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Research article

Distribución espacial de *Pinus* y *Quercus* en un gradiente altitudinal de bosque templado en Guadalupe y Calvo, Chihuahua

Spatial distribution of *Pinus* and *Quercus* in an altitudinal gradient of temperate forest in *Guadalupe y Calvo*, state of *Chihuahua*

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Abstract

The objective of the study was to determine the spatial distribution patterns of *Pinus* and *Quercus* species along an altitudinal gradient in a temperate forest in northwestern Mexico. Individual uniformity (W_i), species mixture (M_i), and size dominance (U_i) were analyzed using structural parameters based on the relationships with the four nearest neighbors. Data were obtained from 37 sampling sites at three different altitude levels (Level 1: 2 200-2 600 m, Level 2: 2 600-2 800 m, and Level 3: 2 800-3 200 m), generating a total of 979 structural groups for all species. *Pinus* contributed 191, 51, and 41 groups at levels 1, 2, and 3, while *Quercus* contributed 192, one and zero, respectively. *Pinus* showed a tendency towards randomness, as did the oaks at Level 1; although, in this analysis, it was observed that at higher altitudes, *Pinus* tends towards a regular distribution. The species mix was medium to high for *Pinus*, which indicates that its individuals are surrounded by trees of different species, unlike *Quercus*. Size dominance revealed that *Pinus* specimens are taller than those of the *Quercus* genus throughout the gradient, especially at Level I. This approach provides an accurate understanding of the role of species in forest ecosystem dynamics.

Key words: Altitude, conservation, size dominance, tree structure, neighborhood indexes, species mix.

Resumen

El objetivo del estudio fue determinar los patrones de distribución espacial de las especies de *Pinus* y *Quercus* a lo largo de un gradiente altitudinal en un bosque templado del noroeste de México. Se analizó la uniformidad de los individuos (W_i), la mezcla de especies (M_i) y la dominancia dimensional (U_i) mediante parámetros estructurales basados en las relaciones con los cuatro vecinos más cercanos. Los datos se obtuvieron de 37 sitios de muestreo en tres niveles altitudinales (Nivel 1: 2 200-2 600 m, Nivel 2: 2 600-2 800 m y Nivel 3: 2 800-3 200 m), lo que generó un total de 979 grupos estructurales para todas las especies. *Pinus* contribuyó con 191, 51 y 41 grupos en los niveles 1, 2 y 3; mientras que *Quercus* aportó 192, uno y cero, respectivamente. *Pinus* evidenció tendencia hacia la aleatoriedad, y los encinos también en el Nivel 1, aunque en este análisis se observó que a mayor altitud *Pinus* tiende hacia una distribución regular. La mezcla de especies fue de media a alta para *Pinus*, lo cual indica que sus individuos están rodeados de árboles de especies diferentes, y con *Quercus* ocurrió al contrario. La dominancia dimensional reveló que los ejemplares de *Pinus* tienen mayor altura que los del género *Quercus* en todo el gradiente, especialmente en el Nivel 1. Este enfoque proporciona una comprensión exacta de la función que cumplen las especies en la dinámica de los ecosistemas forestales.

Palabras clave: Altitud, conservación, dominancia dimensional, estructura arbórea, índices de vecindad, mezcla de especies.

Introduction

Temperate forests cover a wide distribution in Mexico, from the southern region in *Chiapas* State (16° N and 91° W) to the *San Pedro Mártir Sierra* in northern *Baja California* (31° N and 115° W) (Luna-Cavazos *et al.*, 2008; López-Hernández *et al.*, 2018). Species distribution is limited by different climatic and physiographic factors such as temperature, precipitation, humidity, slope, and altitude, among others (Poulos and Camp, 2005; Babst *et al.*, 2019; Dakhil *et al.*, 2019).

Knowledge of the structural composition of forest ecosystems is essential to understand the mechanisms of coexistence between species within plant communities (Gu *et al.*, 2019). In order to characterize the structural diversity of forest stands, three elements are considered: the spatial distribution of trees, the mix of species, and the differentiation in tree sizes (Gadow, 1999; Pommerening, 2002).

At a global level, studies on the structure and relationship of forests with altitude have been carried out, in which it is recognized that altitude plays an important role in the composition and natural distribution of vegetation (Tiwari *et al.*, 2020; Thakur *et al.*, 2021; Asbeck *et al.*, 2022). In Mexico, research has been carried out to test the impact of fires on the distribution, the degree of mixing and the size dominance (Rubio-Camacho *et al.*, 2017), and also, particularly, to define and understand these spatial characteristics in temperate forests (Chávez-Flores *et al.*, 2020; Graciano-Ávila *et al.*, 2020), as well as in forests under conservation (García-García *et al*., 2021). However, both nationally and internationally, little research has been done on the spatial distribution of species in relation to altitudinal gradients.

The *Cerro Mohinora* Natural Protected Area (NPA) covers a wide altitude range between 2 100 and 3 307 masl and harbors a remarkable diversity of ecosystems. In addition to its ecological relevance, it stands out for its abundant rainfall. In it, there are coniferous forests in a pristine state, including associations of genera such as *Abies* Mill., *Picea* A. Dietr., *Pseudotsuga* Carrière, *Pinus* L., and *Quercus* L., which provide habitat for numerous species, some of which are endemic or at risk (Conanp, 2017).

