

Structure, composition and tree diversity in a temperate forest under management

Estructura, composición y diversidad arbórea en un bosque templado bajo manejo

MORA-SANTACRUZ, Antonio[†], ROMÁN-MIRANDA, María Leonor*, NUNGARAY-VILLALOBOS, Omar and GONZÁLEZ-CUEVA, Gerardo Alberto

Departamento de Producción Forestal, Centro Universitario de Ciencias Biológicas y Agropecuarias. Universidad de Guadalajara

ID 1st Author: *Antonio, Mora-Santacruz* / ORC ID: 0000-0002-6169-2077, Researcher ID Thomson: T-4708-2018, CVU CONACYT ID: 96712

ID 1st Coauthor: *María Leonor, Román-Miranda* / ORC ID: 0000-0002-9420-2150M, Researcher ID Thomson: T-4608-2018, CVU CONACYT ID: 264122

ID 2nd Coauthor: *Omar, Nungaray-Villalobos*

ID 3rd Coauthor: *Gerardo Alberto, González-Cueva* / ORC ID: 0000-0003-3231-674X, Researcher ID Thomson: T-4291-2018, CVU CONACYT ID: 16912

DOI: 10.35429/JESN.2019.15.5.29.35

Received April 26, 2019; Accepted June 30, 2019

Abstract

In order to study both diversity indices and structure of forests, which are an essential tool for decision-making in forest management, which show natural successional processes and effects for its management. So the objective of this study was to evaluate structure and diversity of arboreal species in a temperate forest of southern Jalisco state. Five permanent forestry research sites 50 x 50 (2,500 m²) were established, and a census of all tree species was carried out, with normal diameter greater than 7.5 cm. Each individual was measured: height and normal diameter, placing an aluminum plate for identification. We obtained the importance value index (IVI), indices of diversity, richness, and dasometric parameters. There were 17 species, 9 genera and 9 botanical families; the Fagaceae was dominant. *Pinus douglasiana* presented the highest IVI (57.93%); The Shannon index had a value of 2.0; the index of Margalef was 2.4; the forest has a density of 688 trees ha⁻¹, being the most abundant *Styrax ramirezii*; *Pinus herrerae* obtained the highest values in basal area and volume with 30.77 m² ha⁻¹ and 357,325 m³ ha⁻¹ respectively. The values of diversity are influenced by elements of the cloud forest

Dasometric parameters, Diversity índices and Permanent plots

Resumen

El conocimiento de los índices de diversidad y estructura de los bosques, son una herramienta esencial para la toma de decisiones en el manejo forestal, que muestran procesos sucesionales naturales y efectos por su manejo. Por lo que el objetivo del estudio fue evaluar estructura y diversidad de especies arbóreas en un bosque templado del sur de Jalisco. Se establecieron cinco sitios permanentes de muestreo de 50 x 50 m (2,500 m²), se realizó un censo de especies arbóreas con diámetro normal mayor a 7.5 cm, de cada individuo se midió altura total y diámetro normal, colocando una placa de aluminio para su identificación. Se obtuvo el índice de valor de importancia (IVI), índices de diversidad, riqueza y parámetros dasométricos. Se registraron 17 especies, 9 géneros y 9 familias botánicas; la Fagaceae fue dominante. *Pinus douglasiana* presentó el mayor IVI (57.93%); el índice de Shannon tuvo un valor de 2.0; el índice de Margalef fue de 2.4; el bosque presenta una densidad de 688 árboles ha⁻¹, siendo *Styrax ramirezii* la más abundante; *Pinus herrerae* obtuvo los mayores valores en área basal y volumen con 30.77 m² ha⁻¹ y 357.325 m³ ha⁻¹ respectivamente. Los valores de diversidad se ven influenciados por elementos del bosque mesófilo.

Índices de diversidad, Parámetros dasométricos y Sitios permanente

Citation: MORA-SANTACRUZ, Antonio, ROMÁN-MIRANDA, María Leonor, NUNGARAY-VILLALOBOS, Omar and GONZÁLEZ-CUEVA, Gerardo Alberto. Structure, composition and tree diversity in a temperate forest under management. Journal of Environmental Sciences and Natural Resources. 2019, 5-15: 29-35

* Correspondence to Author (email: maryleo7rom@gmail.com)

† Researcher contributing first author.

