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Article

Diversidad e importancia ecológica de la vegetación arbórea en el Parque El Tecuán, Durango, México

Diversity and ecological importance of tree vegetation at El Tecuan Park in the state of Durango, Mexico

Pablito Marcelo López Serrano[1], Daniel José Vega Nieva[2], José Javier Corral Rivas[2], Jaime Briseño Reyes[2*], Pablo Antúnez[3]

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[1]Instituto de Silvicultura e Industria de la Madera, Universidad Juárez del Estado de Durango. México.
[2]Facultad de Ciencias Forestales y Ambientales, Universidad Juárez del Estado de Durango. México.
[3]Instituto de Estudios Ambientales, Universidad de la Sierra Juárez. México.

*Autor para correspondencia; correo-e: jaime.briseno@gmail.com
*Corresponding author; e-mail: jaime.briseno@gmail.com

Abstract

Protected natural areas seek the conservation of biodiversity. The objective of this study was to describe the tree species diversity and its ecological importance in the *El Tecuan* Ecological Park in *Durango*, Mexico. A systematic stratified sampling was carried out with 168 circular sites of 1 000 m^2 each, distributed in 511.16 hectares of the Park, which means a sampling intensity of 3.2 %. At each site, all individuals with a greater or equal to 7.5 cm *DBH* were measured. The diversity of tree species was estimated with the Shannon index, while the ecological importance of the species was described with the parameters relative abundance based on the density or number of trees per hectare, relative dominance according to the basal area, relative frequency and the value of ecological importance (*VIE*). Results showed the presence of four genera: *Arbutus* (Ericaceae), *Juniperus* (Cupressaceae), *Pinus* (Pinacea) and *Quercus* (Fagacea). The Shannon index was 1.89, suggesting mid to high tree species diversity. The observed growing stock was 153.73 m^3 ha^{-1} and the dominant diameter and height classes were 10 cm and 5 m, respectively. The *Pinus* genus had greater richness with nine species, of which *P. cooperi* recorded the highest density values (32.15 %), dominance (37.77 %) and of ecological importance (28.23 %), however, *Quercus sideroxyla* registered the highest relative frequency (18 %). The results here described will allow the development of sustainability actions for the conservation of tree species diversity in the study area.
Key words: Basimetric area, protected natural area, density, dominance, frequency, ecological importance value.

Resumen

El objetivo de las áreas naturales protegidas es la conservación de la biodiversidad. En el presente estudio se describe la diversidad de especies arbóreas y su importancia ecológica en el Parque Ecológico El Tecuán, Durango, México. Se realizó un muestreo sistemático estratificado con 168 sitios circulares de 1 000 m^2, distribuidos en 511.16 hectáreas del Parque, con una intensidad de muestreo de 3.2 %. En cada sitio se midieron todos los individuos con diámetro normal superior o igual a 7.5 cm. La diversidad de especies arbórea se estimó con el Índice de *Shannon*, la importancia ecológica de las especies se describió con los parámetros abundancia relativa basada en la densidad o número de árboles por hectárea, dominancia relativa de acuerdo con el área basal,

frecuencia relativa y el Valor de Importancia Ecológica (*VIE*). Los resultados mostraron la presencia de cuatro géneros: *Arbutus* (Ericaceae), *Juniperus* (Cupressaceae), *Pinus* (Pinacea) y *Quercus* (Fagacea). El Índice de *Shannon* fue de 1.89, que sugiere una diversidad arbórea de media a alta. Las existencias reales registradas fueron de 153.73 m^3 ha^{-1} y las clases de diámetro y de altura dominantes de 10 cm y 5 m, respectivamente. El género *Pinus* tuvo la mayor riqueza de especies (nueve); de ellas, *P. cooperi* presentó los valores más altos de densidad (32.15 %), dominancia (37.77 %) y *VIE* (28.23 %); sin embargo, *Quercus sideroxyla* registró la mayor frecuencia relativa (18 %). Los resultados permitirán desarrollar acciones de sustentabilidad para la conservación de la diversidad arbórea del área de estudio.

