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Artículo

Regeneración y estructura vertical de un bosque de *Pseudotsuga menziesii* (Mirb.) Franco en Chihuahua, México

Regeneration and vertical structure of a *Pseudotsuga menziesii* (Mirb.) Franco forest in *Chihuahua* State, Mexico

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Abstract

For the characterization of the vertical structure of a *Pseudotsuga menziesii* forest in the *Chinatú ejido*, *Guadalupe y Calvo* municipality, *Chihuahua* State, eight circular sites of 1 000 m^2 dispersed in 80.46 ha were randomly sampled. With the information obtained, the vertical structure of regeneration and standing trees was analyzed using the Pretzsch *A* Index, abundance (N ha^{-1}), average, minimum, maximum values and coefficient of variation of height and diameter were estimated normal and coverage, as well as diversity based on the Shannon-Wiener Index (H´) and the Margalef Index (*DMg*). Eight species were registered for the regenerated plant community, the families with the greatest presence were Pinaceae with five species and Fagaceae with two; the mature plant community recorded 10 species, the most predominant being pinaceae with six species and fagaceae with two. The maximum heights of the forest were 8.0 m and 29.0 m for regeneration and mature woodland, respectively. With the Pretzsch Index *A* it was determined that the largest number of individuals belongs to stratum III (Low) for both types of trees. The species with the highest regeneration are *Abies durangensis, Juniperus deppeana, Quercus tuberculata* and *Pseudotsuga menziesii*, the latter of which is dominant in the tree stratum. The studied forest has a low richness and diversity of species, some of high ecological value for conservation and regeneration of the majority of those present.

Key words: Diversity, vertical structure, Fagaceae, Pretzsch Index, Pinaceae, Western *Sierra Madre*.

Resumen

Para la caracterización de la estructura vertical de un bosque de *Pseudotsuga menziesii* en el ejido Chinatú, municipio Guadalupe y Calvo, Chihuahua, se realizó un muestreo aleatorio de ocho sitios circulares de 1 000 m^2 dispersos en 80.46 ha. Con la información obtenida se analizó la estructura vertical de la regeneración y del arbolado mediante el Índice *A* de *Pretzsch*, se estimó la abundancia (N ha^{-1}), los valores medios, mínimos, máximos y coeficiente de variación de la altura y diámetro normal y cobertura, así como la diversidad con base en el Índice de *Shannon*-*Wiener* (*H´*) y el Índice de *Margalef* (D_{Mg}). Se registraron ocho especies para la comunidad vegetal regenerada, las familias con mayor presencia fueron Pinaceae con cinco especies y Fagaceae con dos; la comunidad vegetal madura registró 10 especies, las más predominantes fueron pinaceae con seis taxones y fagaceae con dos. Las alturas máximas del bosque fueron 8.0 m y 29.0 m para regeneración y arbolado maduro, respectivamente. Con el Índice *A de Pretzsch se* precisó que el mayor número de individuos se reúne en el estrato III (Bajo) para ambos tipos de árboles. Las especies con mayor regeneración son *Abies durangensis, Juniperus deppeana, Quercus tuberculata* y *Pseudotsuga menziesii*, la última de las cuales es dominante en el estrato arbóreo. El bosque estudiado cuenta con una riqueza y diversidad de especies baja, algunas de alto valor ecológico para conservación y con regeneración de la mayoría de las presentes.

Palabras clave: Diversidad, estructura vertical, Fagaceae, Índice de *Pretzsch*, Pinaceae, Sierra Madre Occidental.

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Introduction

Conifers in Mexico are widely distributed in the national territory and are present in various types of vegetation such as pine forest, thicket, fir forest, *Pseudotsuga* and *Picea* forest, *Juniperus* forest or thicket, *Cupressus* forest, mesophilic forest of mountain, pine-oak forest, xerophilous scrub and gallery forest (Rzedowski, 1978).