Introduction

Mexico is part of the mega diverse countries, with the largest area of primary forests in the world, the nation is located in the fourth place in species richness (SEMARNAT, 2011). It has a wooded area greater than 64.8 million hectares, of which 52% correspond to temperate forests (Challenger, 1998; CONAFOR, 2012; FAO, 2006).

Previously it was believed that forests were an inexhaustible source of resources, however, this concept has been restructuring as the loss of forest masses increases, which causes the decrease of biodiversity worldwide, which results in the temperature increase (Uribe, 2015). Forest management is a tool that allows to maintain forests and obtain goods and services that they offer.

The importance of knowing the biodiversity of ecosystems, through the indexes of diversity is fundamental in forest management, since silvicultural management practices modify or deteriorate the habitat. Changes in the structure and diversity of the forest can be generated by selective use (Corral et al., 2005).

The forests of the southeastern region of Jalisco are the most important timber in the state, these forests have been used for more than 80 years, applying various management regimes to obtain regular and irregular structures, dominating the latter with short selection. Considering the importance of forest management in this region, especially the Barranca del Calabozo ejido, five permanent forestry research sites were established, in order to assess the dynamics of the forest that allows decisions to be made within the framework of sustainable management. In this context, the objective of this research was: to evaluate the structure, composition and tree diversity in stands under management of temperate forests of southeastern Jalisco.

Methodology

The study was carried out in the El Malacate fraction of the Barranca del Calabozo ejido, in the municipality of Pihuamo, Jalisco. Geographically it is located between the extreme coordinates of 19° 20' 18.9" north latitude and 103° 15' 24.3" west longitude.

The climate according to the Köppen classification modified by García (1987), is of type C (w2) that corresponds to a temperate, sub humid climate with rains in summer; With an average annual temperature between 18 ° C and a rainfall of 1200 mm per year (INIFAP, 2012), the soils are of the chromic Luvisol type, with great moisture retention capacity, thick thickness, with a good amount of cation exchange. (FAO UNESCO, 1990); the vegetation is formed by pine-oak forests with fractions of mountain mesophilic forest, the altitude is 2300 m.

The dasometric information was obtained from five permanent 50 x 50 m (2,500 m²) forest research sites, based on the methodology recommended by Corral et al. (2009). A woodland census was performed, registering trees with normal diameter equal to or greater than 7.5 cm; total height, in addition to all the trees an aluminum plate was placed at the height of 1.30 m, with consecutive number for identification.

To determine the tree composition, the common name and scientific name of each individual was recorded. To estimate species richness, the Margalef index (DMg) was used and for Shannon-Wiener index (H'), using the formulas (Magurran, 2004).

$$D_{Mg} = \frac{S-1}{\ln N} \quad (1)$$

Where:

S= number of species present

ln= natural logarithm

N= total number of individuals summing all species

Shannon-Wiener index was estimated from the following expression:

$$H' = \sum p_i \ln p_i \quad (2)$$

$$p_i = \frac{n_i}{N} \quad (3)$$

Where:

p_i= Proportion of individuals of the species i with respect to the total number of individuals (ie the relative abundance of the species i)

ln= Natural logarithm

n_i= Number of individuals of the species i.

N= Total number of individuals.

To estimate the importance value index (IVI) proposed by Curtís and McIntosh (1951), it is defined by the equation:

$$\text{IVI} = \text{Relative abundance} + \text{Relative dominance} + \text{Relative frequency}$$

Where:

$$\text{Relative abundance} = \frac{\text{Absolute abundance for each species}}{\text{Absolute abundance of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Absolute basal area by species}}{\text{Absolute basal area of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Absolute frequency for each species}}{\text{Absolute frequency of all species}} \times 100$$

The dasometric parameters

Trees per hectare (density): number of trees registered at the sampling sites and inferred to the hectare. The basal area by species was determined with the following formula:

$$G = \frac{\pi * DN^2}{4}$$

Where:

G = Basal area (m^2).