Palabras clave: Área basal, área natural protegida, densidad, dominancia, frecuencia, valor de importancia ecológica.

Introduction

Describing the composition, diversity and structure of a forest ecosystem allows to establish strategies for the conservation of biodiversity. Thus, it is necessary to describe the diversity of species and structural aspects through quantitative indexes (Suárez and Vischi, 1997; Wehenkel *et al.*, 2014; Herrera-Paniagua *et al*., 2018). The study of tree richness and diversity and structural ecological parameters of species such as density, dominance, frequency and importance value, are criteria to assess their behavior in the face of possible natural or anthropogenic disturbances (Graciano-Ávila *et al.*, 2017; Hernández-Salas *et al.*, 2018; Silva-García *et al*., 2021).

One of the traditional methods for describing the richness, diversity, structure and value of importance of tree species is the forest inventory. This procedure leads to the collection of vegetation information necessary to achieve this purpose (Álvarez *et al.*, 2004; Delgado *et al.*, 2016).

In recent decades, Protected Natural Areas PNAs (ANP, for its acronym in spanish) have emerged as an environmental policy instrument to conserve the biological diversity of a given area (Cantú *et al.*, 2004). However, conservation strategies

require, in the first instance, a description of tree richness and diversity, and the estimation of elements that characterize forest structure (Herrera-Salas *et al*., 2018). Mexico currently has 185 PNAs (Conanp, 2022), and new proposals have been made to increase this number, such as the assessment of the ecosystem services they offer to address climate change, mitigate forest deterioration and promote the conservation of resources natural (Bertzky *et al*., 2012; Oceguera-Salazar *et al.*, 2016).

In the state of *Durango*, there are officially six PNAs and their area adds up to a total of 353 229 ha, equivalent to 2.9 % of the national territory; three are of federal jurisdiction and three of state scope (Rentería *et al.*, 2011). Within the latter, the *El Tecuán* Ecological Park is located under the administration of the Ministry of Natural Resources and the Environment of the Government of the State of *Durango* (SRNyMA). This Park represents offers the possibility to carry out actions for the conservation of ecological processes and ecosystem services through the promotion and analysis of knowledge of its natural resources (POGED, 2018). Thus, the objective of this study was to describe the diversity of tree species and their ecological importance in the *El Tecuán* Ecological Park in the state of *Durango*, Mexico.

Materials and Methods

El Tecuán Ecological Park is located in the *Sierra Madre Occidental*, southwest of the state of *Durango* (Figure 1), 57 km from the city of the same name, on Federal Highway No. 40 in its *Durango-El Salto* section; it comprises 894.57 ha.

