Colegio de Postgraduados

Characterization of the understory associated with a pine-oak forest in the Sierra Madre de Chiapas region

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ABSTRACT

Objective: To characterize the understory species associated with a pine-oak forest in the Sierra Mariscal region, Chiapas.

Design/methodology/approach: Six 40 m^2 subplots were established to evaluate the cover, abundance and identity of shrub, herbaceous and sapling components of the understory. Floristic diversity was determined. The level of disturbance was evaluated using the observation method. An analysis of variance and comparison of means by Tukey ($p<0.05$) between structural variables was applied. The relationship between disturbance levels and study sites was performed by correspondence analysis.

Results: The understory is composed of five tree species, three herbaceous and two shrub species. The largest diameter ($p\leq0.0001$ and $F=27.6$) corresponds to herbaceous *Cortaderia selloana* (5.38±0.94 cm) and *Pteridium aquilinum* (4.5±0.96 cm). The greatest height corresponds to *Quercus* sp. saplings (126.3±75.9 cm) and the herbaceous *Cenchrus* sp. (110.2±54.1 cm) and *Pteridium aquilinum* (91.7±40.9 cm), the latter having the highest density (4050 ind. ha^{-1}) and cover (16.2%). Floristic diversity was low in all six sites. Site six was the most diverse and site three the most disturbed.

Study limitations/implications: The study comprised a limited and insufficient area to generalize the conditions of pine-oak forests in the Chiapas highlands. It is suggested to expand the study universe and increase the number of replications.

Findings/conclusions: Variability in understory structure and composition was found that corroborates the relationship between forest diversity and disturbance.

Keywords: understory, saplings, floristic diversity, disturbance.

Image by Gaby Stein at Pixabay

INTRODUCTION

Forests make up a wide range of terrestrial ecosystems, where trees are the dominant structural element (Chazdon *et al.*, 2016). The state or condition of the forest can be described by three characteristics: 1) spatial position or distribution, 2) species diversity and mix, and 3) the arrangement of vertical and horizontal differentiation (Castellanos-Bolaños *et al.*, 2008). The role played by the understory, made up of shrubs, herbaceous, grasses, climber plants, lianas and other low vegetation, also favors the dynamics and stability of forest ecosystems (Nakhoul *et al.*, 2020).

The understory is spatially distributed in a stratum below the canopy and subcanopy, being a key component in the functioning of forests with effects on wildlife (Echiverri and Mcdonald, 2019). This vegetative stratum provides habitat for wildlife and contributes to nutrient cycling, intervening in the maintenance and productive capacity of forests under management (Ampoorter *et al.*, 2014; Davis & Puettmann, 2009), which favors forest productivity and tree regeneration (Landyut *et al.*, 2019). In addition, the understory acts as an important buffer in reducing carbon emissions and mitigating climate change (Jin *et al.*, 2022).

Unfortunately, traditional forest management practices continue to encourage the removal of understory species to minimize competition for resources between upper canopy trees and the understory (Giuggiola *et al.*, 2018). Indeed, soil biochemical processes such as microbial activity, community composition, carbon sequestration and nutrient turnover rate have been affected (Trentini *et al.*, 2018; Fang *et al.*, 2021). Significant alterations in the understory have also been brought about by human disturbances and global changes, such as warming, nitrogen deposition, and changes in precipitation (Chen *et al.*, 2023). All this has an impact on the loss of productivity and stability of the forests (Zhang *et al.*, 2022). Given the importance of the understory as an essential component of forests, it is necessary to implement diagnoses that integrate the structural elements, composition, diversity and abundance of species that make up this vegetative stratum. This allows an approximation of the current state and condition of the forest and the possible variability between zones that show some type of disturbance. Based on the above, the objective of this study was to characterize the understory species (shrubs, herbaceous and regeneration) associated in a pine-oak forest in the Sierra Mariscal region, Chiapas, taking into account elements such as density, cover, diversity and the influence of the levels of disturbance present in the ecosystem studied.

MATERIALS AND METHODS

The present study was conducted in a pine-oak forest in the municipality of El Porvenir, in the Sierra Mariscal de Chiapas, Mexico. The study area is located between the coordinates 15° 45’ 11” LN and 92° 24’ 75” LO, at an average altitude of 2840 m above sea level and a total area of 4 ha (Figure 1).