Pseudotsuga menziesii (Mirb.) Franco is one of the most important conifers in the world from its wide distribution, from the area planted in several countries and from its economic value (Owston and Stein, 1974; Hermann and Lavender, 1999). Fowells (1965) indicates that this species is distributed from British Columbia, Canada, to the southern United States. The natural distribution of this species in Mexico is not as abundant, but it includes forests of the states of *Chihuahua, Sonora, Coahuila, Durango* and *Zacatecas* in the *Sierra Madre Occidental* (Western Mountain Chain), as well as in *Nuevo León* and *Tamaulipas* states in the *Sierra Madre Oriental* (Eastern Mountain Chain); generally, the populations are fragmented, with isolated stands or stains, often dominated by other species (Rzedowski, 1978; Dominguez *et al.,* 2004).

Forest biodiversity assessment helps to conserve forest resources effectively and sustainably order their composition, structure and function (Newton and Kapos, 2002; Del Río *et al*., 2003). For the study of biodiversity, structural indices and dendrometric variables are considered, including diameter, height, basal area, density, among others, in order to achieve a better description (Aguirre *et al.,* 2003).

The structure of a forest mass is related to the habitat and ecological niche of many species of plants and animals, and can be used as an indicator of biodiversity (Murdoch *et al*., 1972; Degraaf *et al.,* 1998). In order to guarantee a sustainable management of ecosystems, it is necessary to characterize their structural diversity, since it is possible to observe both natural succession processes and those caused by anthropogenic activities, and thus, define the activities that should follow in forest management (Jiménez *et al.,* 2001).

In recent years, in the temperate forests of northwestern Mexico, several studies have been carried out that evaluate the diversity and structure of tree vegetation of timber interest in some specific areas (Návar-Cháidez and González-Elizondo, 2009; Aragón-Piña *et al.,* 2010; Hernández-Salas *et al*., 2013; Graciano-Ávila *et al*., 2017). However, these investigations have focused mainly on assessing the composition and horizontal structure, so it is necessary to direct attention to species of high conservation and restricted distribution interest to analyze their regeneration and vertical structure. Therefore, the objective of this study was to determine the richness and diversity of species present in the community, as well as its vertical structure to know the behavior of different tree species and their regeneration in a forest of *Pseudotsuga menziesii* in *Chihuahua* State.

Materials and Methods

Study area

Fieldwork was carried out in a mixed forest consisting mainly of *Pseudotsuga menziesii, Pinus arizonica* Engelm. and *Quercus tuberculata* Liebm.; in the place known as *El Triste*, which is located within the *Chinatú ejido, Guadalupe* and *Calvo* municipality, southwest of the state of *Chihuahua* between 40º00'00" - 80º00'00" N and 40º00'00" - 160°00'00" W (Figure 1).

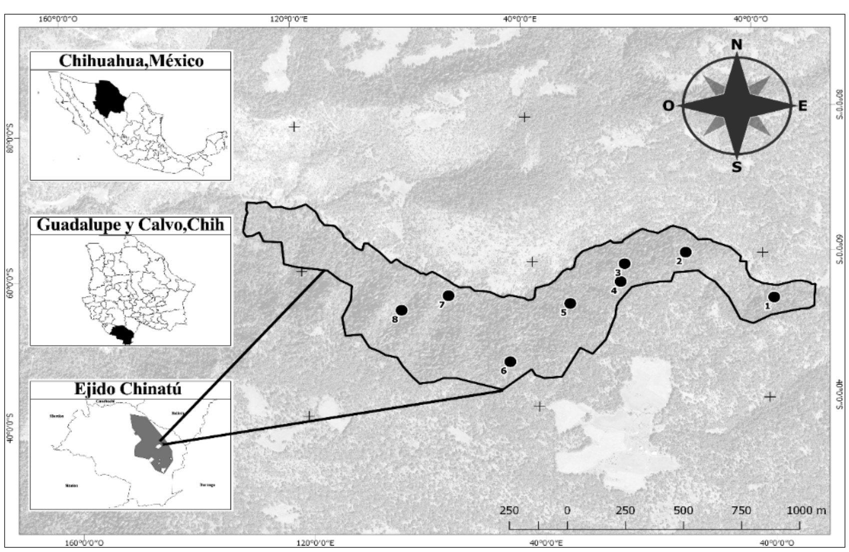

Figure 1. Location of the study area and sampling sites.