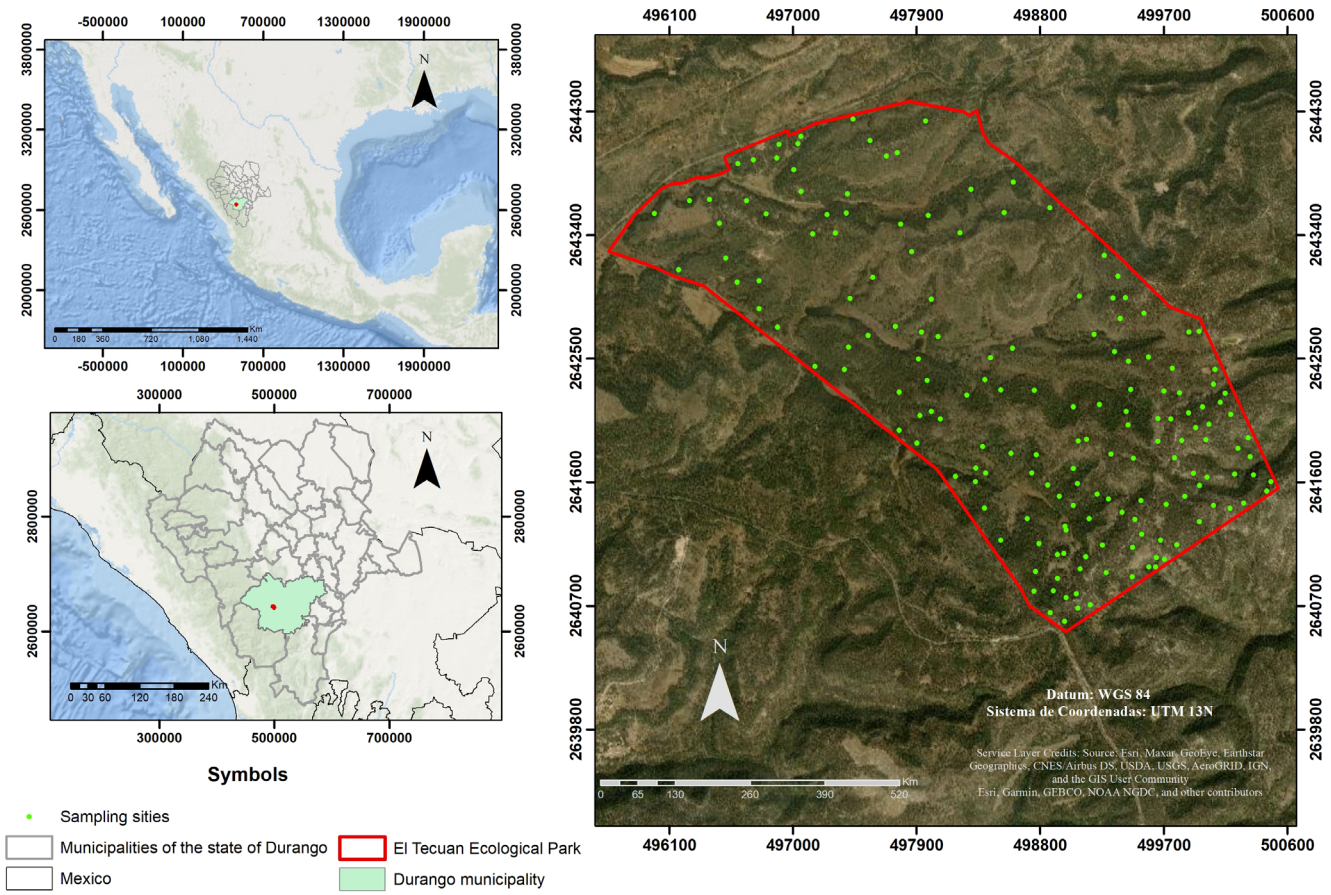

Figure 1. Locatión of *El Tecuán* Ecological Park.

The type of climate according to the Köppen classification modified by García (2001), is temperate with summer rains (Cw). The average annual temperature is 13.9 °C. Is the prevailing soil type in the area (INEGI, 2016).

Vegetation sampling

An inventory was carried out with the support of the Forest Planning System for Temperate Forests (SiPlaFor; http://siplafor.cnf.gob.mx), designed to support the decision-making process in the preparation and execution of forest management programs sustainability in the temperate forests of Mexico. The Park's road surface was generated by means of a multi-resolution segmentation with homogeneous objects in a satellite image of the Sentinel 2A sensor (USGS - https://glovis.usgs.gov – ID: 13QDG) from the year 2017, to then design and define the sample size over the sub-stands or strata.

A stratified systematic sampling was used with 168 circular sites of 1 000 m^2, reaching a 3.28 % sampling intensity of the area classified as protected forest, which covers 511.16 ha. The rest of the Park area (383.41 ha) was excluded from the sampling as it is classified as grasslands, roads, bodies of water and buildings (cabins) (Figure 2). At each sampling site, for all individuals with a diameter at breast height (*DBH*, 1.30 m) greater than or equal to 7.5 cm, the scientific name, the diameter at breast height (cm) measured with a Mantax Haglöf Blue caliper were recorded, and the total height (m) measured with a IV Vertex Haglöf hypsometer.