π = (pi) The ratio between the circumference and the diameter of a circle.

DN = Normal diameter at height (1.30m)

To estimate the total volume per tree, of the genus Pinus and Quercus, the models generated for the Forest Management Unit (UMAFOR) 1404 "Cd Guzmán" were used, in the CONACYT-CONAFOR agreement (2013). For the species considered other leafy or other broadleaved species, the models used in the Comprehensive Management Program of the Atenquique Region (Table 1) were used.

Species	Model
<i>Pinus douglasiana</i>	$vtacc = 0.0000378 * d^{1.917183} * h^{0.826524} + 0.0000813 * d^2$
<i>Pinus devoniana</i>	$vtacc = 0.0000478 * d^{2.106443} * h^{0.800508} + 0.0001054 * d^2$
<i>Pinus herrerae</i>	$vtacc = 0.0000654 * d^{1.992084} * h^{0.841387} + 0.0000714 * d^2$
<i>Pinus oocarpa</i>	$vtacc = 0.0000538 * d^{2.0733857} * h^{0.7998558} + 0.0000895 * d^2$
<i>Quercus candicans</i>	$vtacc = 0.0000765 * d^{1.8181666} * h^{0.9334637} + 0.0002233 * d^2$
<i>Quercus crassifolia</i>	$vtacc = 0.0000337 * d^{1.9711755} * h^{0.0224766} + 0.0002726 * d^2$
<i>Quercus castanea</i>	$vtacc = 0.00006682 * d^{1.868929} * h^{0.91262} + 0.0003244 * d^2$
<i>Quercus rugosa</i>	$vtacc = 0.0000381 * d^{1.9415088} * h^{0.1018952} + 0.0002529 * d^2$
<i>Quercus obtusata</i>	$vtacc = 0.0000218 * d^{1.9324875} * h^{0.2333404} + 0.0002094 * d^2$
<i>Quercus laurina</i>	$vtacc = 0.0000381 * d^{1.9415088} * h^{0.1018952} + 0.0002529 * d^2$
<i>Styrax ramirezii</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$
<i>Arbutus xalapensis</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$
<i>Clethra lanata</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$
<i>Podocarpus matudae</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$
<i>Ternstroemia sp.</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$
<i>Crataegus mexicana</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$
<i>Carpinus caroliniana</i>	$Ln(vtacc) = -11.162 + 2.417212 * Ln(d) + 0.835947 * Ln(h)$

Tabla1 Mathematical models to estimate volumes per tree, where vtacc = total volume tree with bark, d = normal diameter and h = total height

Results and Discussion

Floristic composition

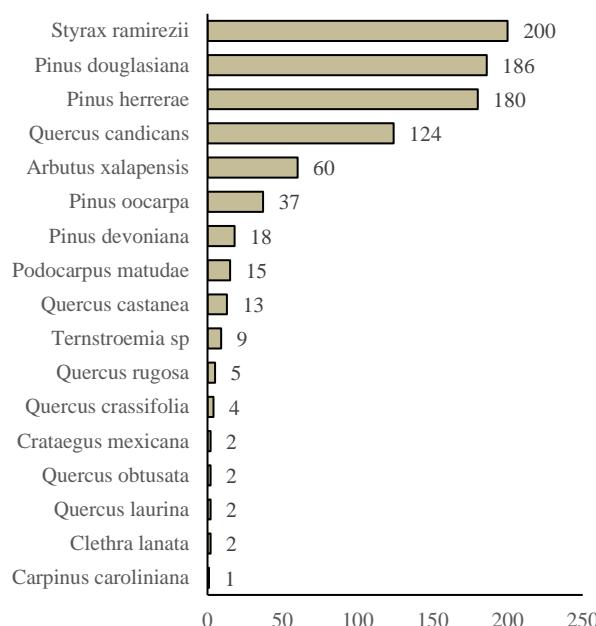
The floristic composition of the tree stratum is represented by pine-oak forests and a portion of mesophilic mountain forest. 17 species, 9 genera, 9 families and five orders were registered. The best represented families were: Fagaceae with six species, followed by the Pinaceae family with four species (Table 2).

