Revista Mexicana de Ciencias Forestales Vol. 14 (77)
Mayo - Junio (2023)

DOI: 10.29298/rmcf.v14i77.1318

Research article

Dinámica estructural y área basal de bosques mixtos en dos áreas naturales protegidas de Jalisco

Structural dynamics and basimetric area of mixed forests in two protected natural areas of Jalisco State

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Fecha de recepción/Reception date: 26 de octubre de 2022
Fecha de aceptación/Acceptance date: 15 de marzo del 2023

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Abstract

The Flora and Fauna Protection Areas *Bosque La Primavera* (BLP) and *Sierra de Quila* (SQ) in the state of *Jalisco*, are frequently affected by anthropic factors that modify their spatial distribution and tree growth. The objective of this study was to compare basal area, stem density and annual periodic increment in basimetric area for type of vegetation in both natural protected areas in the 2005-2020 period. In both areas, were measured the normal diameter (*nd*) and total height of trees in 88 sampling plots, established in 2005 and remeasured in 2013 and 2020. The mean basimetric area of BLP was 13, 12 and 16 m^2 ha^{-1} (2005, 2013 and 2020, respectively), with a mean increment of 0.21 m^2 ha^{-1} year^{-1}; while in SQ it was 16, 18 and 20 m^2 ha^{-1} (for 2005, 2013 and 2020, respectively) with an increment of 0.27 m^2 ha^{-1} year^{-1}. The most representative diameter categories for the dominant species were 10 to 15 cm of *nd* for *Quercus magnoliifolia* in BLP, *Quercus resinosa* and *Pinus douglasian*a in SQ, and 20 to 25 cm of *nd* for *Pinus oocarpa* in BLP. Stem density, basal area and the annual periodic increment was higher in SQ than in BLP, attributable to the forest fires that affected BLP every year, despite that in SQ sanitation fellings were made to control bark beetle outbreaks and mistletoe infestations.

Key words: *Bosque La Primavera*, oak–pine forest, diameter categories, stem density, periodic annual increment, *Sierra de Quila*.

Resumen

Las áreas de protección de flora y fauna Bosque La Primavera (BLP) y Sierra de Quila (SQ) del estado de Jalisco son afectadas con frecuencia por factores antrópicos que modifican la distribución espacial y crecimiento de las especies arbóreas. El objetivo del presente estudio fue comparar el área basal, la densidad de árboles y el incremento periódico anual en área basal por tipo de vegetación en ambas áreas naturales protegidas durante el periodo 2005-2020. En las dos áreas, se midieron el diámetro normal (*dn*) y la altura total de los árboles en 88 sitios de muestreo, establecidos en 2005 y remedidos en 2013 y 2020. El área basal promedio del BLP fue de 13, 12 y 16 m^2 ha^{-1} para 2005, 2013 y 2020, respectivamente, con un incremento promedio de 0.21 m^2 ha^{-1} $año^{-1}$; mientras que en SQ fue de 16, 18 y 20 m^2 ha^{-1} para 2005, 2013 y 2020, con un incremento promedio de 0.27 m^2 ha^{-1} $año^{-1}$. Las categorías diamétricas más representativas para las especies dominantes fueron 10 a 15 cm de *dn* para *Quercus magnoliifolia* en BLP, *Quercus resinosa* y *Pinus douglasiana* en SQ, y 20 a 25 cm de *dn* para *Pinus oocarpa* en BLP. La densidad, el área basal y el incremento periódico anual en área basal fueron mayores en SQ, atribuible a los incendios que afectan cada año al BLP, a pesar de que en SQ se hicieron cortas de saneamiento por ataque de plagas e infestaciones por muérdago.

Palabras clave: Bosque La Primavera, bosques de encino-pino, categorías diamétricas, densidad, incremento periódico anual, Sierra de Quila.

Introduction

Protected Natural Areas (ANP, for its acronym in Spanish) frequently have land tenure problems (González *et al.*, 2014), lack of resources and invasion (Maldonado *et al.*, 2020). In addition, they do not have management programs or they are not applied (Maldonado *et al.*, 2020). This has caused the risk of disturbance factors such as droughts, diseases and pests, to increase the vulnerability of wooded areas to those caused by man such as fires and land use change (González *et al.*, 2014).

In the state of *Jalisco*, the *Bosque La Primavera* (BLP, for its acronym in Spanish) Flora and Fauna Protection Area (APFF, for its acronym in Spanish) provides environmental services such as aquifer recharge, carbon capture and recreation from its proximity to the *Guadalajara* Metropolitan Area (ZMG, for its acronym in Spanish) (Balderas and Lovett, 2013). In this APFF, there is the forest management program published in the Official Gazette of the Federation in 1984, however, only protection activities are carried out (Álvarez, 2016).