The forest extends over 80.46 ha and its altitude varies between 2 530 and 2 830 m. It belongs to the *Río Fuerte* hydrological region, to the *Sierra Tarahumara* physiographic province and the Great Plateau and Chihuahuan Canyon subprovince. Litosol is the predominant type of soil in the area and Regosol only covers a minimum part. The region's climate is classified as subhumid temperate, with an average annual temperature of 13.7 °C and an average annual rainfall of 1 126.8 mm (Chávez, 2009).

Field Evaluation

To evaluate the plant community, eight circular sampling sites of 1 000 m^2 were established, which were randomly distributed in the study area. In each of them, specimens with normal diameter ($d_{1.30}$) ≥ 7.5 cm were considered for adult trees, and as regeneration for children under 7.5 cm, but greater than 0.25 m in total height (Conafor, 2012). For each individual the species was recorded, the total height (h) with a Suunto Pm-5 hypsometer; the normal diameter (DAP, for its acronym in Spanish) with a 5 m Forestry Suppliers diameter tape, and the projection diameter of the crosshead crown, with a 100 m Truper™ fiberglass tape measure (north-south and east-west).

Data analysis

To assess the vertical structure of the plant community, the Pretzsch Index (*A*) was used, with which the vertical structure is divided into three strata. Stratum I (high), which represents the range of 80-100 %, in which the tallest tree constitutes 100 %; from this individual, the following strata are classified: Stratum II (medium), which refers to the 50-80 % range and Stratum III (low), 0-50 % (Aguirre, 2002; Pretzsch, 2009). For a better interpretation of the result, A_{max} is calculated which corresponds to the maximum value for each of the species in each stratum; this value is reached when all the species occur in the same proportion, both in the stand and in the different strata (Corral *et al*., 2005) (Table 1).

Table 1. Pretzsch Index *(A)*.

Index/Equation	Description
$A = \sum_{i=1}^{S} \sum_{j=1}^{Z} p_{ij} * ln\, p_{ij}$ $A_{max} = ln(S * Z)$ $A_{rel} = \frac{A}{\ln (S*Z)} * 100$	*S*= Number of present species *Z*= Number of height strata P_{ij}= Percentage of species in each zone $P_{ij} = n_{ij}/N$ $N_{i,j}$= Number of individuals of the same species (*i*) in the zone (*j*) *N*= Total number of individuals

Abundance was determined for each of the strata according to the number of individuals present (N ha^{-1}), the average, minimum, maximum value and coefficient of variation obtained from the height and diameter variables. The diversity of the plant community was assessed using the Shannon-Weiner index (*H'*) (Shannon, 1948), Margalef index (D_{Mg}) (Magurran, 2004) and true diversity (*D*), which allows a better comparison of the richness of species (Jost, 2006) (Table 2).

Table 2. Species richness and diversity indexes.