Because of this, it is important to document the spatial interaction of tree species along altitude gradients. This would make it possible to generate more appropriate proposals for their conservation, restoration and use with an adaptive approach.

The objective of the present study was to characterize the spatial evenness, degree of mixing, and size dominance of *Pinus* and *Quercus* species along an altitudinal gradient in a temperate forest of the *Cerro Mohinora* NPA, located in *Guadalupe y Calvo*, state of *Chihuahua*, Mexico.

Materials and Methods

Study area

The research was carried out in the *Cerro Mohinora* Natural Protected Area (NPA), located in *Guadalupe y Calvo* municipality, *Chihuahua*, northwestern Mexico (between 25°40'48'' and 26°13'12'' N and 106°31'48'' and 107°06'00'' W) (Figure 1). Average annual precipitation varies between 200 and 1 800 mm, with a monthly average of 0-40 mm in the driest month. The average annual temperature varies from 5 to 12 °C, with an average of -3 to 18 °C in the coldest month (Arriaga *et al.*, 2000).

Figure 1. Location of the study area and distribution of sampling sites.

Sampling design

A total of 37 circular sampling sites with a size of 1 000 m^2 each were established randomly and distributed in six north-facing stands, because in this exposure there are mostly populations of such genera as *Pseudotsuga*, *Picea* and *Abies*. These genera are of conservation interest due to their protected status (García-Arévalo, 2008; Semarnat, 2019) at an altitude gradient ranging from 2 200 to 3 200 masl, where three altitude levels were defined to cover the maximum altitudinal range, and the different types of vegetation registered in the management program of the

NPA (Conanp, 2017): Level 1 (2 200-2 600 m), Level 2 (2 600-2 800 m), and Level 3 (2 800-3 200 m). Two stands were considered at each altitude level to include the different vegetation types present, and a sampling intensity of 2 % was applied.

In each of the 1 000 m^2 sites, mensuration information of the tree stratum was collected, focusing on individuals with a normal diameter (*ND*) ≥7.5 cm. The tree variables recorded included total height (*h*) and *ND*. The height was estimated using a Suunto® Pm-5 clinometer, while the normal diameter was measured using a Haglöf® Mantax Blue aluminum caliper. The distance from the trees to the center of the site was recorded with a 20 m Truper® TP20ME tape measure. In addition, a Brunton GEO® Pocket compass was used to obtain the azimuth. The correct nomenclature and identity of the species was verified using the Tropicos® platform (Tropicos, 2022).

Data analysis

The spatial distribution patterns were determined with structural parameters based on the relationships between a reference tree (*i*) and its four nearest neighbors, which appropriately expresses the spatial structural characteristics of the plant communities and allows the design of more appropriate management practices for the specific conditions of the forests (Hui and Gadow, 2002; Pastorella and Paletto, 2013; Rubio-Camacho *et al.*, 2023).

According to Gadow *et al.* (1998), the angle uniformity index (W_i) is based on the measurement of the angles between neighbors to a reference tree *i* and their comparison with a standard angle α, and acquires values from zero to one; a value close to zero reflects regularity; values close to 0.5 show a predisposition to randomness, and those close to one indicate clustering scenarios.

$$W_i = \frac{1}{n}\sum_{j=1}^{n} W_{ij} \qquad (1)$$

Where:

W_i = Index value for the reference tree j^{th}

n = Number of neighboring trees considered

V_{ij} = Variable 1 when the j^{th} angle α between two next neighboring trees is less than or equal to the standard angle α, otherwise, it takes a value of 0

The species mix was determined based on the species mix index (M_i). Füldner (1995) defines it as the proportion of the nearest neighbors n that are not of the same species as the reference tree.

$$M_i = \frac{1}{n}\sum_{j=1}^{n} V_j \qquad (2)$$

Where:

M_i = Index value for the reference tree j^{th}

n = Number of neighboring trees considered

V_j = Equal to 0 when the tree j belongs to the same species as reference tree i, and equal to 1 otherwise (Gadow *et al.*, 2007).

The height dominance between genera was tested with the size dominance index (U_i), which reflects the proportion of neighboring trees that are smaller than the reference tree *i* (Gadow *et al.*, 1998).

$$U_i = \frac{1}{n}\sum_{j=1}^{n} V_j \qquad (3)$$

Where:

M_i = Index value for the reference tree j^{th}

n = Number of neighboring trees considered

V_j = Equal to 1 if the tree j is smaller than the reference tree i, and 0 otherwise

With four neighboring trees, the (U_i) dominance index takes five values and is useful for interpreting the relative dominance of a species or genus (Aguirre *et al.*, 2003; Gadow *et al.*, 2007).

The indexes were analyzed using the R Studio software (Versión: 2023.09.1+494) (R Core Team, 2019), within an observation window (*W*) (sampling sites) where the previously described formulas are run. In this observation window, the edge effect was considered. This effect plays an important role in the proper interpretation of the spatial structure, as within the sampling sites there are trees that are located close to the edge, while their nearest neighbors are regularly located outside the edge, which results in errors in the estimation of the neighborhood values of the trees that are inside the sampling sites (Pommerening and Stoyan, 2006).

