*, *C. alliodora* and *T. rosea*) contribute to the supply of a large part of precious woods produced in the state. It is estimated that almost two thirds of this wood is obtained from STP and other regional agroforestry systems (Calzada, 1997). A similar situation was reported in Costa Rica, where in 1990, trees outside of the forest (including scattered trees in pastures) accounted for 43.4% of the total volume of harvested lumber and by 1998, this figure had increased to 51.1% (Morales and Kleinn, 2002). Besides the fact that the number and diversity of scattered trees found represent in themselves an elevated biodiversity and improve vegetational and structural complexity of the pastures, they also contribute to biodiversity in other ways. Many of the trees host a variety of epiphytes in their trunks and branches, which further increases plant diversity within the pastures. Common epiphytes in trees in SRT silvopastoral systems include Araceae (e.g., a variety of species of *Anthurium*, *Philondendron* sp. and *Syngonium neglectum*), bromeliads (*Aechmea bracteata*, *Catopsis* sp. and several species of *Tillandsia*) and orchids (*Encyclia* sp., *Epidendrum* sp., *Maxillaria* sp., *Nidema boothii*, *Notylia barkeri*, *Oncidium* sp. and *Stelis* sp.) (Grande *et al*., 2006). Without a doubt, STP also enrich faunal biodiversity. Several tree species (among which *S. mombin*, *B. simaruba*, *B. crassifolia*, *E. cyclocarpum* and *G. ulmifolia* stand out) are important food sources for wild fauna. Although, *B. simaruba* was not one of the most abundant, many bird species which consume its fruit whole have been identified. The fruits of *E. cyclocarpum* fall to the ground when they mature and are consumed by cattle and horses, which spread the seed. *B. crassifolia* is another tree species which provides habitat and food for wild fauna, while *G. ulmifolia* seed is dispersed by birds and mammals including cattle, squirrels, parakeets, monkeys and parrots which use it as food. *Cecropia obtusifolia* is another species which although not as numerous in the pastures, its fruits are avidly consumed by a variety of vertebrates and invertebrates and therefore it is also considered to be very important for conservation of wild fauna (Vazquez *et al*., 1999). Although, producers greatly intervene with respect to trees, the diversity of local woody species is still largely conserved, allowing for connectivity among fragments of remnant vegetation, thus benefitting wild fauna and a variety of environmental, economic and social aspects.

Several scattered trees are valuable for obtaining firewood. For example, it is estimated that from 100 m of living fence of *G. sepium* with densities of 60-75 plants, 80-90 kg of dry firewood may be obtained in a year and a half (Ruiz, 2000). Also, *G. ulmifolia* firewood is one of the five most important in rural Tabasco, due to it particular characteristics (principally its high specific weight) which allow for obtaining greater quantities of energy per unit of firewood consumed. These and other species contribute to satisfying firewood consumption in the local area and in the state of Tabasco, estimated at approximately 1.3 m^3/capita/year (Perez, 1983).

Foliage or fruits of several scattered trees (e.g., *G. sepium*, *Erythrina* sp., *P. edulis*, *G. ulmifolia* and *E. cyclocarpum*) are recognized forage resources whose potential and use have been widely publicized and promoted in agroforestry systems in a variety of tropical regions worldwide (Kass, 1994; Simons and Stewart, 1994; Stewart and Simons, 1996; Giraldo, 1999). Nevertheless, in the study region, producers take advantage of very few tree species for forage and among those species found in pastures in this study, there were notably few individuals of *Leucaena leucocephala*. Also, there was a significant absence of *B. alicastrum*, another regionally known forage tree. Although, many ranchers are aware of and encourage livestock consumption of foliage and fruits of some of the species mentioned, currently STP contribute very marginally to animal feed in the zone.