Index	Equation	Description
Margalef (D_{Mg})	$D_{Mg} = \frac{(S-1)}{ln(N)}$	*S*= Number of species *N*=Total number of individuals
Shannon-Weiner (*H'*)	$H' = \sum_{i=1}^{S} p_i \times ln(p_i)$ $p_i = {}^{n_i}/_{N}$	*S*= Number of species P_i= Rate of individuals of the *i* species
True diversity (*D*)	$D = \exp(H') = exp\left[\sum_{i=1}^{S} p_i ln p_i\right]$	p_i= Relative abundance of the *i*-^{eth} species *S*= Number of species

Results and Discussion

Composition. In the regeneration stage, eight species belonging to six genera of three families were registered (Figure 2). Those with the highest number of species were Pinaceae with five and Fagaceae with two. For the mature plant community (Figure 2), 10 species of seven genera were registered in four families; the families with more species were Pinaceae with six and Fagaceae with two. These results coincide with those of Aragón-Piña *et al.* (2010), Hernández-Salas *et al.*, (2013) and Graciano (2017), who agreed that these families are widely distributed in the *Sierra Madre Occidental*, in which the *Pinus* and *Quercus* genera stand out. The maximum height of regeneration was 8.0 m and 29 m for mature trees.

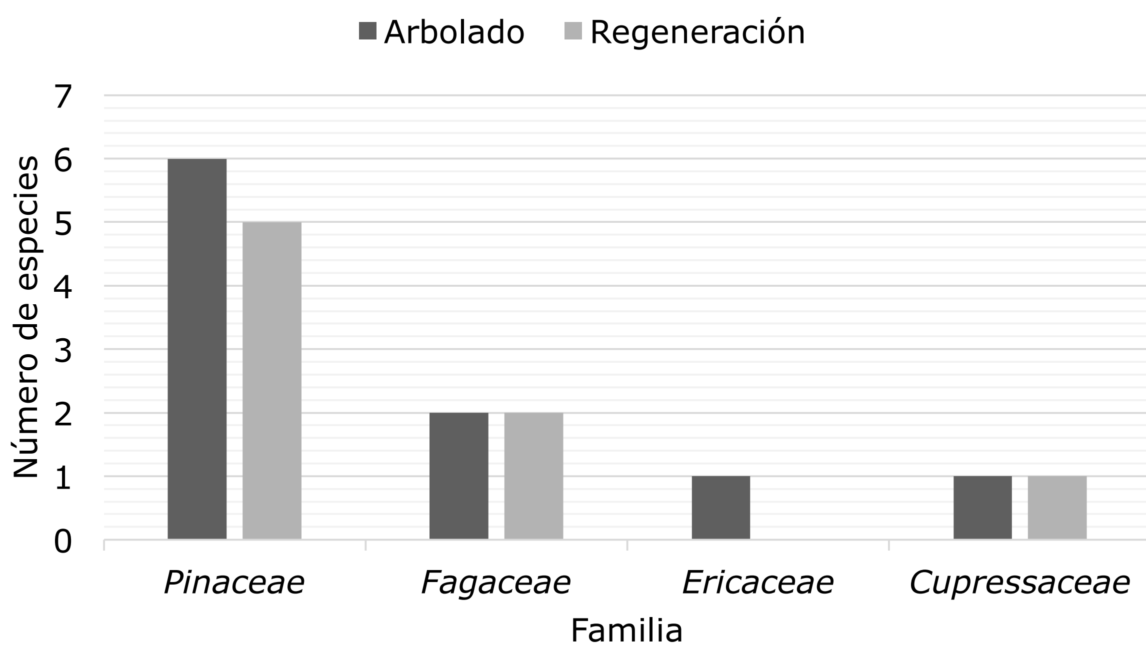

Figure 2. Vegetable composition of regeneration and trees.

Vertical distribution. For regeneration (Table 4), the result of the A index was 1.85, with an A_{max} value of 3.18 and an A_{rel} of 58.21 %, while the mature plant community reflected an A index of 2.58, A_{max} of 3.40 and A_{rel} of 75.56 %. The above suggests that the tree stratum has a great diversity of species with respect to height.

The above figures are similar to those reported by Méndez *et al*. (2014) who calculated an A = 2.07 with A_{max} = 2.70, and by Jiménez *et al.* (2001) that recorded an A = 2.07 and A_{max} = 3.50; both in mixed coniferous and broadleaved forests. This vertical distribution analysis showed that as tree height increases, species diversity decreases. Such authors mentioned that the greatest biological heterogeneity was presented as the zone of the strata decreases.