In order to prevent these errors, the nearest neighbor edge correction estimator (*NN1*: Nearest-neighbour edge-correction concepts) was applied, which consists of excluding as reference tree (*i*) those whose distance to their *j*th nearest neighbor is less than the distance between (*i*) and the edge of the sampling site (*W*). Also, those trees may be part of other close neighboring structural groups (Pommerening and Stoyan, 2006).

Statistical analysis

All indexes, graphs and statistical analyses were performed with the R software (R Core Team, 2019). The means and their 95 % confidence intervals (*CI*) were calculated by site and altitude level using BOOTSTRAP simulations (999). In addition, the statistical contrasts between treatments were determined with the percentile method of the BOOTSTRAP distribution for two independent samples, using the pb2gen function in R (Mair and Wilcox, 2020).

Results and Discussion

Mensuration characteristics

Table 1 shows the means of the estimated mensuration variables for all the species recorded. Four *Pinus* species were present in Level 1. No individuals of the species *Pinus engelmannii* Carrière were observed in levels 2 and 3, because its distribution range varies from 1 600 to 2 600 m (Jiménez and Méndez, 2021). The opposite was the case for the density of individuals of *Pinus durangensis* Martínez and *P. strobiformis* Engelm. in Level 2, where it is higher than in levels 1 and 3, as these pines develop optimally at altitudes equal to or above 2 400 masl (Pérez-Olvera and Dávalos-Sotelo, 2008). In the case of *Quercus*, four species reached their highest density at Level 1 (2 200-2 600 m) and decreased in number or were absent at levels 2 and 3; this reduced occurrence at higher altitudes may be ascribed to the fact that usually, *Quercus* species are not abundantly distributed at altitudes around 2 800 and 3 000 masl (Martínez-Calderón *et al.*, 2017; Uribe-Salas *et al*., 2019).

Table 1. Mensuration characteristics of species present in the altitude gradient.

Species	**Density (*N* ha^{-1})**			**$D_{1.30}$ (cm)**			***h* (m)**		
	N1	**N2**	**N3**	**N1**	**N2**	**N3**	**N1**	**N2**	**N3**
Abies durangensis Martínez	16	162	269	20.57	18.04	19.78	13.99	12.72	10.63
Arbutus arizonica (A. Gray) Sarg.	9	0	0	19.25	0.00	0.00	7.07	0.00	0.00
Arbutus xalapensis Kunth	19	4	0	22.76	14.38	0.00	8.12	7.45	0.00
Juniperus deppeana Steud.	8	8	1	19.10	10.64	26.00	7.97	5.71	6.20
Pinus arizonica Engelm.	77	33	27	20.89	19.13	20.05	14.33	9.17	11.12
Pinus strobiformis Engelm.	18	59	19	25.00	21.29	17.16	14.90	11.83	9.10
Pinus durangensis Martínez	14	23	5	38.11	33.31	36.86	17.51	15.88	15.86
Pinus engelmannii Carrière	80	0	0	21.30	0.00	0.00	13.52	0.00	0.00
Populus tremuloides Michx.	35	22	30	16.32	10.73	31.06	8.55	7.95	17.09
Pseudotsuga menziesii (Mirb.) Franco	6	109	104	56.25	26.72	22.88	19.71	17.30	10.82
Quercus crassifolia Bonpl.	25	0	0	17.22	0.00	0.00	10.10	0.00	0.00
Quercus fulva Liebm.	35	1	0	19.62	44.00	0.00	9.76	22.50	0.00
Quercus rugosa Née	29	1	0	23.50	38.00	0.00	10.12	21.60	0.00
Quercus sideroxyla Bonpl.	169	1	1	16.65	19.00	48.50	10.12	9.50	12.35

Picea mexicana Martínez	0	0	46	0.00	0.00	21.91	0.00	0.00	10.13
Total general	540	424	501						

$D_{1.30}$ = Average normal diameter at 1.30 m; *h* = Average height; N1 = Altitude Level 1 (2 200-2 600 m); N2 = Altitude Level 2 (2 600-2 800 m); N3 = Altitude Level 3 (2 800-3 200 m).

It is important to note that the presence and patterns of vegetation along altitude gradients are generated by virtue of the complex interaction of various factors such as altitude, exposure to solar radiation, and the topographic position of plant populations, among other observable elements (Girardin *et al.*, 2014; Jadán *et al.*, 2017; Cabrera *et al.*, 2019).

In this sense, a significant dominance of *Abies durangensis* Martínez and *Pseudotsuga menziesii* (Mirb.) Franco is observed at Level 3, where environmental conditions are adverse for most *Pinus* and *Quercus* species, as altitude influences temperature and humidity both in the environment and in the soil. This can result in reduced growth of individuals, reduced regeneration survival, impact on seed viability, and deterioration of vegetation vitality (Champo-Jiménez *et al.*, 2012; Gutiérrez and Trejo, 2014; Villanueva-Díaz *et al.*, 2018).