Species	Family	Order
<i>Arbutus xalapensis Kunth</i>	Ericaceae	Ericales
<i>Carpinus caroliniana Walter</i>	Betulaceae	Fagales
<i>Clethra lanata M. Martens & Galeotti</i>	Clethraceae	Fagales
<i>Crataegus mexicana Loudon</i>	Rosaceae	Rosales
<i>Quercus candicans Née</i>	Fagaceae	Fagales
<i>Q. castanea Née</i>	Fagaceae	Fagales
<i>Q. crassifolia Bonpl.</i>	Fagaceae	Fagales
<i>Q. obtusa Bonpl.</i>	Fagaceae	Fagales
<i>Q. laurina Humb. Et Bonpl</i>	Fagaceae	Fagales
<i>Q. rugosa Née</i>	Fagaceae	Fagales
<i>Pinus devoniiana Lindl.</i>	Pinaceae	Pinales
<i>Pinus douglasiana Martínez</i>	Pinaceae	Pinales
<i>Pinus herrerae Martínez</i>	Pinaceae	Pinales
<i>Pinus oocarpa Schiede ex Schtdl.</i>	Pinaceae	Pinales
<i>Podocarpus matudae Lundell</i>	Podocarpaceae	Ericales
<i>Styrax ramirezii Greenm.</i>	Styracaceae	Ericales
<i>Ternstroemia sp.</i>	Pentaphylacaceae	Ericales

Table 2 Tree species present in the study area

Unlike what was reported by Graciano-Ávila et al. (2017), Those who studied an area of 2.50 ha, in a pine and pine-oak forest in the state of Durango, where they pointed to the Pinaceae family with a greater number of species (five), it should also be noted that although in our case it was a smaller sampled area (1.25 ha), a greater diversity of species was obtained with 17 against 13, represented in nine families against five, reported in the study cited and was even greater than that indicated by López-Hernández et al . (2017) in Puebla with only 11 species in five genera.

Figure 1 shows the distribution of trees by species; the total density was 860 individuals, distributed in 17 species; *Styrax ramirezii* (200 trees), *Pinus douglasiana* (186 trees), *P. herrerae* (180 trees) and *Quercus candicans* (124 trees) were the ones with the highest density, the rest (170 trees) complements the total. *Carpinus caroliniana* (1 tree) and *Podocarpus matudae* (15 trees), are listed within NOM-059-SEMARNAT-2010, threatened (A) and with special protection (Pr), respectively.

**Graphic 1** Número de árboles por especie

Diversity

The species richness index of Margalef (DMg) was 2.4, higher than that reported by Návar and González (2009) of 1.04, in Durango forests and by Hernández et al. (2013) in temperate forests of Chihuahua of 0.9. The Shannon-Wiener (H') diversity index was 2.0; This diversity value is greater than that reported by García et al (2012) in forests in the Sierra Madre Oriental of the state of Nuevo León, and by Hernández et al (2013), in temperate forests of Chihuahua with 0.34.

Importance Value Index

Abundance

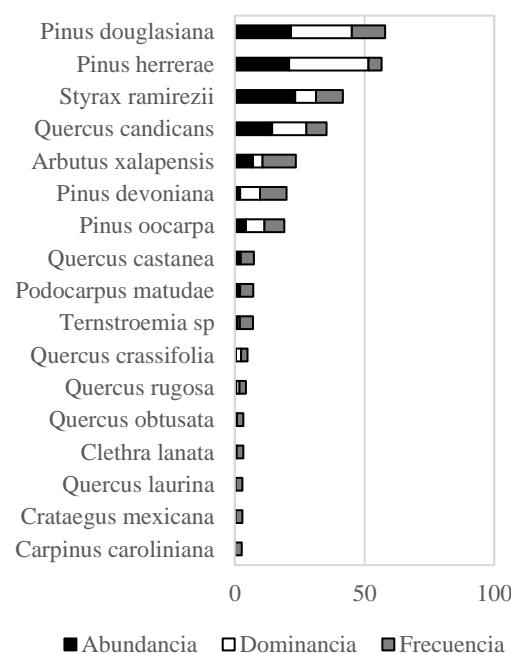
The most abundant species were: *Styrox ramirezii* with 200 trees, which represented 23.26% of the total; followed by *Pinus douglasiana* (186 trees), which represent 21.63% and *P. herrerae* (180 trees) with 20.93% of the total.