Regeneration in stratum I has 1.01 % of the individuals, II, 4.02 % and III, 94.97 % (Table 3). According to Lamprecht (1990), the species present in all strata are defined as species with continuous vertical distribution (DVC); *P. arizonica* presented this distribution as it was registered in the three strata (Table 3). The trees behaved in a similar way (Table 3) since stratum I had 2.72 % of the individuals, II with 28.26 % and III with 69.02 %, similar percentages to those reported by Jiménez *et al.* (2001) who evaluated a multicohortal forest of *Pinus - Quercus* in northeastern Mexico. The species with DVC in the tree stratum were *Q. tuberculata, P. menziesii* and *Abies durangensis* (Table 4).

Table 3. Number and percentage of individuals present in the stages of regeneration and adult trees.

Stratum	**Regeneration**		**Trees**	
	Number of individuals	**% of individuals**	**Number of individuals**	**% of individuals**
I	2	1.01	13	2.72
II	8	4.02	130	28.26
III	189	94.97	318	69.02
Total	199	100.00	461	100.00

Table 4. Results of abundance (N ha^{-1}), coverage (m^2 ha^{-1}) and height (m) of the species in the different strata considered for the Pretzsch index (*A*), the Shannon index (*H´*) and the true diversity index (*D*) of the regeneration strata.

Stratum	Species	Abundance	Coverage				Height				*H'*	*D*
		N ha^{-1}	Mean	Min	Max	CV	Mean	Min	Max	CV		
I	*Quercus tuberculata* Liebm.	1	3.50	3.50	3.50	0.00	7.00	7.00	7.00	0	0.05	1.05
	Pinus arizonica Engelm.	1	3.10	3.10	3.10	0.00	8.00	8.00	8.00	0		
	Subtotal	2										
II	*Pseudotsuga menziesii* (Mirb.)Franco	5	2.15	1.70	2.60	22.00	4.65	4.00	6.00	6	0.2	1.17
	Pinus arizonica Engelm.	4	2.17	1.80	2.50	16.00	4.06	4.00	4.10	26		
	Juniperus deppeana Steud.	1	2.50	2.50	2.50	0.00	4.10	4.10	4.10	0		
	Subtotal	10										
III	*Abies durangensis* Martínez	75	1.37	0.40	3.80	80.00	1.42	0.40	2.50	79	1.6	5.10
	Juniperus deppeana Steud.	65	1.24	0.30	3.90	79.00	1.39	0.50	3.50	81		
	Quercus tuberculata Liebm.	34	1.32	0.20	3.40	84.00	1.46	0.30	3.10	87		
	Pseudotsuga menziesii (Mirb.)Franco	30	1.33	0.20	2.30	76.00	1.36	0.30	3.50	77		
	Pinus arizonica Engelm.	20	1.31	0.40	2.30	58.00	1.62	0.50	2.50	69		
	Pinus ayacahuite Ehrenb. ex Schltdl.	9	1.37	0.30	1.40	75.00	0.91	0.40	1.75	76		
	Picea chihuahuana Martínez	3	0.78	0.65	1.05	38.00	0.83	0.56	1.10	56		
	Quercus sideroxyla Humb. & Bonpl.	1	1.18	1.80	1.80	0.00	1.60	1.60	1.60	0		
	Subtotal	236										
	Total	248										