On the other hand, the *Sierra de Quila* (SQ, for its acronym in Spanish) APFF is located 100 km from the ZMG. Despite having been decreed in 1982, it still does not have a published management program up to now, so only protection activities are carried out (Conanp, 2022). In addition, the impact of natural and anthropic disturbances on the forest communities of both APFFs is quantitatively unknown.

One way to assess the impact of natural and anthropic disturbances on forests is through structural and growth analysis of tree stands using quantitative (Aguirre *et al.*, 2003) and dynamic analysis of changes in parameters such as basimetric area (*AB*) and the density of trees.

More than 208 thousand people attend the BLP annually according to the visitor registry of the *Bosque La Primavera* Decentralized Public Organization (OPD) for the year 2021, who carry out recreational activities such as camping, cycling and hiking. In the case of SQ, the annual visitors are around 7 thousand (OPD *Sierra de Quila* visitor record for the year 2021) and recreational activities are also carried out.

Another factor that distinguishes these two APFFs is land tenure, since while in SQ there are eight *ejidos*, one indigenous community and 10 small properties, in BLP 50 % of the area belongs to small owners who mostly own fenced off their properties (Álvarez, 2016).

This suggests a differential human pressure in both APFF. Although both in BLP and in SQ, human activity generates contamination of the riverbeds, scattered garbage, and damage to the vegetation (Álvarez, 2016), the deterioration can be more severe in BLP, where the influx of visitors is greater and shorter he distance to the urban area.

Therefore, the objective of this work was to compare the basimetric area, tree density and the increase in the basimetric area by type of vegetation in both natural protected areas in the 2005-2020 period under the following hypothesis: The proximity to the ZMG of the *Bosque La Primavera* APFF causes a greater negative effect on the structure and development of the trees compared to the *Sierra de Quila* APFF, which presents less anthropic pressure.

Materials and Methods

Study area

Field work was carried out in *Bosque La Primavera* (BLP) and *Sierra de Quila* (SQ) Flora and Fauna Protection Areas (APFF) in the state of *Jalisco*. BLP is located in the *Sierra La Primavera*, west of the *Guadalajara* city metropolitan area (Figure 1). It was decreed on March 6, 1980 with 30 500 ha, between 20º32' to 20º44' N and 103º28' to 103º42' W. Its altitudinal range is 1 400 to 2 200 m, in *Tala*, *Zapopan* and *Tlajomulco* municipalities, *Jalisco*. The predominant climate is temperate sub-humid and semi-warm sub-humid (García, 2004). The average annual precipitation fluctuates between 800 and 1 000 mm, and the average annual temperature is 20 °C. The predominant type of vegetation is mixed pine-oak or oak-pine forests, although there are also areas of gallery forest and low deciduous forest (Gallegos *et al.*, 2014).