Dominance

The total basal area was 30.77 m², where the most dominant species were: *Pinus herrerae* (11.75 m²) representing 30.55% of the total species, followed by *P. douglasiana* (9.03) with 23.48%. The two species make up 43.03% of the total of 17 species found.

Frequency

The most frequent species are *Pinus douglasiana* and *Arbutus xalapensis* (they occur in all sampling sites) with a frequency of 12.82%, followed by *Styrox ramirezii* and *Pinus devoniana* with 10.26%, the other species have lower values. The species with the highest importance value index (IVI) was *P. douglasiana* (57.93%), *P. herrerae* (56.61%) and *Styrox ramirezii* (42.88%), were the most outstanding species having the highest values, the species more rare, with less value was *Carpinus caroliniana* with 0.90%. (Graphic 2, Table 3). Graciano-Avila et.al. (2013) report that *P. cooperi* (79.05%) and *P. durangensis* (70.89%) had the highest IVI values, these species were the most important in forests of the La Victoria de Durango ejido.

**Graphic 2** Importance Value Index (IVI)

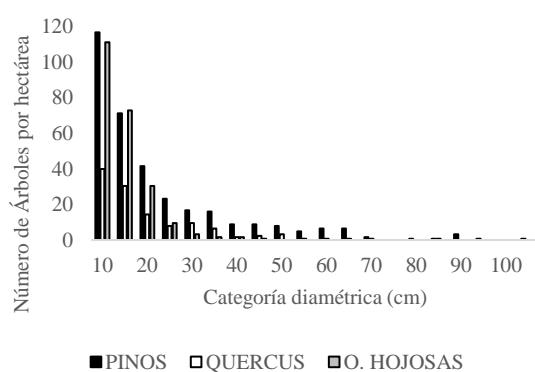
Species	Abundance		Dominance		Frequency		IVI
	Abs.	Rel (%)	Abs.	Rel (%)	Abs.	Rel (%)	
<i>Pinus douglasiana</i>	186	21.63	9.03	23.48	5	12.82	57.93
<i>Pinus herrerae</i>	180	20.93	11.75	30.55	2	5.13	56.61
<i>Styrox ramirezii</i>	200	23.26	3.11	8.09	4	10.26	42.88
<i>Quercus candicans</i>	124	14.42	5.08	13.21	3	7.69	39.17
<i>Arbutus xalapensis</i>	60	6.98	1.41	3.68	5	12.82	21.23
<i>Pinus devoniana</i>	18	2.09	2.91	7.57	4	10.26	18.31
<i>Pinus oocarpa</i>	37	4.3	2.75	7.15	3	7.69	18.18
<i>Quercus castanea</i>	13	1.51	0.29	0.76	2	5.13	7.08
<i>Podocarpus matudae</i>	15	1.74	0.11	0.28	2	5.13	1.53
<i>Ternstroemia sp</i>	9	1.05	0.34	0.87	2	5.13	1.50
<i>Quercus crassifolia</i>	4	0.47	0.74	1.91	2	5.13	7.08
<i>Quercus rugosa</i>	5	0.58	0.46	1.19	1	2.56	1.45
<i>Quercus obtusata</i>	2	0.23	0.21	0.54	1	2.56	1.11
<i>Clethra lanata</i>	2	0.23	0.19	0.48	1	2.56	1.95
<i>Quercus laurina</i>	2	0.23	0.05	0.13	1	2.56	0.98
<i>Crataegus mexicana</i>	2	0.23	0.03	0.08	1	2.56	0.96
<i>Carpinus caroliniana</i>	1	0.12	0.01	0.03	1	2.56	0.90
Total	860	100	38.47	100	39	100	300

Table 3 Abundance, dominance, frequency and Importance Value Index of the species (sorted in descending order according to their IVI)