Sampling and site distribution

A random site sampling design was established in which six circular sites were established with an area of 400 m^2 for each site in which the tree, canopy and subcanopy

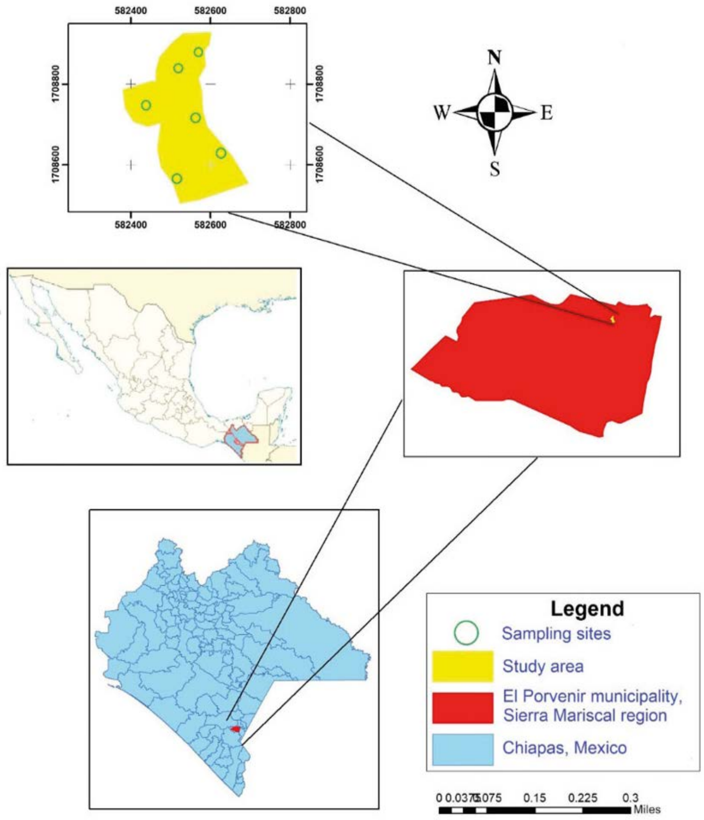

Figure 1. Geographic location of the study area and distribution of sites.

were evaluated, the results of which correspond to another work. For the present study, six concentric circular sub-sites were defined (within each site). In each circular subsite a central point was taken, and from this, four ropes with a radius of 3.57 m were established to obtain the desired surface of 40 m^2 (0.004 ha).

Characterization of the understory

The characterization of the understory includes shrubs, herbaceous and saplings (saplings with DN $<$2.5 cm and height $\leq$1.3 m), the latter according to the criteria used by López-Toledo *et al.* (2012). An inventory of the understory species was conducted, evaluating structural parameters such as density (ind. ha^{-1}), normal diameter (DN) and average height by species. In each subsite, four 1 m^2 squares were established to average the percentage of cover per species, according to the indicators of Westhoff and Van der Maarel (1978) as shown in Table 1.

Floristic diversity by sites was determined using the Shannon, Simpson and Hill Equity indices (Moreno, 2001) with the help of Past software version 3.2 (Hammer *et al.*, 2009).

The level of disturbance was evaluated using the observation method, based on the criteria established by García *et al.* (2016). For this, three criteria were established: i) not disturbed, ii) semi-disturbed and iii) disturbed, considering as undisturbed that area that resulted in little or almost no alteration (less than 5%), semi-disturbed when the area presents

Table 1. Scale used to calculate percent cover in herbaceous and shrub vegetation (adapted from Westhoff and Van der Maarel, 1978).

Value	Percentage of coverage
9	More than 75% of the total
8	Between 50 and 75% (62.5%)
7	Between 25 and 50% (37.5%)
6	Between 12.5 and 25% (18.75%)
5	Between 5 and 12.5% (8.75%)
4	Less than 5%, but more than 10 individuals, too many to count
3	Less than 5%, more than 10 individuals, and can be counted
2	Less than 5%, between 3 and 10 individuals
1	Less than 5%, 1 to 3 individuals

close to a 50% of affectations produced by man and disturbed when high anthropogenic influence is appreciated (more than 80%).

Statistical analyses were performed with jmp pro 14 software (Statistical Analysis System [SAS], 2019). The results obtained were analyzed by analysis of variance (ANOVA) and comparison of means by Tukey ($p \leq 0.05$) between the structural variables (normal diameter and height) evaluated in the study sites. A correspondence analysis was performed to determine the relationship between the nominal variables (degree of anthropization) and the sites. The dimensionality of the solution was determined from the minimum ([rows, columns] -1). For this, the statistical package SPSS version 23.0 was used.