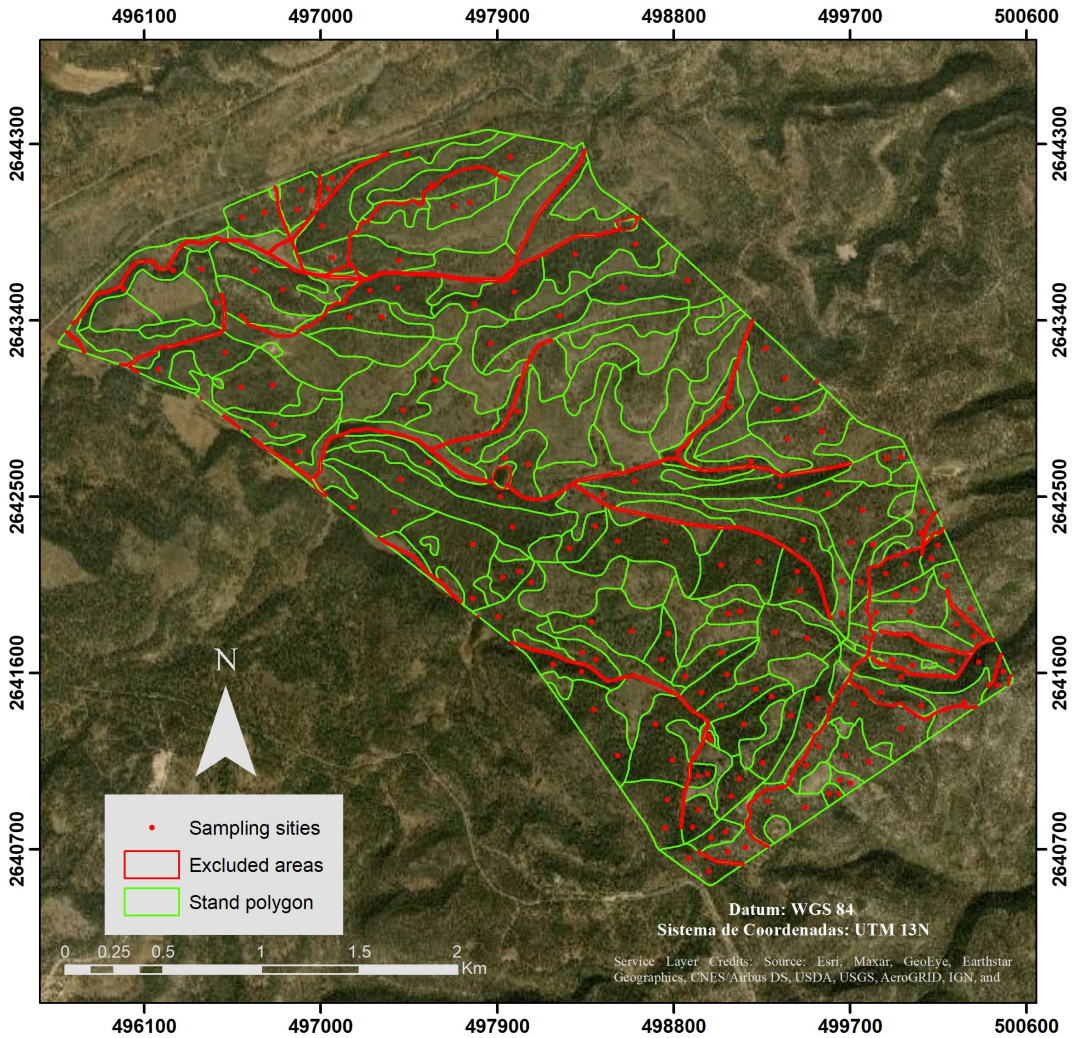

Figure 2. Stand area calculation and sampling sites of *El Tecuán* Ecological Park.

Diversity and importance value

To describe the diversity of tree species and their ecological importance, the following variables were calculated from the mensuration information recorded at the sampling sites.