Dasometric Parameters

Individuals by diametric category

Individuals by diametric category the horizontal structure shows an irregular, incoethane structure in the form of an inverted "J" (Liocourt curve). The largest number of individuals correspond to the smaller categories, between 10 and 15 cm in normal diameter, with few individuals larger than 70 cm. The group of other leaflets as a whole has smaller diameters, not larger than 40 DN, while the group of the genus Pinus showed the largest diameters with records of 90 to 105 cm DN (Graphic 3). Juarez et al. (2014) analyzed the silvicultural structure of a temperate forest in Tamaulipas, Mexico, reporting the largest number of trees in diametric categories between 10 and 20 cm of the *Quercus* and *Pinus* genera, similar to those obtained in the present study.



Graphic 3 Diameter distribution

Species	Arb/ha	AB/ha (m ²)	Vol/ha (m ³)	Altura media (m)	DN Medio (cm)
<i>Pinus devoniana</i>	14.4	2,3284	32,311	21.44	41.25
<i>Pinus douglasiana</i>	148.8	7,2266	81,342	15.47	20.58
<i>Pinus herrerae</i>	144.0	9,4016	141,680	16.10	21.58
<i>Pinus oocarpa</i>	29.6	2,1995	24,572	16.75	27.93
<i>Quercus candicans</i>	99.2	4,0653	41,412	12.08	19.19
<i>Quercus castanea</i>	10.4	0,2337	2,176	8.31	15.25
<i>Quercus crassifolia</i>	3.2	0,5888	4,895	12.13	47.81
<i>Quercus laurina</i>	1.6	0,0404	0,411	11.95	16.43
<i>Quercus obtusata</i>	1.6	0,1669	1,463	14.40	35.90
<i>Quercus rugosa</i>	4.0	0,3669	3,165	12.18	33.54
<i>Arbutus xalapensis</i>	48.0	1,1310	6,756	9.98	15.93
<i>Carpinus caroliniana</i>	0.8	0,0089	0,039	13.00	11.90
<i>Clethra lanata</i>	1.6	0,1480	1,285	17.40	33.05
<i>Crataegus mexicana</i>	1.6	0,0245	0,088	8.75	13.45
<i>Podocarpus matudae</i>	12.0	0,0858	0,269	9.25	9.44
<i>Styrax ramirezii</i>	160.0	2,4898	13,904	13.29	13.25
<i>Ternstroemia sp</i>	7.2	0,2692	1,557	12.40	19.06
Total	688.0	30,7754	357,325		

Table 4. Dasometric parameters

Trees per hectare

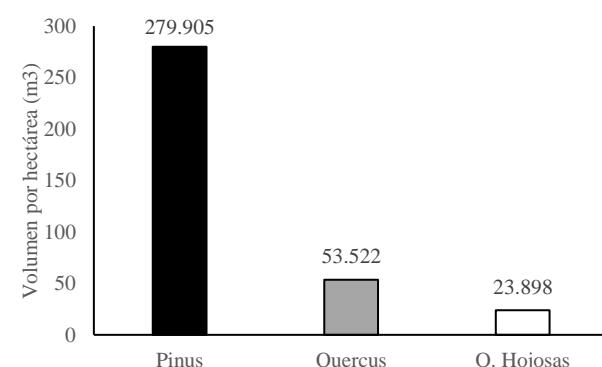
The density expressed in number of trees per hectare was 688; the species that presented the greatest amount were: *Styrax ramirezii*, *Pinus douglasiana* and *P. herrerae* with 160, 148.8 and 144 ha⁻¹ trees, the rest (235.2 ha⁻¹ trees) are made up of the other 13 species. The density of 688 ha⁻¹ trees can be considered high, compared to that obtained by Martínez, et al (2012). In permanent research sites "El Polo" Madera, in Chihuahua, where they report values from 348,404 to 1,272 ha⁻¹ trees, the latter mostly corresponds to young trees.

Basal area per hectare

In the case of the total basal area per hectare, it was 30,775 m²; the highest values corresponded to the genus *Pinus* with 21,156 m² ha⁻¹, followed by the genus *Quercus* with 5,462 m² ha⁻¹ and other leafy with 4,157 m² ha⁻¹. The values of the basal area are similar to those reported by Martínez, et al. (2012), where it reports values from 22.1 to 30.6 m² ha⁻¹.