Abundance. *Q. tuberculata* and *P. arizonica* shared stratum I of the regeneration with 1 N ha^{-1} each; in stratum II, *Q. tuberculata* did not appear, *P. menziesii* was present with 5 N ha^{-1}, *P. arizonica* with 4 N ha^{-1} and *Juniperus deppeana* Steud. 1 N ha^{-1}. In stratum III, eight species were identified, of which the most abundant were *Abies durangensis* with 75 N ha^{-1}, *J. deppeana* with 65 N ha^{-1}, *Q. tuberculata* with 34 N ha^{-1} and *P. menziesii* with 30 N ha^{-1} (Table 4). The most abundant species in this forest without disturbance are from the Pinaceae family, which coincides with the results of Méndez (2014), which should be treated with reservation because their data comes from a post-fire evaluation. In this type of forest with disturbance, up to 812 N ha^{-1} (Alanís *et al*., 2011), and 3 400 N ha^{-1} (González-Tagle *et al.,* 2008) are recorded with a higher frequency of Fagaceae.

It was observed that all species in regeneration have a presence in the woodland, in addition *Arbutus xalapensis* Kunth appears with 43 N ha^{-1} in stratum III. The forest has a greater abundance of *P. menziesii* than in stratum I of the woodland obtained 8 N ha^{-1}, *Q. tuberculata* and *Abies durangensis* 3 N ha^{-1}; stratum II was integrated by nine species of which *P. menziesii* stand out with 58 N ha^{-1}, *P. arizonica* with 28 N ha^{-1} and *Q. tuberculata* with 13 N ha^{-1} and in stratum III, 10 species were recorded, the most abundantof which were *P. menziesii* with 89 N ha^{-1}, *P. arizonica* with 55 N ha^{-1}, *Arbutus xalapensis* with 43 N ha^{-1} and *Q. tuberculata* with 33 N ha^{-1} (Table 4). This is consistent with Camacho *et al*. (2014) who reported greater biological diversity in stratum III, of a pine-oak forest in *Nuevo León*, Mexico.

Regeneration and tree variables. Regeneration in stratum I showed an average crown diameter (Coverage) of 3.40 m and an average height of 7.5 m; in stratum II, the average cup was 2.27 m, while the height was 4.27 m; and, stratum III averaged a cup diameter of 1.37 m with an average height of 1.32 m. The tallest individuals came from *P. arizonica* with 1.62 m and *Quercus sideroxyla* Humb. & Bonpl with 1.60 m (Table 4).

In regard to trees (Table 5), in stratum I, the average diameters measured between 42.92 cm and 53.67 cm, with a maximum of 73.0 cm in the case of *Q. tuberculata*. The average total height was 25.12 m, with a maximum of 29.0 m for *Abies durangensis*; in stratum II, average diameters were recorded between 26.43 cm and 53.50 cm, and reached 88.5 cm for *Q. tuberculata* and 94.0 cm in *Pseudotsuga menziesii*, which coincides with Dominguez-Calleros *et al.* (2014) who confirmed that this species registered the largest diameters. Regarding height, the average was 16.58 m with a maximum of 21.60 m for *Pinus durangensis* and in stratum III in specimens whose diameters measured between 12.50 cm and 18.48 cm, the average height was 8.59 m. *Pseudotsuga menziesii* obtained similar values to those of Encina-Domínguez *et al*. (2008), since this species together with *Q. tuberculata, P. arizonica* and *Abies durangensis* reached a maximum value of 13.50 m (Table 5).

Table 5. Results of abundance (N ha^{-1}), normal diameter (cm), canopy cover (m) and height (m) of the species in the different strata considered for the Pretzsch index (*A*) and index of Shannon (*H´)* and true diversity index (*D*) of the strata in the mature vegetal community.