Spatial distribution of trees in the altitudinal gradient

Figure 2 illustrates the spatial distribution of trees in each of the Level 1 sites based on the *NN1* estimator, which means that only those trees that could be considered as tree *i* of the structural group are represented. A total of 393 structural groups consisting of a reference tree and four neighboring trees were used in the analysis of the neighborhood indexes. Furthermore, the *Quercus* and *Pinus* genera were identified as having the highest number of structural groups, amounting to 192 and 141, respectively.

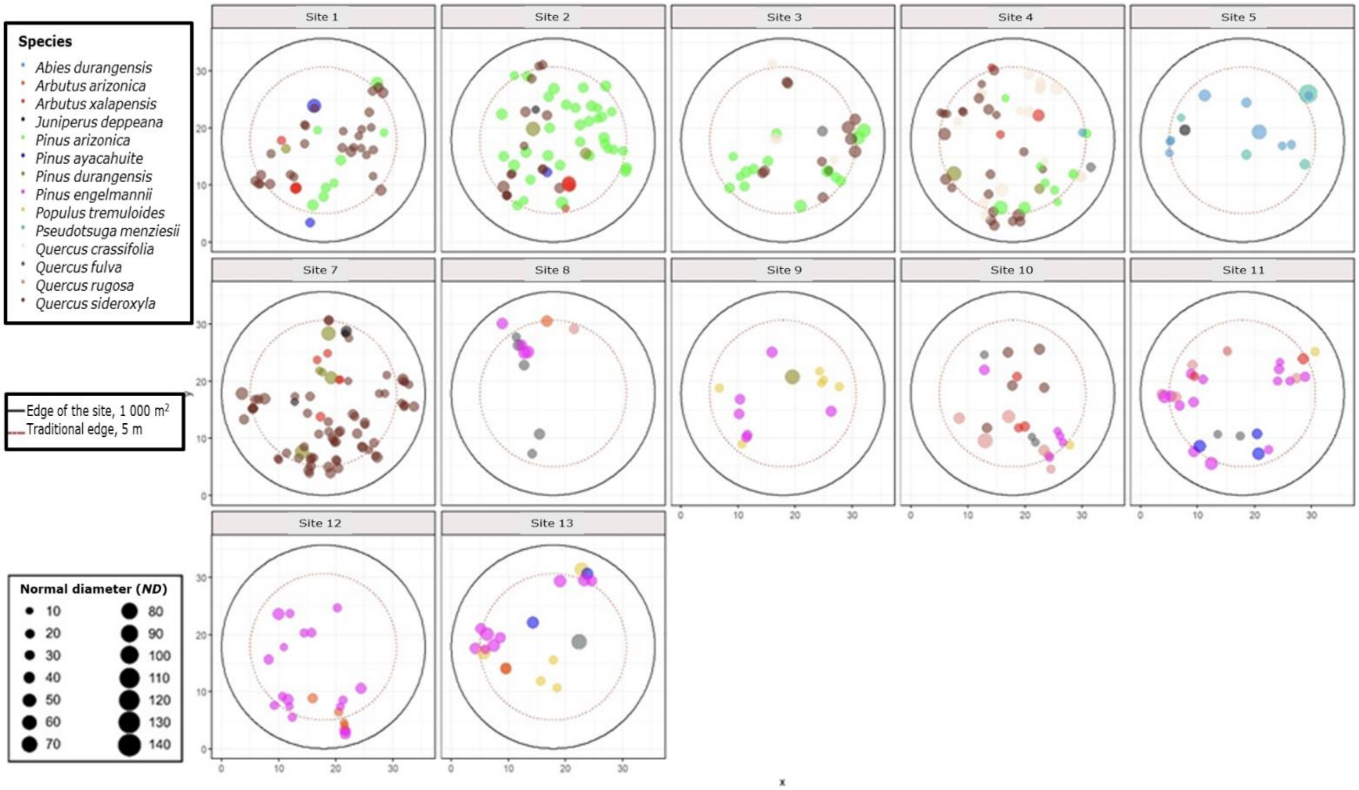

Figure 2. Spatial distribution of trees in each of the sites by genus at Level 1.

On the other hand, Figure 3 shows the spatial distribution of trees in each of the Level 2 sites. 183 structural groups were included in this analysis. Sites 2, 8, and 1 had the highest number of clusters with 36, 28 and 27, respectively. In this case, *Pinus* was represented in terms of structural groups by 51, while *Quercus* was part of only one structural group.