Tree diversity was quantified with the Shannon index (*Hi*), one of the most used measures that reflects the diversity of species, and whose expression, according to Gadow (1993), is as follows:

$$H_i' = -\sum p_i ln p_i \qquad (1)$$

Where:

p_i = Proportional abundance of the i^{th} species

ln = Base 10 natural logarithm

The Shannon index commonly fluctuates between 0.5 and 5. A high value expresses a greater number of species.

The value of ecological importance (*VIE*) of the tree species, was estimated from the relative abundance based on the density or number of trees, the relative dominance according to the Basimetric Area (*AB*) value, and the relative frequency based on of the presence of species in the sampling sites. These variables were estimated with the following expressions (Franco *et al.,* 1989):

$$Relative\ density = \frac{NAi}{NAT} \times 100 \quad (2)$$

$$Relative\ dominance = \frac{ABi}{ABT} \times 100 \quad (3)$$

$$Relative\ frequency = \frac{Fi}{FT} \times 100 \quad (4)$$

$$VIE = \frac{Relative\ density + Relative\ dominance + Relative\ frequency}{300} \quad (5)$$

Where:

NAi = Number of trees of the *i* species

NAT = Number of trees of the present species

ABi = Basimetric area of the *i* species

ABT= Basimetric area of all the species

Fi = Number of sampling sites in which the *i* species is present

Ft = Total number of sampling sites

Results and Discussion

In total, 354 trees per hectare belonging to 18 species, four families (Ericaceae, Cupressaceae, Pinaceae and Fagaceae) and four genera (*Arbutus*, *Juniperus*, *Pinus* and *Quercus*) were recorded. The genus *Pinus* had the highest richness with nine species, and in contrast, *Arbutus xalapensis* Kunth was the only recorded species of the genus. Table 1 lists the species recorded at the sampling sites.

Table 1. Composition of tree species present in the *El Tecuán* Ecological Park.

Family	Genus	Scientific name	Common name
Ericaceae	*Arbutus*	*Arbutus xalapensis* Kunth	*Madroño*
Cupressaceae	*Juniperus*	*Juniperus deppeana* Steud.	*Táscate*
Pinaceae	*Pinus*	*Pinus teocote* Schltdl. & Cham.	*Ocote* pine
		Pinus engelmannii Carrière	Royal pine
		Pinus cooperi C. E. Blanco	Chinese pine
		Pinus durangensis Martínez	Scorrel pine
		Pinus leiophylla Schiede ex Schltdl. & Cham.	Dark-colored pine
		Pinus arizonica Engelm.	White pine
		Pinus strobiformis Engelm.	*Cahuite*
		Pinus maximinoi H. E. Moore	*Ocote*
		Pinus oocarpa Schiede ex Schltdl.	*Trompillo* pine
Fagaceae	*Quercus*	*Quercus sideroxyla* Bonpl.	Short oak
		Quercus laeta Liebm.	White oak
		Quercus rugosa Née	Dark-colored oak
		Quercus durifolia Seemen	*Laurillo* oak
		Quercus crassifolia Bonpl.	Red oak
		Quercus grisea Liebm.	Grey oak
		Quercus eduardi Trel.	White oak

The estimated species diversity with the Shannon index was 1.89, which suggests that species diversity in the study area is medium to high. This index is higher than

that of Méndez *et al.* (2018) who observed a richness of five species and an index of 0.78 in a similar forest in the *Sierra Madre del Sur*. Likewise, Graciano-Ávila *et al.* (2017) recorded a Shannon index of 1.81 and a richness of 13 species in a mixed pine-oak forest under management for the *El Salto* region in the state of *Durango*. The greater species richness and the similarity between the diversity value of this study and the value reported by Graciano-Ávila *et al.* (2017) could be attributed, among other reasons, to the fact that the park's forest, despite being located in an area with less forest potential, is protected from timber harvesting, extensive livestock farming and different anthropogenic activities that could affect the diversity of species.