Stratum	Species	Abundance	Normal diameter				Canopy cover				Height				*H'*	*D*
		N ha^{-1}	$\overline{X}$	Min	Max	CV	$\overline{X}$	Min	Max	CV	$\overline{X}$	Min	Max	CV		
	PsMe	8	42.92	23.20	63.50	38	8.47	4.35	10.95	43	24.15	23.10	26.30	8		
	QuTu	3	53.67	34.00	73.00	36	14.43	10.20	18.65	0	24.00	22.00	26.00	9	0.12	1.13
I	*AbDu*	3	45.15	28.00	62.30	54	10.85	7.95	13.75	57	27.20	25.40	29.00	9		
	Subtotal	13														
	PsMe	58	27.89	11.30	94.00	52	5.77	1.93	9.95	41	16.22	13.90	20.50	12		
	PiAr	28	29.74	14.40	53.00	54	6.11	2.90	10.85	40	16.10	13.80	20.00	12		
	QuTu	13	29.80	20.50	88.50	54	7.51	3.60	4.80	39	15.55	13.80	17.80	12		
	AbDu	16	26.80	13.00	39.50	45	6.61	4.85	9.25	40	15.95	14.00	20.10	14		
	PiAy	6	29.80	16.20	46.00	50	9.29	5.00	13.20	43	18.28	14.80	21.30	12	0.81	2.26
II	*PiDu*	4	50.83	42.50	62.00	20	7.55	6.65	8.15	28	18.57	14.80	21.60	19		
	QuSi	3	26.43	28.00	38.00	47	6.98	5.15	8.80	45	14.20	14.10	14.30	13		
	PiCh	3	35.37	25.80	35.70	27	6.31	5.45	7.18	30	16.60	16.30	16.90	4		
	JuDe	1	53.50	53.50	53.50	0	8.85	8.85	8.85	0	17.80	17.80	17.80	0		
	Subtotal	130														
	PsMe	89	16.55	7.50	42.00	59	4.62	2.40	10.20	40	9.20	4.40	13.50	34		
	PiAr	55	16.72	7.80	34.30	59	3.46	1.60	8.20	40	8.40	2.30	13.50	36		
	ArXa	43	18.48	7.50	82.40	63	5.51	2.00	9.10	45	7.54	3.50	12.00	37		
	QuTu	33	17.16	8.00	64.00	61	5.97	2.00	15.75	41	8.29	3.10	13.50	36		
	JuDe	36	17.81	8.00	31.50	60	3.83	1.90	6.90	41	5.45	2.00	12.00	37		
III	*PiAy*	15	16.44	7.70	24.10	61	4.25	2.50	6.10	40	7.57	4.30	11.30	35	1.64	5.15
	AbDu	21	17.10	9.60	22.00	60	5.33	3.45	7.50	41	11.01	7.50	13.50	36		
	QuSi	14	17.29	9.00	22.50	62	5.24	3.55	7.65	41	8.45	3.50	12.90	35		
	PiCh	11	16.72	8.70	31.60	34	4.58	2.65	6.30	28	10.16	7.50	13.40	30		
	PiDu	1	12.50	12.50	12.50	0	3.65	3.65	3.65	0	9.80	9.80	9.80	0		
	Subtotal	318														
	Total	460														

Psme = *Pseudotsuga menziesii* (Mirb.) Franco; *Qutu* = *Quercus tuberculata* Liebm; *AbDu* = *Abies durangensis* Martínez; *Piar* = *Pinus arizonica* Engelm.; *PiAy* = *Pinus ayacahuite* Ehrenb. ex Schltdl.; PiDu = *Pinus durangensis* Martínez*; QuSi* = *Quercus sideroxyla* Humb. & Bonpl.; *PiCh* = *Picea chihuahuana* Martínez; *Jude* = *Juniperus deppeana* Steud; *ArXa* = *Arbutus xalapensis* Kunth*.*

In stratum I, the trees showed an average crown diameter of 11.25 m with a minimum of 4.35 m and a maximum of 18.65 m; in stratum II the average was 6.46 m, with minimums of 1.93 m and maximums of 13.20 m and in stratum III it was 4.53 m, with minimums of 1.60 m and maximums of 15.75 m. The species with outstanding values in this variable were *Q. tuberculata* with an average of 14.43 m and *Abies durangensis* with 10.85 m (Table 5).