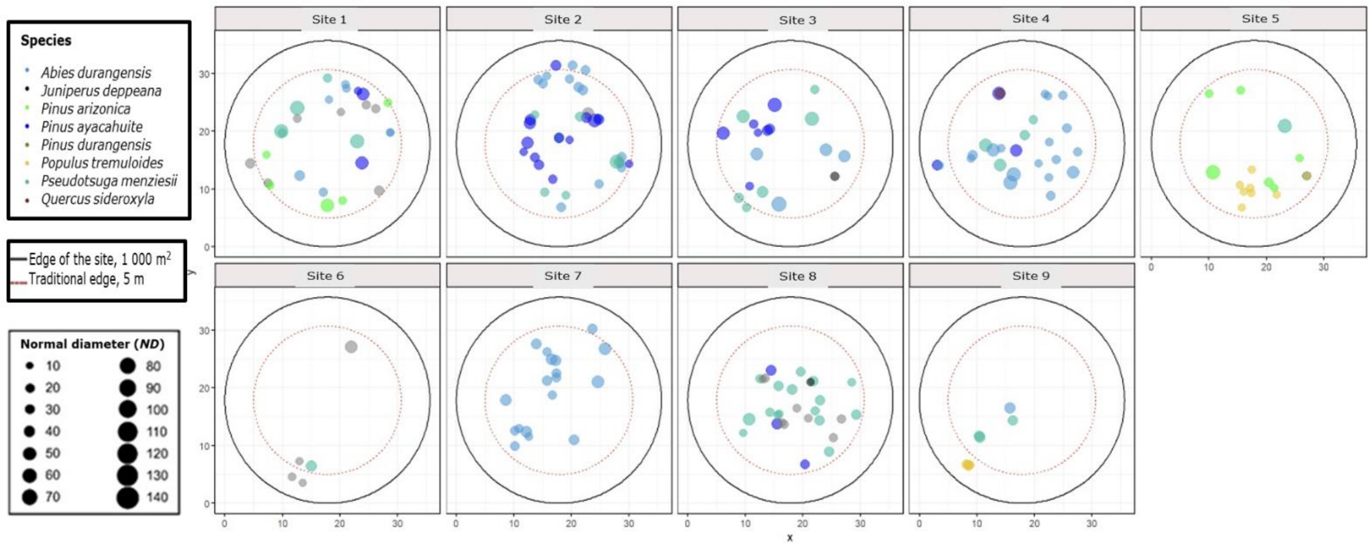

Figure 3. Spatial distribution of trees in each of the sites by genus at Level 2.

Finally, Figure 4 shows the spatial distribution of trees in each of the Level 3 sites, in which 403 structural groups were considered. As for *Pinus* species, 26 structural groups were registered for *P. arizonica* Engelm., 12 for *P. strobiformis*, and three for *P. durangensis*. No structural groups were obtained for *Quercus sideroxyla* Bonpl., the only oak species present at this altitude.