Figure 3 shows the distribution of the number of trees per hectare and by category of diameter and height. It is observed that in both variables the distributions fit an inverted-J or negative exponential type. This type is frequently observed in forests under an irregular management scheme, as is the case of the mixed and irregular forests of the *Sierra Madre Occidental* (Návar-Cháidez y González-Elizondo *et al.*, 2009). Likewise, they have been described in many forests in protected status throughout the world. For this reason, it is considered as the structure that represents the ideal number of trees per diameter class for a given basal area, and, therefore, it is used as a reference when developing forest management methods with selective felling or continuous cutting cover (Buongiorno and Michie, 1980).

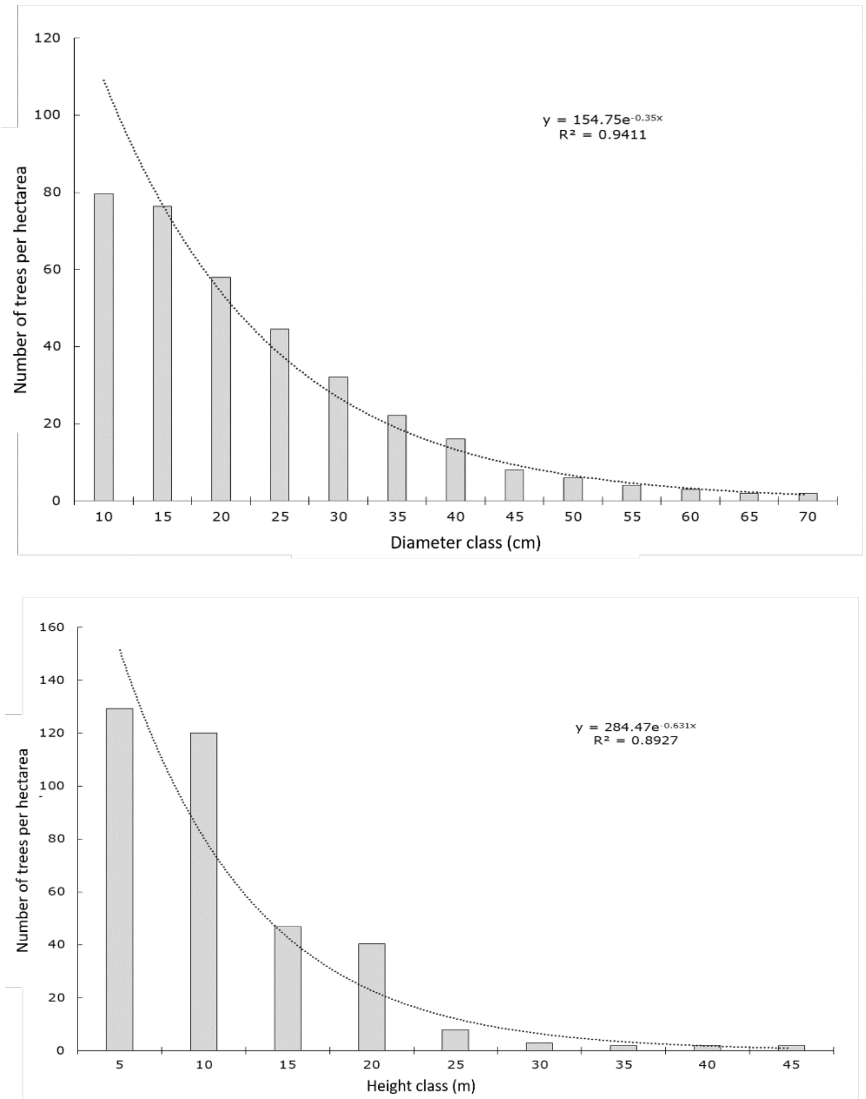

Figure 3. Distributions of diameter (top) and height (bottom) per hectare of trees studied in *El Tecuán* Ecological Park.

The greatest number of trees accumulates in the diameter classes of 10 and 15 cm (80 and 76 trees ha^{-1}, respectively) and the number of individuals decreases as the diameter size increases. The foregoing results mainly from natural mortality events in this type of individuals, since commercial exploitation is not allowed in the Park.