A little appreciated characteristic of STP is their contribution to honey production, an activity which in Tabasco yielded >1500 tons from 2001-2009 (ASERCA, 2010). Honey production depends on a variety of native species of the remnant evergreen rain forest, as well as trees present in SPS. Many trees found in greater and lesser abundances in the pastures are well known nectar and pollen providers in other tropical areas of Mexico (Miranda *et al*., 2004; Roman and Palma, 2007). Some of the principal species are *B. simaruba*, *B. crassifolia*, *C. odorata*, *C. alliodora*, *E. cyclocarpum*, *G. sepium*, *G. ulmifolia*, *I. jinicuil* and *T. rosea*. Many of these have numerous showy flowers or large inflorescences and flower throughout several months of the year (principally

May and June) (Ochoa and De La Cruz, 2002). Several STP are very promising for ecological restoration and reforestation (Arriaga *et al*., 1994; Vazquez *et al*., 1999), fundamental activities for confronting the severe deforestation which has occurred in the past and the current loss of natural vegetation in the region. Some species, such as *C. odorata*, *C. pentandra*, *E. cyclocarpum*, *G. sepium* and *G. ulmifolia* have received a great amount of attention in exploratory studies of evaluation, conservation, collection, use of germoplasm, phenology, genetic improvement, flowering, fruiting, silviculture and ecological zoning in the south-southeast region of Mexico (Vera, 2003). *C. odorata* and *C. alliodora* are of priority for activities coordinated by the FAO and other organizations at a global, regional and/or national level. *Cordia* sp., *Platymiscium* sp. and *C. odorata* are timber trees which are useful for lumber in the Mesoamerican region and marketed internationally and therefore organizations such as the United Nations Environmental Program seek to promote their sustainable management. Only one of the principal scattered trees in pastures (*C. odorata*) is currently considered to be vulnerable by the International Union for Conservation of Nature which means it faces a high risk of extinction in the field in the mid-term. The low densities found for many tree species 28 of the species or 37% of the total showed only one or two individuals in the pastures. While damage and mortality of saplings caused by cattle at pasture and/or herbicide use or weeding by machete completely or partially explains the low number of individuals of several tree species (Camargo *et al*., 2000), the low densities of some trees favors disappearance of entire species in pastures simply due to cutting by machete or loss otherwise of a few trees. This poses the urgency of caring for and maintaining in pastures valuable tree species of the original vegetation such as gusano (*Lonchocarpus hondurensis*), amate (*F. oerstediana*), macayo (*Andira galeottiana*) and leucaena (*L. leucocephala)* which showed the lowest densities.

The risk of local extinctions also highlights the need to strengthen and promote strategies among producers which lead to diversification and increased tree cover in pastures. The increase of scattered trees through selective weed control in which only undesirable or excess plants are eliminated is a practice commonly carried out by local producers which is particularly important for promoting the presence of timber species in the pastures. This practice would explain the presence of the five most abundant species (*C. alliodora*, *C. odorata*, *T. rosea*, *Z. riedelianum* and *B. mexicanum*). Another potential alternative for promoting presence of scattered trees is the establishment of living fences in pastures where they do not yet exist in order to reduce pressure on STP. The decrease in the use of lumber and/or dead fences by ranchers would also help to maintain and/or increase STP. The lesser use of dead fences could be compensated by a greater use of living fences in pastures, while the exclusion of pasturing in some areas of the farm would favor natural regeneration of trees and allow for producing lumber and/or fence posts in order to satisfy producer requirements. This would help to compensate the decreased volumes of both products obtained from scattered trees. One of the ways in which producers of Tabasco benefit from natural regeneration is the use of secondary vegetation in order to obtain lumber, fenceposts, stakes, firewood and forage. Secondary vegetation is also important in reducing the impact of animal stamping and soil erosion, as well as for conservation of biodiversity, particularly wild fauna. Producers also make use of regeneration by taking advantage of areas with trees generally planted close to pasture areas or the rancher's house in which part or all of the lumber required for the producer's own use or for sale is produced. Any alternatives aimed at maintaining, diversifying or increasing tree coverage in pastures should consider management activities currently carried out by ranchers in their pastures and the factors which influence their decisions. Based on this criteria, easily adoptable strategies may be proposed which guide producer decision making, as has been pointed out by Villanueva *et al*. (2003b).

CONCLUSION

In this study, findings indicate that density, abundance and diversity of STP were relatively high. STP have many uses, among which timber stands out however, they are threatened due to the low number of individuals of many species in the pastures.

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