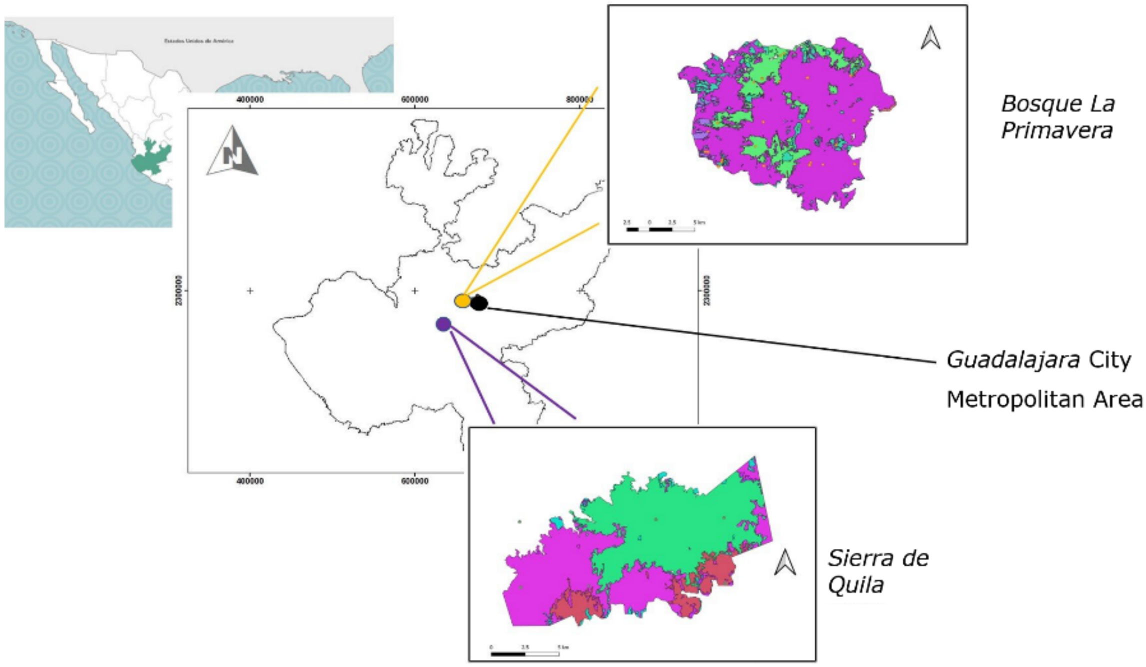


Figure 1. Location of *Bosque La Primavera* and *Sierra de Quila* Flora and Fauna Protection Areas.

The *Sierra de Quila* APFF was decreed on August 4th, 1982 with 15 192 hectares in *Tecolotlán*, *Tenamaxtlán*, *San Martín Hidalgo* and *Cocula* municipalities, *Jalisco* (Figure 1). It is located between 20º14' to 20º21' N and 103º57' to 104º07' W. The altitude ranges between 1 350 and 2 560 m. The climate is humid temperate, with average annual temperature between 12 and 18 °C; average annual rainfall is 900 mm. The types of vegetation reported are mainly oak-pine forest, oak forest, gallery forest and low deciduous forest (Villavicencio *et al*., 2012).

In both APFF, according to González-Abraham *et al*. (2015) the vegetation cover is in good environmental conditions. The zoning of the BLP according to the forest management program published in the *Diario Oficial de la Federación* (DOF, for its acronym in Spanish) (Official Gazette of the Federation) (Semarnat, 2001) is agroecosystems, sustainable use of natural resources, special use, protection, recovery, public use and restricted use while in SQ it is sustainable use of ecosystems, preservation, public use and recovery, however, the management program is not published in the DOF.

Field data

The BLP used information from 37 permanent sites the 400 m^2 established for National Forest and Soil Inventory (Infys, for its acronym in Spanish), whose first measurement was carried out in 2005, and the second in 2013 (Conafor, 2019). In addition, data from 20 permanent sites 1000 m^2 established in 2005 were used to define indicators for BLP restoration after fire. In the SQ, the information was collected in 31 permanent sites established for the Infys, where the first and second measurements were made in the same years previously mentioned.
A stratified sampling design was used. The types of vegetation were the strata oak forest (OF), pine forest (PF), mixed pine-oak forest (MPOF), mixed oak-pine forest (MOPF) and seasonaliy dry tropical forest (SDTF). All sites were remeasured in 2020.

The vegetation types considered in this study were defined based on the basal area calculated from the 2020 inventory data, also using the Rzedowski (2006) classification of vegetation types and the Lamprecht mixing ratio (Alvis, 2009).

For the collection of field information in 2020, the center was located with a Garmín eTrex 10 GPS and the site was delimited according to the surface. At each site, the normal diameter (*dn*, for its acronym in Spanish) (1.30 m above the soil surface) was measured with a 283D Forestry Suppliers cloth diametric tape, and the total height with a 360PC/360R Suunto tandem clinometer of all individuals with *dn*≥7 cm. With the *dn* data, the individual basimetric area (*BA*) was calculated.

Sampling sites

From the field data, the types of vegetation that are mostly shared by both APFFs were determined. In each type of vegetation, the number of sampling sites was different (Table 1), since the Infys conglomerates were based on the total area.

Table 1. Permanent sites by types of vegetation.

Type of vegetation	BLP sites	SQ sites
Oak forest (OF)	25	11
Pine forest (PF)	12	
Mixed oak-pine forest (MOPF)	7	7
Mixed pine-oak forest (MPOF)	8	6
Seasonaliy dry tropical forest (SDTF)	5	7
Total	57	31
Total area	30 500 ha	15 192 ha

No natural areas with forests dominated by pine species were found in the SQ APFF, which coincides with what was recorded by Villavicencio *et al.* (2012) and Flores *et al.* (2013).

Tree vegetation structure

To analyze the horizontal structure, frequency histograms were used in which the diameter category was assigned to each 5 cm of normal diameter for the tree species of each APFF.