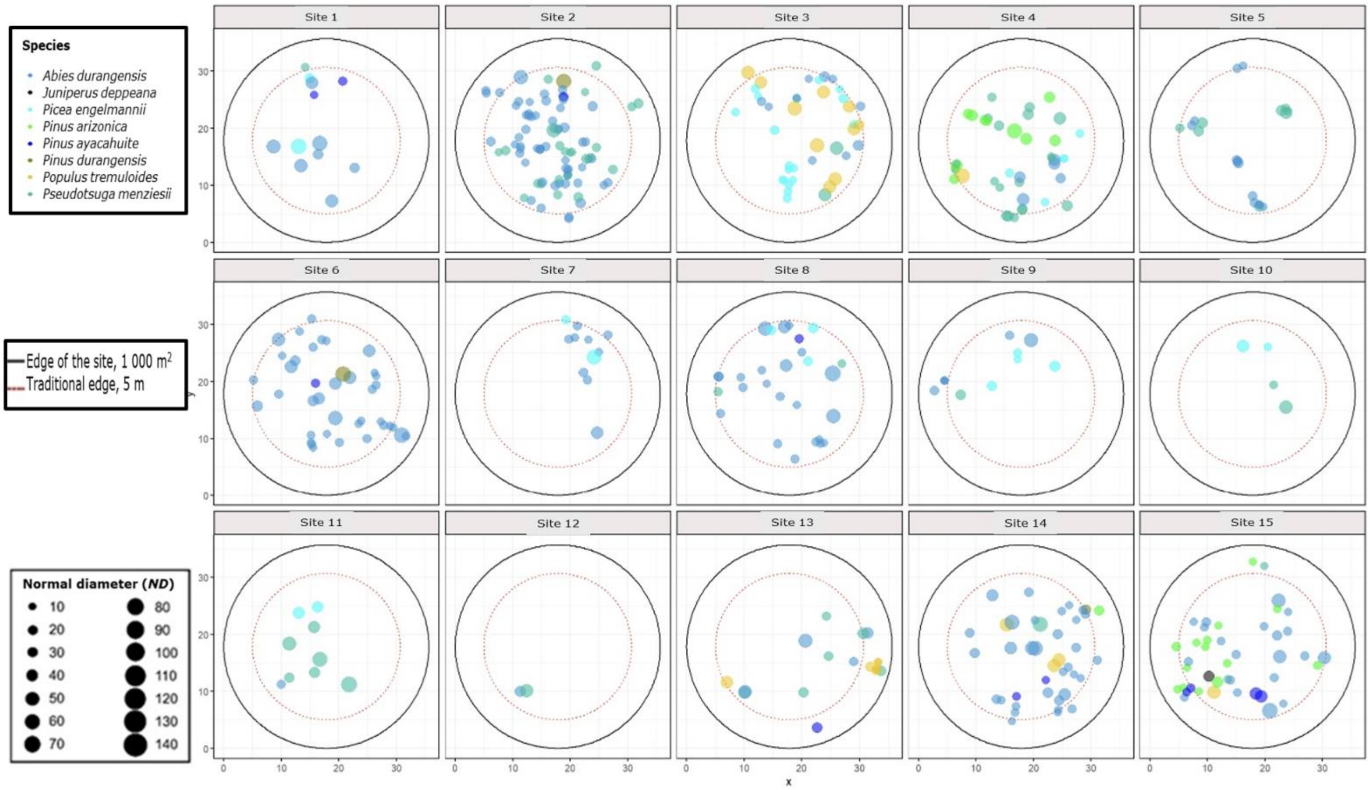

Figure 4. Spatial distribution of trees in each of the sites by genus at Level 3.

It was observed that, the lower the tree density, the lesser the number of structural groups, as shown in Level 2, however, the distance between trees is also a determining factor. García-García *et al.* (2021) cited 203 groups for a density of 254 *N* ha^{-1} in a *Pseudotsuga menziesii* forest with presence of *Pinus* and *Quercus*. Rubio-Camacho *et al.* (2017) carried out a genus analysis and identified a total of 213 *Pinus* and 193 *Quercus* clusters in one of the studied plots. In the second plot, 129 *Pinus* and 189 *Quercus* clusters were recorded. These results were associated with densities of 242 and 211 individuals per hectare, respectively. Castellanos-Bolaños *et al.* (2010) document between 123 and 365 groups for various *Pinus*-*Quercus* associations, with the exception of the association dominated by *Pinus patula* Schltdl. & Cham., for which they obtained 1 176 groups.

Angle uniformity index (*W_i*)

According to an overall analysis of W_i, the structural groups of the *Pinus* and *Quercus* genera exhibited contrasting results (Figure 5): on the one hand, *Pinus* structural groups occurred at all three altitudinal levels, while *Quercus* groups, only at levels 1 and 2. *Quercus* registered a mean value of 0.545, with a confidence interval (*CI*) of 0.498, 0.609; while *Pinus* obtained a W_i=0.527 [*CI*, 0.493, 0.57] at Level 1, although this difference was not statistically significant. At Level 2, *Pinus* (W_i=0.53 [*CI*, 0.469, 0.611]) did exhibit a significant difference (d=0.28 [*CI*, 0.22, 0.35], p<0.001], unlike the *Quercus* group (W_i=0.25 [*CI*, 0.25, 0.25]).

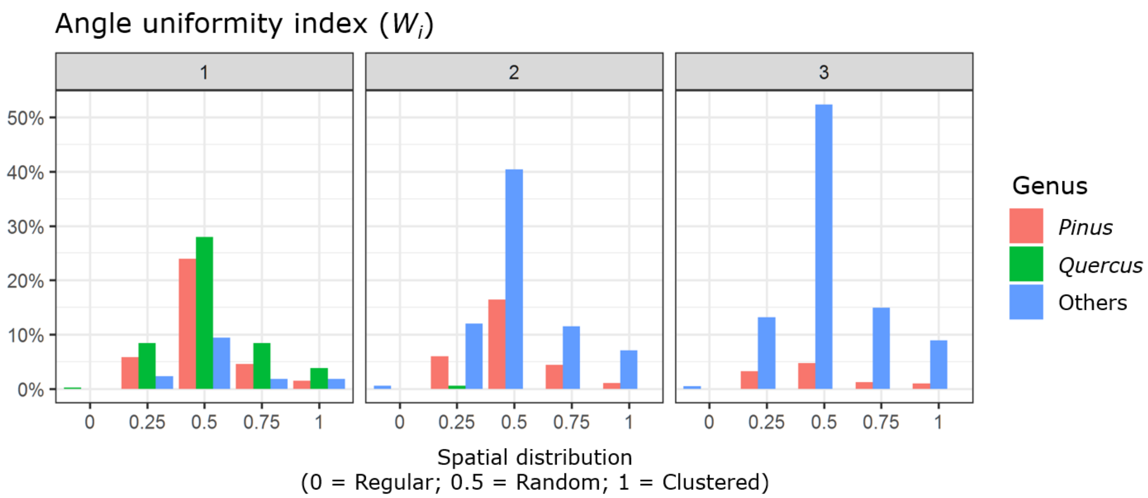

Figure 5. Angle uniformity index (W_i) by genus and altitude level.

The specific analysis showed that *Pinus* species maintain a mean of approximately 0.50, with the exception of *P. strobiformis* in Level 1, where it exhibited a mean of 0.66 [*CI*, 0.47-0.84]. It should be noted that *P. engelmannii* did not occur at sites 2 and 3.

The same trend was observed for the *Quercus* species, as all four species present had average uniformity values, although the average index for *Q. sideroxyla* decreased to 0.25 [*CI*, 0.25-0.25]. The mean uniformity in both genera indicates that two of the four neighboring trees have an angle of less than 90° with respect to the reference tree, resulting in a random distribution.