These results agree with those of Hernández-Salas *et al.* (2013), who evaluated the composition and diversity of species in temperate forests under exploitation in the state of *Chihuahua*, in a similar way, they recorded the highest densities for the smaller diameter classes, a finding attributable to the effect of timber use of trees in stages of maturity.

According to the results in Table 2, *Pinus cooperi* C. E. Blanco was the species with the highest density (32.15 % and 112 trees ha^{-1}) and relative dominance (37.77 % and 6.15 m^2 ha^{-1}). This species has been recorded as the most abundant in studies of temperate climate forests in the state of *Durango* (Návar-Cháidez and González-Elizondo, 2009; Valenzuela and Granados, 2009; Graciano-Ávila *et al*., 2017). The genus with the highest density and dominance in the Park was *Pinus* with a density of 204 trees per hectare (57.60 % relative density) and a basal area of 11.33 m^2 ha^{-1} (69.56 % relative dominance). This result coincides with previous studies in which the *Pinus* genus has been recorded as the most abundant and dominant in temperate forests of the country (Hernández-Salas *et al.*, 2013; Delgado *et al.*, 2016; Humano, 2020).

Table 2. Ecological and structural variables calculated for the species present in *El Tecuán* Ecological Park.

Species	Density		Dominance (*AB*)		Frecuency		*VIE*
	N ha^{-1}	%	m^2 ha^{-1}	%	F_i	%	
Pinus cooperi C. E. Blanco	112	32.15	6.15	37.77	98	14.95	28.29
Quercus sideroxyla Bonpl.	91	25.96	3.43	21.08	123	18	21.68
Pinus teocote Schltdl. & Cham.	57	16.44	2.91	17.87	106	15.53	16.61
Pinus leiophylla Schiede ex Schltdl. & Cham.	24	7	1.94	11.91	55	7.98	8.96
Arbutus xalapensis	15	4.4	0.27	1.66	77	12.63	6.23

Kunth							
Quercus crassifolia Bonpl.	12	3.56	0.31	1.88	53	5.08	3.76
Quercus laeta Liebm.	12	3.51	0.33	2.05	35	4.79	3.51
Juniperus depeana Steud.	8	2.25	0.22	1.33	33	7.69	3.45
Quercus durifolia Seemen	8	2.21	0.36	2.24	29	4.21	2.89
Pinus durangensis Martínez	5	1.33	0.22	1.33	26	3.77	2.14
Pinus engelmannii Carrière	2	0.51	0.09	0.53	17	2.47	1.17
Quercus rugosa Née	1	0.34	0.02	0.11	6	0.87	0.44
Quercus grisea Liebm.	1	0.15	0.01	0.07	4	0.58	0.27
Pinus strobiformis Engelm.	1	0.09	0.02	0.1	3	0.58	0.26
Pinus arizonica Engelm.	1	0.03	0.002	0.01	2	0.29	0.11
Pinus oocarpa Schiede ex Schltdl.	1	0.03	0.001	0.01	2	0.29	0.11
Pinus maximinoi H. E. Moore	1	0.02	0.005	0.03	1	0.15	0.07
Quercus eduardii Trel.	1	0.02	0.001	0.01	1	0.15	0.06
Total	354	100	16.28	100		100	100

Fi = Number of sites where the *i* species appeared; *VIE* = Ecological importance value.

In spite of the high density of the *Pinus* genus, *Quercus sideroxyla* Bonpl. was the most frequent species (18 % of the relative frequency), since it was recorded in 123 of the 168 sampling units, while *Pinus maximinoi* H. E. Moore and *Quercus eduardii* Trel. were the least frequent with relative frequency values of 0.15 % (Table 2). This result agrees with that obtained by García *et al.* (2019) who analyzed the diversity and vertical structure of unmanaged coniferous forests in *Chihuahua*,

Mexico, also reporting the highest densities and frequencies for *Pinus* and *Q. sideroxyla*.