Increase in basimetric area

Forest growth for each APFF was determined by considering the annual periodic increase (*IPA*, for its acronym in Spanish) in basimetric area as an indicator. From the remeasured data of the trees in the years 2005, 2013 and 2020, it was determined as the difference of the average estimate per hectare in the year 2020 minus the average of the reference year (2005 and 2013) divided by the number of years in the period by type of vegetation.

Data analysis

With the field data, the average per site, hectare and type of vegetation was obtained. The Shapiro-Wilks (Flores y Flores, 2021) normality test and the Levene variance homogeneity test (Bisquerra, 1987) were applied.

Using a mixed linear model under the repeated measures approach, the relationship between the dependent variables basimetric area, tree density and periodic annual increase in basimetric area was established, with the factors year of measurement, natural protected area and type of vegetation. Since in some cases the sampling sites are contained in a conglomerate, the use of mixed linear models with random intercept was decided. The structure of the model was:

$$Y_{iJ} = (b_0 + \alpha_1) + b_1 x_{1ki} + \cdots + b_n x_{nki} + e_{ij^k} \quad (1)$$

Where:

Y_{iJk} = Response variable, basimetric area, tree density, *IPA* in basimetric area

$b_0 + b_1 x_{1ki} + \cdots + b_n x_{nki}$ = Fixed part

$\alpha_1 + \ eijkl$ = Random factor

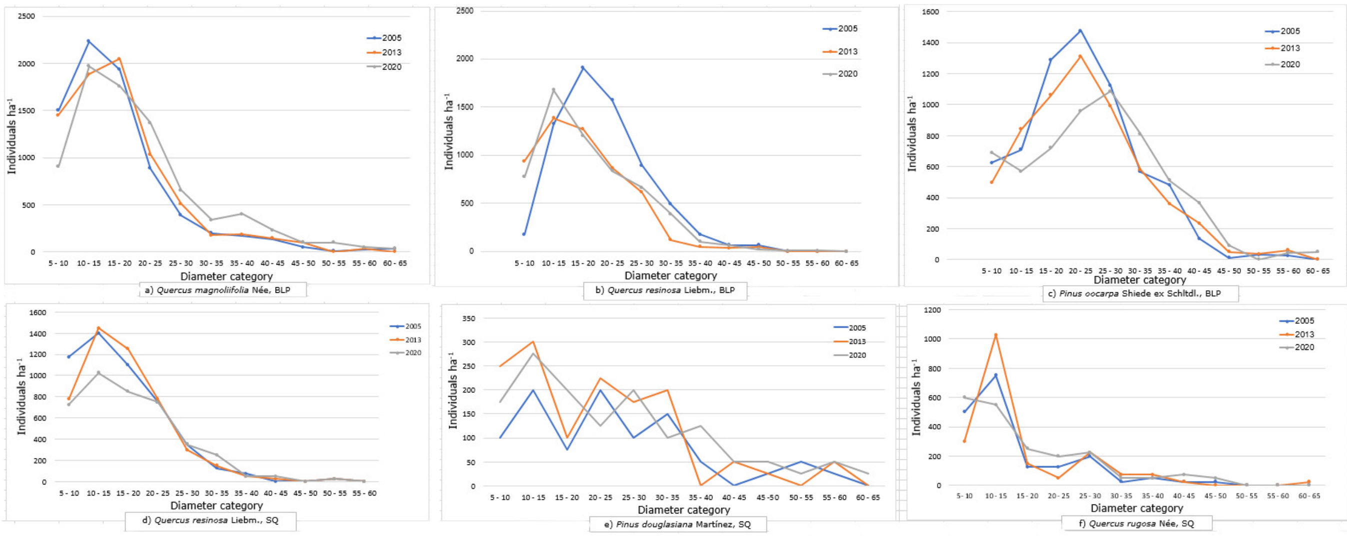
Analyzes were performed with SIGMA PLOT software 12.0 version (Systat Software Inc., 2012) and R software 4.1.1 version (R Core Team, 2020).

Results

Diametric structure

In BLP, the species with the largest basimetric area were *Quercus magnoliifolia* Née, *Q. resinosa* Liebm. and *Pinus oocarpa* Schiede ex Schltdl., while for SQ were *Q. resinosa*, *Q. rugosa* Née and *P. douglasiana* Martínez. Values up to 60 cm *dn* are recorded for all species, except for *P. oocarpa* and *P. douglasiana* with individuals up to 80 cm *dn*.

Quercus magnoliifolia and *Q. resinosa* in BLP, as well as *Q. rugosa* and *Q. resinosa* in SQ showed an inverted J-shaped diametric structure; the 10-15 cm diameter category gathered the largest number of individuals (Figure 2a, b, d, f).



a) *Quercus magnolifolia* Née, b) *Q. resinosa* Liebm. and c) *Pinus oocarpa* Schiede ex Schltdl. in *Bosque La Primavera*; d) *Q. resinosa*, e) *P. douglasiana* Martínez and f) *Q. rugosa* Née in *Sierra de Quila*.