Volume per hectare

For the determination of the volume, the absolute values of the five sampling sites were used and subsequently the inference was made for one hectare. The total volume per hectare grouping all trees was 357,325 m³ (total tree volume); the *Pinus* had the highest volumes with 279,905 m³ ha⁻¹, followed by the genus *Quercus* with 53,522 m³ ha⁻¹ and the other leafy with 23,898 m³ ha⁻¹ (Graphic 4)



Graphic 4 Volume per hectare by gender and group of species

Martínez, et al. (2012), reported volumes from 88.6 to 261.7 m³ ha⁻¹ and Reyes et al. (2016) in Durango forests, they indicated total real stocks, inferred to the hectare of up to 198,625 m³.

In both cases the volumes are lower than those obtained in the present study, which indicates that the stands where the sampling sites were located have good site quality, that is, they are areas with good timber production.

Conclusions

The tree floristic composition is represented by 17 species, 9 genera, grouped into 9 families and 5 orders. The best represented botanical family was Fagaceae.

The specific wealth of the studied community was 17 species, with a Margalef index (D_{mg}) of 2.4; in relation to the value of diversity, the Shannon-Wiener index (H') was 2.0. Apparently, the diversity values were influenced by elements of the mountain mesophilic forest.

The importance value index (IVI) indicates that *P. douglasiana* (57.93%), *P. herrerae* (56.61%) and *Styrax ramirezii* (42.88%), were the most outstanding species having the highest values.

The volume per hectare of all species was 357,325 m³ ha⁻¹; the highest volume corresponded to the genus *Pinus* (279,905 m³ ha⁻¹), followed by the genus *Quercus* (53,522 m³ ha⁻¹) and with the lowest volumes for the other leafy (23,898 m³ ha⁻¹). *P. herrerae*, was the species with the highest volume with 141,680 m³ ha⁻¹

The stands where the sampling sites were located presented a good site quality, that is, they are areas with good timber production.

Acknowledgments

To the University of Guadalajara and to the 2016 Academic Bodies Strengthening Program (IDCA 23528). To the ejido authorities, to the forestry consultancy “Asesores Forestales de Occidente” S. A., especially to the director Ing. Aldo Rivera and the Association of Foresters of the Sierra del Tigre, El Halo and the Volcanoes.

References

- Challenger, A. 1998. Utilización y conservación de los ecosistemas terrestres de México, pasado, presente y futuro de México, CONABIO, Instituto de Biología, UNAM, Agrupación Sierra Madre, S.C.P., 847 p.
- Clifford, H.T. y Stephenson, W. 1975. An introduction to numerical classification. Academic Press, London. 350 pp.
- CONAFOR (Comisión Nacional Forestal). 2012. Inventario Nacional Forestal y de Suelos, informe del 2004-2009 (1a. ed). Zapopan, Jalisco, México: CONAFOR. 22 p.
- CONAFOR-CONACYT. 2013. SiBiFor Biblioteca digital del sistema biométrico para la planeación del manejo forestal sustentable de los ecosistemas con potencial maderable en México. <http://fcfposgrado.ujed.mx/sibifor/inicio/buscar.php?a=volumen%20total0arbol#>,
- Corral-Rivas, J. J.; Aguirre, O.; Jiménez, J. y Corral, S. 2005. Un análisis del efecto del aprovechamiento forestal sobre la diversidad estructural en el Bosque Mesófilo de Montaña “El Cielo”, Tamaulipas, México. Investigaciones Agrarias: Sistemas de Recursos Forestales, 14 (2), 217-228.
- Corral-Rivas, J. J.; Vargas, L.B.; Wehekell, C.; Aguirre, C. O.; Álvarez, G. J. y Rojo, A.A. 2009. Guía para el Establecimiento de Sitios de Investigación Forestal y de Suelos en Bosques del Estado de Durango. Editorial UJED. Durango. 81p.
- Curtis J.y McIntosh R. 1951. An upland forest continuum in the pariré-forest border region of Wisconsin. Ecology 32: 476-496 p.
- FAO. 2006. Tendencias y perspectivas del sector forestal en América Latina y el Caribe. Roma 60: 100 p.
- FAO-UNESCO. 1990. Mapa mundial de suelos. Informes sobre recursos mundiales de suelos. Organización de las Naciones Unidas para la Agricultura y la Alimentación. Roma. 60: 142 p.