This index has been applied in forests under conservation near the study area, where both *Quercus* ($\bar{x}$=0.47 [*CI*, 0.39-0.53]), and *Pinus* ($\bar{x}$=0.49 [*CI*, 0.40-0.57]) have a random distribution (García-García *et al.*, 2021). Likewise, Rubio-Camacho *et al.* (2017) indicate that the average value for two evaluated plots in a pine-oak forest is 0.49. Graciano-Ávila *et al.* (2020) cite the same distribution in *Pinus* and *Quercus* dominated forests in *Durango*, Mexico.

Species mix index (M_i)

The spatial mix of species also shows contrasting results among the analyzed groups (Figure 6). In first place, *Quercus* registered a mean value of 0.559 [*CI*, 0.385, 0.724], while *Pinus* had a M_i=0.545 [*CI*, 0.432, 0.645] at Level 1, with no statistically significant difference. At Level 2, *Pinus* (M_i=0.673 [*CI*, 0.509, 0.844]) did exhibit a significant difference (d=0.321 [*CI*, 0.168, 0.493], p<0.001) in relation to the *Quercus* group with an M_i equal to 1. This indicates that *Quercus* is surrounded by trees of different genera.

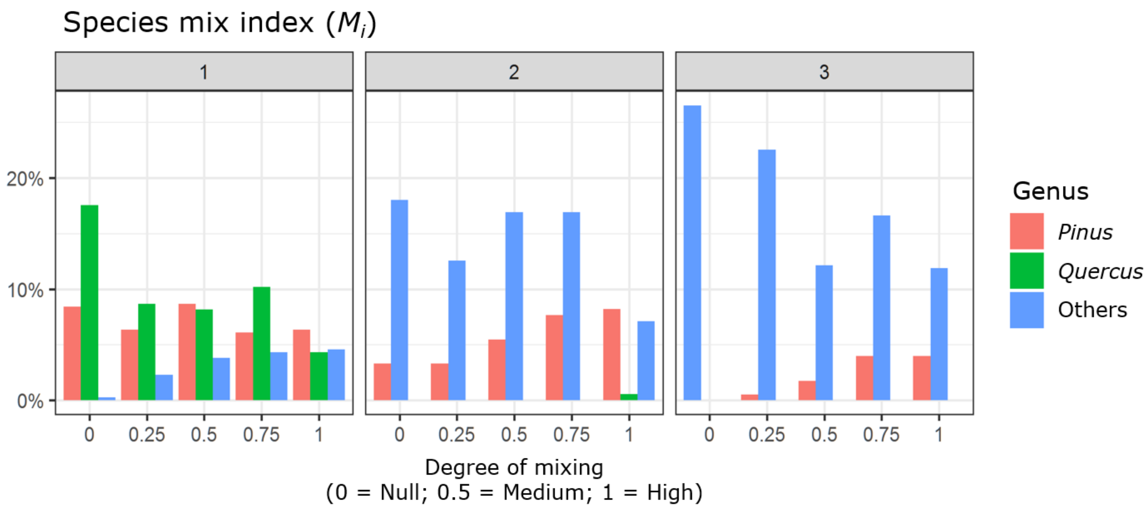

Figure 6. Species mix index (M_i) by genus and altitude level.

Particularly, the *Pinus* species with the highest degree of mixing are *Pinus strobiformis* (P1 $\bar{x}$=0.87, P2 $\bar{x}$=0.66 y P3 $\bar{x}$=0.87) and *P. durangensis* (P1 $\bar{x}$=0.86, P2 $\bar{x}$=0.85 y P3 $\bar{x}$=1.00), these values indicate that most of the reference trees are surrounded by individuals of species other than the reference tree.

Conversely, *P. arizonica* ($\bar{x}$=0.45) and *P. engelmannii* ($\bar{x}$=0.36) showed less mixing in P1, while in levels 2 and 3 *P. arizonica* expanded its mix to $\bar{x}$=0.66 and $\bar{x}$=0.71, respectively. *Quercus crassifolia* Bonpl. ($\bar{x}$=0.59), *Q. fulva* Liebm. ($\bar{x}$=0.73), and *Q. rugosa* Née ($\bar{x}$=0.68) exhibited a medium-high degree of mixing in P1, where only *Q. sideroxyla* had a low degree of mixing ($\bar{x}$=0.28), that is, it corresponds to a species that is usually surrounded by individuals of the same species or with a tendency to group together.

The mixing index (M_i) has been evaluated in several temperate forests of the country with predominance of *Pinus* and *Quercus*, in which lower mean values of mixing than those documented herein have been recorded. In comparison, the forest that is the object of the present study have an outstandingly high diversity and coexistence of species, except for *P. arizonica* and *P. engelmannii* in P1, which have a similar or lower value (Castellanos-Bolaños *et al.*, 2010; Graciano-Ávila *et al.*, 2020; Silva-González *et al.*, 2022).

Height dominance index (UH_i)

The height dominance index showed that *Pinus* species tended to be medium to high; its highest average value of UH_i of 0.633 [*CI*, 0.556, 0.705] was recorded at Level 1, while *Quercus* had 0.396 [*CI*, 0.305, 0.503]. These differences were statistically significant (d=0.235 [*CI*, 0.108, 0.357], p<0.01) and were repeated at Level 2 (d=0.293 [*CI*, 0.204, 0.390], p<0.001) with *Pinus* as the dominant genus, having a UH_i=0.541 [*CI*, 0.452, 0.632], unlike *Quercus*, which exhibited a UH_i=0.25 [*CI*, 0.25, 0.25] (Figure 7).