Figure 2. Number of trees by diameter category for the species indicated in the two APFF.

In the case of *P. oocarpa* in BLP, the diameter category with the most individuals went from 10-15 cm in the years 2005 and 2013 to the 25-30 cm class in 2020 (Figure 2c). This trend coincided with a decrease in the number of individuals of the diameter category 10-15 from 1 310 individuals ha^{-1} in 2013 to 960 individuals ha^{-1} in 2020. *P. douglasiana* in SQ had a dispersed structure due to the fact that there is a decrease of individuals for the diameter categories 15-20, 25-30 and 30-35 cm *dn* in the different periods (Figure 2e).

Generalized mixed linear models

The coefficients of the models with random intercept for the variables basimetric area, tree density and periodic increase in basimetric area are shown in Table 2. Most of the estimated parameters are significant ($p \leq 0.05$) for tree density. In contrast, only half of the parameters were significant for basimetric area and *IPA*.

Table 2. Estimated parameters for the dependent variables tree density, basimetric area and *IPA* in basimetric area.

Parameter	Tree density	Basimetric	*IPA* in

		area	**basimetric area**
Intercept	526.7 (55.3)**	15.3 (1.4)**	0.10 (0.10)
Year	0.09 (1.5)	0.26 (0.04)**	0.05 (0.01)**
ANP	152.9 (71.1)*	6.5 (1.8)**	-0.03 (0.1)
TV MOPF	16.4 (96.4)	-2.4 (2.4)	0.06 (0.16)
TV MPOF	254.6 (85.7)**	-2.9 (2.2)	0.08 (0.14)
TV PF	-281.1 (101.9)**	0.69 (2.6)	-0.005 (0.16)
TV SDTF	-349.9 (101.1)**	-14.8 (2.5)**	-0.37 (0.16)*
Standard deviation	286.62	7.17	0.00003
Residuals	142.65	3.70	0.65

ANP = Protected Natural Area; TV MOPF = Mixed oak-pine forest type of vegetation; TV MPOF = Mixed pine-oak forest type of vegetation; TV PF = Pine forest type of vegetation; TV SDTF = Seasonaliy dry tropical forest type of vegetation; *IPA* = Annual Periodic Increase. *significance $\alpha<0.05$, ** significance $\alpha< 0.01$.

Tree density

In general terms, tree density was higher in SQ than in BLP throughout the study period. Between periods, the OF and PF of the BLP kept their density constant, since they did not show significant differences between years, which did occur in the MOPF and MPOF, which registered a decrease in density (Table 3).

Table 3. Average density by type of vegetation per sampling year in the *Bosque La Primavera* (BLP) and in *Sierra de Quila* (SQ).

Type of vegetation	Year 2005		Year 2013		Year 2020		Average per type of vegetation	
	Trees ha^{-1}±Standard Error							
	BLP	SQ	BLP	SQ	BLP	SQ	BLP	SQ
Oak forest	569±86a	625±91	568±83	579±87	613±108	490±111	583	565
Pine forest	247±38		250±38		243±51		247	
Mixed oak-pine forest	558±143	788±175	389±97	888±145	468±95	963±143	471	879
Mixed pine-oak forest	241±80	378±30	201±72	434±39	201±69	522±58	214	445
Seasonaliy dry tropical forest	64±12	450±12	34±5	432±10	132±43	250±23	77	377
General average	336	560	288	583	331	556		

There are no significant differences in density throughout the study period. A high variability was detected in this criterion in the two APFF, since there are significant differences between them (p<0.034) and between the types of vegetation with the exception of the MOPF (Table 3).

Increase in *BA*

BA increased from 2005 to 2020 in both BLP and SQ. Such increment is greater in SQ (p<0.001) except for the MOPF in 2005, where it is greater in BLP (Table 4).

Table 4. Average basimetric area (m^2 ha^{-1}) per type of vegetation and measurement years in *Bosque La Primavera* (BLP) and *Sierra de Quila* (SQ).