Pinus cooperi recorded the highest ecological importance value (28.23 %), followed by *Q. sideroxyla* (21.68 %). On the contrary, the species with the lowest importance values were *P. maximinoi* and *Q. eduardii* with 0.07 % and 0.06 %, respectively (Table 2 and Figure 4). The *Pinus* genus stood out for the highest *VIE* with 57.73 %, followed by the *Quercus* genus with 32.29 %, *Arbutus* (6.22 %) and *Juniperus* (3.76 %). These results coincide with those obtained by Hernández-Salas *et al.* (2013), who referred to two *Pinus* species with the highest values of ecological importance, followed by *Quercus* species, in a study carried out in the *El Largo y Anexos ejido*, *Madera* municipality, in *Chihuahua* State, Mexico.

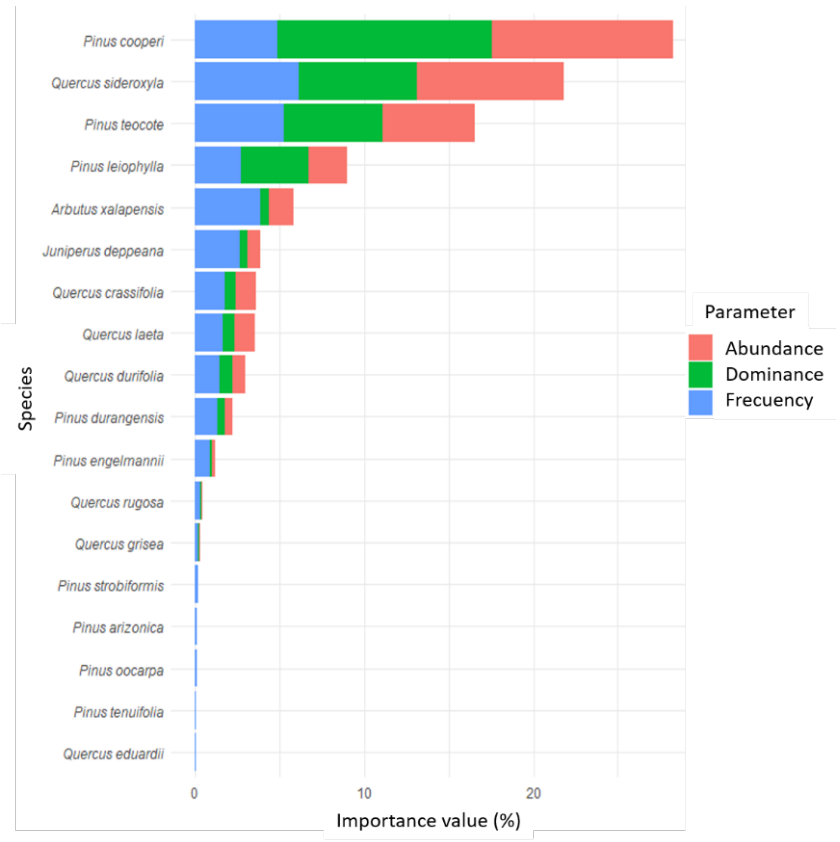

Figure 4. Estimation of the abundance, dominance, frequency and value of ecological importance for the tree species recorded in *El Tecuán* Ecological Park.

Conclusions

In *El Tecuán* Ecological Park, the *Pinus* genus predominates (with nine species), followed by *Quercus* (with seven species). The diversity of tree species described through the Shannon index is considered to be between medium and high. *Pinus cooperi* is the species with the highest density, relative dominance (*AB*) and ecological importance values. The results obtained from this study can be useful as a baseline to assess possible changes in the diversity and tree structure of the Park over time, and by having its forest in protected status, they also represent scientifically based information to develop key indicators of sustainability for the conservation of timber species in other forests subject to logging.

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Conflict of interests

The authors declare no conflict of interest.

Contribution by author

Pablito Marcelo López Serrano: field data analysis and writing of the manuscript; Daniel José Vega Nieva: support in data analysis; José Javier Corral Rivas: review of the manuscript and support in data analysis; Jaime Briseño Reyes and Pablo Antúnez: writing and reviewing of the manuscript.

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