RESULTS AND DISCUSSION

The understory vegetation consists mainly of five tree species, three herbaceous and two shrub species. The herbaceous stratum is composed of the species *Pteridium aquilinum* with a density of 4050 ind ha^{-1}, *Cenchrus* sp. with 2500 ind ha−1 and *Cortaderia selloana* with an average of 400 ind ha^{-1}. The shrubs found were *Baccharis* with a density of 3650 ind ha^{-1} and *Rubus ulmifolius* with an average of 250 ind ha^{-1}. The regeneration is made up of saplings with a diameter $<$2.5 cm of the species *Pinus ayacahuite* (550 ind ha^{-1}), *Pinus maximinoi* (300 ind. ha^{-1}), *Quercus* sp. (250 ind ha^{-1}), *Prunus serotina* (100 ind ha^{-1}) and *Cupressus lindley* (100 ind. ha^{-1}).

The diameter of these species shows significant differences ($p \leq 0.0001$ and $F = 27.6$), whose highest mean value corresponds to the herbaceous *Cortaderia selloana* (5.38$\pm$0.94 cm) and *Pteridium aquilinum* (4.5$\pm$0.96 cm) and the lowest mean value to *Cenchurus* sp. (1.06$\pm$0.22 cm) (Table 2).

With respect to height, the regeneration of *Quercus* sp. (126.3$\pm$75.9 cm) and the herbaceous *Cenchrus* sp. (110.2$\pm$54.1 cm) and *Pteridium aquilinum* (91.7$\pm$40.9 cm) show the highest average values. The density of understory species is 8350 ind ha^{-1}; the highest number of individuals belongs to *Pteridium aquilinum* (4050 ind ha^{-1}) with a coverage of 16.2%. This density of understory species determines the dynamics of the

Table 2. Main tree, herbaceous and shrub species forming the understory in the study area.

Species	Common name	Biological form	ND (cm±S.D.)	H (cm±D.E.)	D (ind ha^{-1})	Co (%)
Quercus sp.	Tulán, roble	tree	1.26±0.65bc	126.3±75.9a	150	0.6%
Pinus ayacahuite	Pino tabla	tree	1.62±0.33bc	64.3±36.9ab	550	2.2%
Pinus maximinoi	Pino ocote	tree	1.18±0.94bc	95.8±91.88ab	300	1.2%
Prunus serotina	Capulín blanco	tree	0.5±0.14bc	22±5.6b	100	0.4%
Cupressus lindley	Ciprés nuculpat	tree	0.45±0.07bc	18.5±4.9b	100	0.4%
Pteridium aquilinum	helecho, chipe	herbaceous	4.5±0.96a	91.7±40.9a	4050	16.2%
Cortaderia selloana	paja	herbaceous	5.38±0.94a	87.2±31.1ab	400	1.6%
Baccharis sp.	escobillo	bush	2.43±0.27b	78.3±39.5ab	3650	15%
Cenchrus sp.	mozote	herbaceous	1.06±0.22c	110.2±54.1a	2500	10%
Rubus ulmifolius	mora	bush	0.68±0.22bc	41.2±21.1ab	250	1.2%
Total					8350	48.8%

ND: normal diameter, H: height, D: density, Co: cover. Different letters show significant statistical differences ($p \leq 0.05$).

overstory (Nakhoul *et al.*, 2020) and can be influenced by the structural arrangement of the dominant canopy, which controls the availability of light, water and soil nutrients (Barbier *et al.*, 2008) in the study area. In the understory of the evaluated community, the predominant life form is herbaceous, followed by shrubs and trees, a result that supports the record of Mejía *et al.* (2018) for the understory in dense pine and oyamel forest in Nevado de Toluca, Mexico, where the shrub stratum was the richest. The authors refer that it is possible that species richness in the herbaceous stratum is determined by multiple factors, such as slope or orientation, temperature, precipitation, solar radiation, among others.

Floristic diversity was low for all study sites (Table 3), due to anthropogenic actions. Site six was presented as the most diverse area, expressed through the Shannon index, with higher equitability (Equity) and lower dominance (Simpson). These results correspond with what was reported by Valdés *et al.* (2014) and García *et al.* (2016) for pine forests, attributing the low diversity to the influence of anthropization and ecosystem type. According to Alvis Gordo (2009), natural tropical forests are heterogeneous and are made up of a high diversity of species, with different successional ages: sapling, latizal and fustal. In the study areas this does not correspond, first, to the nature of the pine forest where few species are abundant and, second, to the disturbances that limit and interrupt the successional stages of the forest.

Table 3. Values of floristic diversity in the understory sites in the study area.