Type of vegetation	**Year 2005**		**Year 2013**		**Year 2020**		**Average**	
	Basimetric area m² ha⁻¹±Standard Error							
	BLP	**SQ**	**BLP**	**SQ**	**BLP**	**SQ**	**BLP**	**SQ**
Oak forest	14.6±2	24.9±2	15.2±2	25.1±3	20.5±2	24.5±3	17	25
Pine forest	16.2±3	-	17.1±3	-	20.3±4	-	18	
Mixed oak-pine forest	18.5±3	11.9±2	13.9±3	17.3±1	19.8±3	21.2±2	17	17
Mixed pine-oak forest	13.7±2	17.5±3	13.3±2	19.9±2	15.6±2	25.8±4	14	21
Seasonaliy dry tropical forest	2.2±1	8.5±2	2.0±1	8.2±2	4.2±1	7.3±1	3	8
General average	13	16	12	18	16	20		

BA increased from 2005 to 2020, and significant differences were detected between periods ($p<0.000$). While between types of vegetation there were significant differences in SDTF ($p<0.000$), which registers *BA* losses in 2020 in SQ, but not for the rest of the types of vegetation.

BA in SQ increased in the same period in all types of vegetation, with the exception of OF and SDTF that had a decrease of 0.60 and 0.90 m^2 ha^{-1}, respectively (Table 4).

BA in BLP went from 13 to 16 m^2 ha^{-1}, with an increase in the 15-year period of 3 m^2 ha^{-1}, while in SQ, it increased from 16 to 20 m^2 ha^{-1}, that is, 4 m^2 ha^{-1}.

The average increase in *BA* in the years considered is greater in SQ than in BLP, which is a significant difference ($p<0.000$); however, from 2013 to 2020, it is higher in BLP than in SQ (Table 5).

Table 5. Increase in basimetric area in the 2005 to 2020 period by type of vegetation in *Bosque La Primavera* (BLP) and *Sierra de Quila* (SQ) Flora and Fauna Protection Areas.

Type of	**Increase in basimetric**	**Increase in basimetric**	**Increase in basimetric**

vegetation	area 2005-2013		area 2013-2020		area 2005-2020	
	Basimetric area m^2 ha^{-1} year^{-1}+Standard Error					
	BLP	SQ	BLP	SQ	BLP	SQ
Oak forest	0.07$\pm$0.1	0.02$\pm$0.1	0.74$\pm$0.2	-0.07$\pm$2	0.39$\pm$0.1	-0.02$\pm$2
Pine forest	0.11$\pm$0.2		0.46$\pm$0.3		0.27$\pm$0.1	
Mixed oak-pine forest	-0.57$\pm$0.2	0.91$\pm$2	0.85$\pm$3	0.48$\pm$1	0.12$\pm$2	0.68$\pm$1
Mixed pine-oak forest	-0.04$\pm$0.1	0.40$\pm$0.2	0.32$\pm$0.1	0.74$\pm$0.2	0.13+0.1	0.59+0.1
Seasonaliy dry tropical forest	-0.03$\pm$0.04	-0.04$\pm$0.2	0.32$\pm$0.1	-0.51$\pm$0.3	0.13$\pm$0.04	-0.16$\pm$0.1
General average	-0.09	0.32	0.54	0.16	0.21	0.27

When the increase in *BA* by type of vegetation is analyzed, the periodic annual increase in basimetric area (*IPA*) is greater in BLP than SQ for OF and SDTF in the periods analyzed, but in mixed forests it is greater in SQ than in BLP (Table 5). In both APFF there are years in which there is a loss of *BA*, the most evident of which is from 2005 to 2013 (Table 5).

IPA in BLP went from having a negative trend in the 2005 to 2013 period to 0.54 m^2 ha^{-1} year^{-1} from 2013 to 2020, which is a significant growth of the forest mass (p<0.001). There is evidence that in BLP the *IPA* was continuous throughout the study times. In contrast, in SQ *IPA* decreased between 2005 and 2020, except for the BMPE. However, it is noteworthy that in the SBC, *IPA* is negative throughout the time of interest (Table 5). When comparing *IPA* between types of vegetation in each APFF, no significant differences were recorded between periods (Table 1).

Discussion

Diametric structure

Quercus resinosa, *Q. magnoliifolia*, *Q. rugosa* and *Pinus oocarpa* showed an inverted J diametric structure in both APFF, which in a way indicates that the tree community has constant recruitment (Chávez-Flores *et al.*, 2020). Castañeda-González *et al*. (2012) reported for the BLP in 2012 that the 15-20 cm diameter category was the most abundant in burned areas, which differs from what was found in this investigation, since the 20-25 cm category was the most abundant in 2013. This may be due from the fact that the authors only measured burned sites west of the BLP. In 2020, the category with the largest number of individuals was 25-30 cm, but without an increase in the previous category, which can be attributed to the lower incorporation in this category as a result of the loss of trees from the fire of 2012 that affected about 8 thousand hectares (Gallegos *et al.,* 2014).