García., E. 1987. Modificaciones al sistema de clasificación climática de Köppen. Instituto de Geografía, UNAM. México. 246 p.

González E. S.; González, E. M. y Cortez O. A. 1993. Vegetación de la reserva de la biosfera "La Michilia", Durango, México. Acta Botánica Mexicana, 22, 1-104.

Graciano, A.G.; Aguirre, C.O.A.; Alanis R.E. y Lujan S.J.E 2017. Composición, estructura y diversidad de especies arbóreas en un bosque templado del noroeste de México. Ecosistemas y Recursos Agropecuarios, 4(12), 535-542. doi: 10.19136/era. a4n12.1114

Hernández, J.; Aguirre, O.; Alanís, E.; Jiménez, J. y González, M. A. 2013. Efecto del manejo forestal en la diversidad y composición arbórea de un bosque templado del noroeste de México. Revista Chapingo serie Ciencias Forestales y del Ambiente, 19 (3), 189-199. <http://www.redalyc.org/pdf/617/61750015003.pdf>

INIFAP (Instituto Nacional de Investigaciones forestales, Agrícolas y Pecuarias). 2012. Estadísticas Climáticas Normales del Estado de Jalisco. Centro de Investigación Regional Pacífico Centro. Libro Técnico No. 2. Jalisco. 132 p.

Juárez, S.M.; Domínguez C.P. y Návar CH.J. 2014. Análisis de la estructura silvícola en bosques de la Sierra de San Carlos, Tamaulipas, México. Foresta Veracruzana 16(1):25-34.

López, H. J.A.; Aguirre, C.O.A.; Alanís, R. E; Monárez, G. J.C.; González, T.M. y Jiménez, P. J. (2017). Composición y diversidad de especies forestales en bosques templados de Puebla, México. Madera y Bosques, 23(1), 39-51. doi:10.21829/myb.2017.2311518

Magurran, A.E.2004. Measuring biological diversity. Blackwell. Cambridge, USA. 256 p <http://silvicultoresdejalisco.org.mx/wp-content/uploads/2017/05/Memoria-del-Estudio-Regional-Forestal-1404.pdf>

Martínez, S.M.; Pérez, S.G.; Gádara, V.G.A.; Hernández, L.A., González, M.C.J.; Armendáriz, O.R.; Chacón, S.M.J.; Moreno, G.A. y Meléndez, O.M.C. 2012. Estado actual del conocimiento de sitios permanentes de investigación silvícola (SPIS) en el estado de Chihuahua. SAGARPA-INIFAP. 125 p.<https://brioagropecuario.com/index.php/2017/06/30/estado-actual-del-conocimiento-de-sitios-permanentes-de-investigacion-silvicola-spis-en-el-estado-de-chihuahua/>

Návar, C. J.J., y González, G. S. 2009. Diversidad, estructura y productividad de bosques templados de Durango, México. Polibotanica, 28, 71-87. Obtenido de <http://www.scielo.org.mx/pdf/polib/n27/n27a5.pdf>

Reyes, M. J. L.; Bretado, V. J. L.; Loera, G. M. H.; Simental, C.A.J.; Castillo, O. I.; Moreno, S. R.; Antuna, M. E. y Soto, M. A. 2016). Evaluación de existencias volumétricas conforme a la legislación forestal vigente en México. AGROFAZ, 16 (1) 77-83.

SEMARNAT (Secretaría de Medio Ambiente y Recursos Naturales). 2011. Anuario Estadístico de la Producción Forestal. 228 p.

URIBE, E. 2015. El cambio climático y sus efectos en la biodiversidad en América Latina. Santiago de Chile. Comisión Económica para América Latina y el Caribe (CEPAL). 84p.