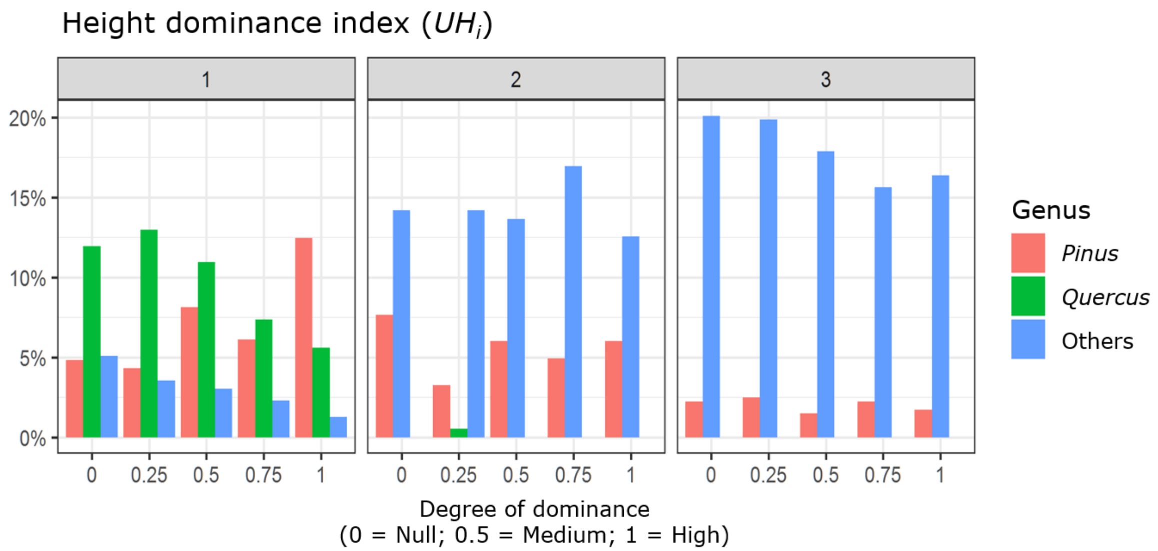

Figure 7. Distribution of the height dominance index (UH_i) of *Quercus* species by altitudinal level.

The dominance of *P. durangensis* stands out, having obtained an average of $\bar{x}$=0.82, $\bar{x}$=0.52, and $\bar{x}$=0.75 for levels 1, 2, and 3, respectively; these values show that when this species is a reference tree, it tends to be taller than its closest neighbors. The rest of the taxa in the three levels had means of 0.41-0.63, with the exception of *P. arizonica*, whose mean value in P2 (0.34) was low. *Quercus* species maintained a downward trend, among them *Q. sideroxyla* obtained the highest mean ($\bar{x}$=0.42) in P1, which showed that this species regularly has a lower height than its neighbors.

The results obtained herein agree with those reported by other authors, who also evaluated temperate forests, and indicate that structural groups dominated by *Pinus* are dominant in height (García-García *et al.*, 2021); while *Quercus* tends to surround itself with much larger neighbors (Rubio-Camacho *et al.*, 2017). A decrease in the mean number of *Pinus* individuals was observed at levels 2 and 3, which may be due to the fact that at these levels the forest is dominated in density by other genera such as *Pseudotsuga* and *Abies*, which tend to be taller (Table 1).

Conclusions

The results of the analysis of the *Pinus* and *Quercus* genera along the altitude gradient indicate that they exhibit some significant differences in the uniformity of angles and species mix at altitude Level 2, as well as in the size dominance in terms of height at levels 1 and 2. This is largely due to species composition, which also changes with the gradient; *Quercus* loses presence and dominance as the altitude rises. The angle uniformity index (W_i) showed that there is a random distribution of *Pinus* and *Quercus*, similar to that of other temperate forests in the country, although in this study, at higher altitudes *Pinus* shows a tendency to regularity. This is also reflected in the species mix (M_i); thus, *Pinus* individuals tend to mix more with other species with increasing altitude. Finally, according to the size dominance index for height (UH_i), *Pinus* species are taller than *Quercus* species throughout the gradient, a characteristic that is observed in several temperate forests in Mexico. This work highlights the relevance of generating more species-specific information through the indices utilized.

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Conflict of interest

Eduardo Alanís Rodríguez, as Section Editor, declares that he did not participate in the editorial process of this document.

Contribution by author

Samuel Alberto García-García, Eduardo Alanís Rodríguez and Ernesto Alonso Rubio-Camacho: study idea, data recording, interpretation of results and writing of the manuscript; Óscar Alberto Aguirre-Calderón and José Israel Yerena-Yamallel: review and analysis of data and writing of the Discussion; Luis Gerardo Cuéllar Rodríguez and Alejandro Collantes Chávez-Costa: general review and drafting of Conclusions.

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