In SQ, in the years 2012 to 2017, sanitation actions were carried out in OF and MOPF areas due to outbreaks of *Dendroctonus mexicanus* Hopkins (1905) bark beetles and mistletoe (Semarnat Notifications 2012 to 2017 http://sngf.semarnat.gob.mx:8080/sngfev2/servlet/sngf) (Trigueros *et al*., 2014), which coincides with the decrease in *BA* in OF (Table 4). The remaining trees in the sites reached the following diameter category in the period as shown in Figure 2e; however, the infestation continued until 2018, causing loss of trees, which is reflected in the decrease of the 20-25 cm category in 2020. For its part, in the 2020 remeasurement, in the SDTF of the *Ambrosio ejido* and the OF of the *Tenamaxtlán* *ejido*, the sites were without vegetation due to the extraction of firewood for the production of charcoal.

Tree density

In BLP, the average density in 2013 was 288 trees ha^{-1}. This finding differs from what was reported by Gallegos *et al.* (2014) who counted 213 trees ha^{-1}. Castañeda-González *et al.* (2012) registered for BLP, an average of 536 trees ha^{-1} and Balderas *et al.* (2013) 385 trees ha^{-1}. These differences can be attributed to the scale of the research, since Castañeda-González *et al.* (2012) and Gallegos *et al.* (2014) measured only sites affected by fires, while Balderas *et al.* (2013) only mixed forests unaffected by recent fires, but it can also be the result of the variation in density in BLP (Table 3).

Gallegos *et al.* (2014) mentioned that the return interval between high intensity fires is only 7 years in BLP, which has not allowed regeneration to be established in the damaged areas, and its effect on density is related to the intensity of the fire that causes the loss of trees (Cadena–Zamudio *et al.*, 2022).

In *Sierra de Quila*, since there is no impact by fire, the disturbance factor that can be decisive in the regulation of tree density is the attack of pests, similar to what Alfaro-Reyna *et al.* (2022) in pine and oak forests in *Tamaulipas* State.

Návar-Cháidez and González-Elizondo (2009) argued that the density is modified as a result of the intraspecific competition of the species, so that in monospecific forests it tends to be lower than in mixed forests, which coincides with what was found in SQ, but it differs with what was found for BLP (Table 2).

The dispersion of density in the APFF BLP and SQ is characteristic of patchy forests (Gadow *et al.*, 2007). The averages in the MOPF (468 trees ha^{-1}) and BMPE (201 trees ha^{-1}) in the BLP in the year 2020 (Table 2) are less than the 500 trees ha^{-1} calculated by Luján (2021) for the mixed and irregular forests of the region of *El Salto*, *Durango*, but they coincide with what Baez *et al.* (2015) in pine-oak forests (490 trees ha^{-1}), where the authors associated the largest number of trees with a high diversity of species.

The attack of pests and diseases is the main disturbance factor that affects the density in SQ, as pointed out by Trigueros *et al.* (2014). The opposite happens in the BLP, where anthropic factors such as fire, serve as an indirect regulator of forest density.

Increase in Basimetric Area

BA in the BLP during the 15-year period increased by 3 m^2 ha^{-1} with an *IPA* of 0.21 m^2 ha^{-1} $year^{-1}$, while in SQ it was 4 m^2 ha^{-1} in the same period with an *IPA* of 0.27 m^2 ha^{-1} $year^{-1}$, which indicates that there is growth in both APFF despite the fact that there are times and types of vegetation with *BA* loss. Návar-Cháidez and González-Elizondo (2009) mentioned that growth tends to increase with the increase in the removal of the basimetric area in *Durango* forests, since competition decreases and the remaining trees increase in diameter in response (Baez *et al.*,2015).

The difference in *IPA* between APFF is not significant (p=0.505). In BLP, the *IPA* increases significantly (p<0.001) between periods, while in SQ it a decreases (Table 5).

In BLP, the frequency and magnitude of fires is what affects *BA* to a greater extent (Balderas *et al.*, 2013). The 2005 fire according to Castañeda-González *et al.* (2012), caused a loss of 10 m^2 ha^{-1}, while Huerta-Martínez and Ibarra-Montoya (2014) recorded a loss of 1.31 % of forest mass in BLP due to fires that occurred from 1998 to 2012, which may be the cause of the loss of basimetric area but also that the *IPA* of the remaining trees increases significantly (Table 1).

In SQ, Baez *et al.* (2015) established that the increase in *BA* is modified by factors such as competition, diseases and pests (Alfaro-Reyna *et al.,* 2022), as it happens in SQ where *BA* decreases between periods for OF and MOPF (Table 4).