Indexes	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Shannon (H’)	1.00	1.42	1.39	1.47	1.46	1.59
Equity (J’)	0.72	0.79	0.71	0.79	0.79	0.82
Simpson (D)	0.43	0.29	0.31	0.34	0.34	0.28

Disturbance levels

Correspondence analysis showed a significant correlation ($p \leq 0.05$) between study sites and disturbance levels (Table 4) with total inertia values of 1.746. The solution indicated that only the first axis is significant with an inertia ratio that explained 53.6% of the total variance. This demonstrates the degree of deterioration of the understory where inappropriate management practices are carried out.

The permuted correspondence analysis allowed the formation of three groups, depending on the disturbance levels (Figure 2). Sites 1, 2 and 6 were in the undisturbed category, sites 4 and 5 semi-disturbed and site 3 disturbed, considered the most vulnerable to disturbances, which demonstrates the effect of disturbances associated with clear-cutting without management criteria and grazing in this study site.

Although three of the six sites evaluated are associated with the conserved level, inadequate management practices such as grazing, logging and opening of trails were observed in these sites, which can change the condition of the pine-oak understory in

Table 4. Correspondence analysis between disturbance levels and study sites.

Dimension	Own value	Inertia	Chi-square	Sig.	Inertia ratio		Confidence	
					Explained	Accumulated	Standard deviation	Correlation
1	0.97	0.94			0.54	0.54	0.02	0.17
	0.90	0.81			0.46	1.00	0.03	
Total		1.75	420.89	0.00[a]	1.00	1.00		

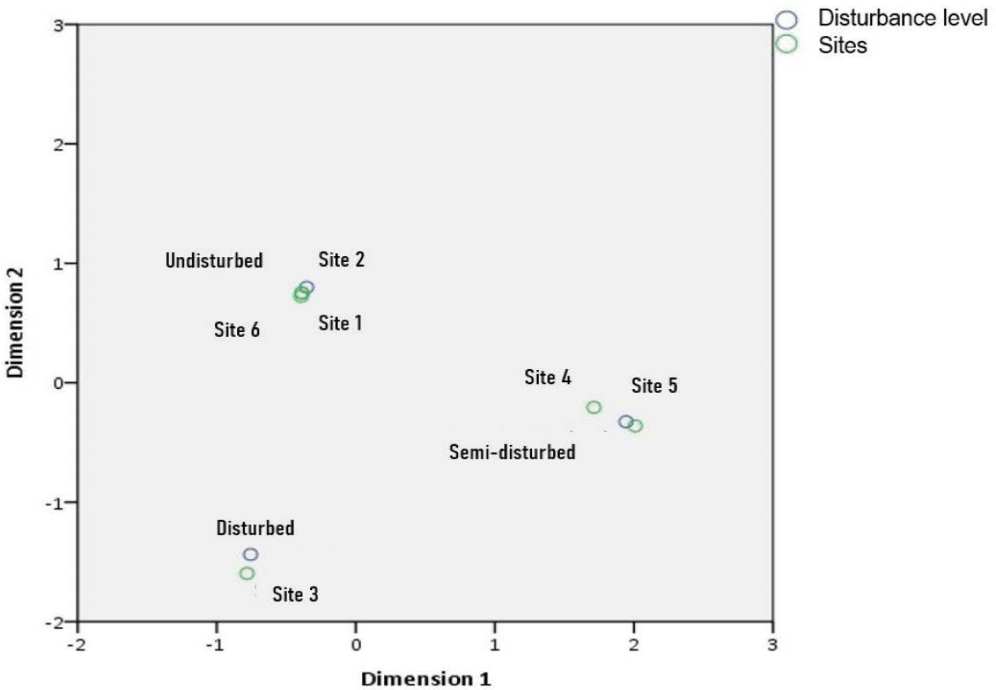

Figure 2. Two-dimensional representation of the relationship between disturbance levels and sites.

a short period of time. Disturbance of the vegetation caused by anthropogenic factors significantly alters the communities (De la O-Toris *et al.*, 2012). In this regard, Ruiz *et al.* (2022) assert that any change in the historical disturbance regime of an ecosystem can alter species composition by decreasing the importance of native species, creating opportunities for the entry of exotic species, or both.

CONCLUSIONS

Given the lack of works oriented to evaluate the structure, composition and diversity of understory species in the Pine-Oak forests of the Sierra de Chiapas, the analysis of the state and condition of the forests allowed us to identify the configuration of structural parameters and species dominance. Statistical differences were found in the height and normal diameter of understory species, with variation in the mean of the data obtained. Variability was found in the structure and composition of the understory, which demonstrates the relationship between diversity and forest disturbance, linked to logging without management criteria and grazing in the most disturbed sites. The results suggest management, conservation and restoration tasks in the evaluated forest ecosystem.

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