Diversity and richness of species. The diversity of species in the regeneration plant community through the Shannon Index (*H'*) was generally low; the highest value was verified in stratum III with 1.63, while for stratum I and II it was 0.05 and 0.16, respectively. Margalef (1972) mentions that the Shannon Index normally ranges from 1 to 5, with values less than 2 being interpreted as low diversity, 2 to 3.5 medium diversity, and greater than 3.5 as high diversity. Therefore, the forestry community studied has a low diversity. The number of effective species or true diversity (*D'*) for stratum I was 1.05, II 1.17 and III 5.10, meaning that stratum III has 4.3 times more diversity than stratum II and 4.8 than I (Table 4).

With the Margalef Index (D_{Mg}) in the plant regeneration community, D_{Mg} = 1.52 was determined, similar to the D_{Mg} value = 1.32 recorded by Villavicencio *et al.* (2012) in a temperate pine-oak forest of the *Sierra de Quila, Jalisco* and far superior to that of Méndez *et al.* (2014) who calculated a value of D_{Mg} = 0.76 in a pine-oak forest of the *Sierra de Guerrero*, Mexico. However, the wealth is lower than that found in the submontane scrubland by Canizales *et al.* (2009) who obtained a value of D_{Mg} = 6.34; Mora *et al.* (2013) estimated a D_{Mg} of 6.27 and for subdeciduous medium forest, Gutiérrez-Báez *et al.* (2012) of D_{Mg} = 15.23.

The mature plant community as well as the regeneration presented a low diversity based on the Shannon Index (*H'*), the highest value was presented in stratum III with *H'* = 1.64 while for stratum I and II it was *H'*= 0.12 and *H'* = 0.81, respectively. The number of effective species or true diversity (*D'*) for stratum I was *D'* = 1.13, for II it was *D'*= 2.26 and III *D'* = 5.15, which means that stratum III has 2.2 times more diversity than II and 4.5 than I (Table 5).

The Margalef Index (D_{Mg}) resulted in D_{Mg} = 1.52 (Table 5), which indicates a species richness similar to that obtained by Graciano *et al.* (2017) and González *et al.* (2018), who recorded D_{Mg} = 1.53 and D_{Mg} = 1.98 in temperate forests of the states of *Durango* and *Nuevo León*; otherwise, that of Hernández-Salas et al. (2013), because they calculated D_{Mg} = 1.04 and D_{Mg} = 0.90 in productive pine and oak forests in the state of *Chihuahua.*

Conclusions

The studied community has natural regeneration of most of its species despite having large trees that cause a closed canopy; *Pinus durangensis* and *Arbutus xalapensis* do not show it, which can be attributed to the shortage of mature individuals. Most of them were presented in stratum III, which suggests that the forest has a high capacity for recovery and replacement of mature trees, which leads to ecosystem conservation.

Based on abundance and defined vertical structure strata, the forest studied is a community dominated mainly by *Pseutotsuga menziesii* in all woodland strata, stratum I with less presence of *Abies durangensis* and *Quercus tuberculata*, while in II and III have associations with *P. arizonica, Q. tuberculata* and *A. xalapensis*. Three species with continuous vertical distribution (*P. menziesii, A. durangensis* and *Q. tuberculata*) were registered, these being the ones that dominate the upper canopy.

The study of new populations of *Pseudotsuga menziesii* such as this one, provides quantitative information for decision-making in favor of conservation, especially if it coexists with endemic and protective species (*Abies durangensis* and *Picea chihuahuana*).

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Samuel Alberto García García: study approach, field data collection, writing and correction of the manuscript; Eduardo Alanís Rodríguez: study approach, organization of work, data analysis, writing and correction of the manuscript; Oscar Alberto Aguirre Calderón and Eduardo Javier Treviño Garza: statistical analysis and correction of the manuscript; Gabriel Graciano Ávila: supervision of field data collection, statistical analysis and correction of the manuscript.

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