Balderas *et al.* (2013) calculated 17 m^2 ha^{-1} of *BA* for the MOPF in BLP for the year 2013, which coincides with the results of this research. *BA* in SQ (Table 3) is similar to what Dávila-Lara *et al.* (2019) found in mixed pine-oak forests of *San Luis Potosí* (18.9 m^2 ha^{-1}), but it is lower compared to the mixed forests managed in *Durango* (21.77 m^2 ha^{-1}) (Chávez-Flores *et al*., 2020).

On the other hand, the loss of *BA* in a forest is due to the effect of human activities such as inappropriate forest management (Návar-Cháidez and González-Elizondo, 2009), land use change, forest fires (Huerta-Martínez and Ibarra-Montoya, 2014) or the absence of management. In this study, the presence of some factors was identified that could explain the reduction in the increment *BA* in the sampling sites in the two APFF, such as the change in land use, grazing, the opening of spaces for walkers and fires forests, which coincide with the decrease in the increment in *BA* in both APFF.

Comparison of the APFF *Bosque La Primavera* and *Sierra de Quila*

Composition in the two APFF is different in terms of the species with the greatest presence; *Quercus magnolifolia* is the dominant species in BLP, while *Quercus resinosa* is in SQ, which coincides with what was indicated by Trigueros *et al.* (2014) and Cadena-Zamudio *et al.* (2022). The diameter structure is similar in both areas because they are irregular forests similar to a J (Gadow *et al.*, 2007), in which the most recurrent category is that of 10-15 cm *dn*, depending on the species.

Tree density is higher in SQ than in BLP, especially in MOPF, MPOF and SDTF. Forestry management is not applied in both areas. Therefore, they present a high variability in density, in addition to the fact that there is a loss of individuals attributable to fires and unregulated felling.

BA in both SQ and BLP, increased in all types of vegetation in the study period, with the exception of SDTF in SQ. The behavior of the *IPA* in *BA* between APFF resulted with differences in the period. It is noteworthy that the *IPA* in *BA* went from having a negative to a positive trend in the mixed forests of BLP, while the SBC of SQ is negative throughout the period.

Finally, it is important to mention that the proximity of BLP to the ZMG influences the recurrence of fires and the change in land use, phenomena that are of anthropic origin (Balderas *et al.*, 2013), which is also observed in SQ with the extraction of individuals for firewood and charcoal. However, the variables analyzed in this study in SQ are modified as a consequence of the application of clearing cuts due to pest attacks.

Conclusions

The diametric structures of BLP and SQ indicate that trees with diameters of up to 20 cm predominate, although there are also specimens with diameters greater than 40 cm, but they are scarce. The species with the highest *BA* for both APFF have an inverted J-shaped diametric structure, which reflects a constant incorporation of individuals into their populations, despite the anthropic pressure to which they are subjected. *BA* in BLP was modified in part by the loss of individuals due to anthropic factors such as fires, land use change and lack of management. For its part, the *BA* in SQ varied in part due to natural factors such as mortality caused by pest attacks, although some anthropic factors such as the cutting of individuals for the production of firewood and charcoal have also influenced this change.

The *AB* increased in both BLP and SQ in the study period and was higher in SQ. The *IPA* in *BA* showed a negative trend in the 2005-2013 period in both APFF, which coincides with a high incidence of fires in BLP, as well as with the application of treatment to combat pests in SQ, although extraction continued of infested and dead individuals until the year 2018.

The anthropic pressure in the BLP caused by its proximity to the ZMG causes fires to frequently occur and, therefore, is one of the possible factors that determine the modification of the structure of the arboreal community analyzed. The alteration of these variables in SQ may also be due to the effect of disturbance factors such as pest attacks.

Acknowledgements

To *Bosque La Primavera* and *Sierra de Quila* Decentralized Public Bodies for allowing access to the APFF, for their support in logistics, as well as to all the staff who accompanied us on the tours. To Conahcyt for granting the Scholarship to the main author.

Conflict of interest

The authors declare they have no conflicts of interest.

Contribution by author

Consuelo Marisel Figueroa Navarro: drafting of the document, preparation of the project, data collection in the field and office work; Eduardo Salcedo Pérez: preparation of the research proposal, review of the writing and interpretation of results; Agustín Gallegos Rodríguez: data analysis and interpretation of results; Benedicto Vargas Larreta: manuscript review; Francisco Martín Huerta Martínez: review of the manuscript; Gregorio Ángeles Pérez: review of the manuscript and data analysis.

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