Population structure indicators in an uneven aged mixed confierous stand

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1. Introduction

The main functions of a tree crown are assimilation, respiration and transpiration. Assimilation, which is known as photosynthesis in green plants, can be described as the process by which light energy is trapped by chlorophyll and used to produce sugar from carbon dioxide and water. Another important process that takes place in the leaves besides photosynthesis is respiration. Respiration refers to the process by which the energy stored in reduced carbon compounds during photosynthesis is released by oxidation in a form that can be used in assimilation and growth, and in maintenance of cell structure and function. Transpiration is another function of the tree crown. Transpiration is the process of taking water from the soil through plant roots and the loss of this water into the atmosphere as water vapor through the leaves (Kozlowski *et al.*, 1991).

The tree crown is one component of net primary production and its dimensions reflect general tree health. Dense and large crowns are associated with potential growth rates. Sparse and small crowns can prove responsive to unfavorable site conditions (competition, moisture, diseases). Tree crowns are highly variable. Their general shape varies from relatively dense conoid crown-shapes for conifers of an excurrent habitat to wide open shapes for many broad-leaved trees of a deliquescent habitat (Husch, *et al.,* 1982). Tree crown investigation contributes to several key forest ecosystem attributes: biodiversity, productivity, sustainability, forest management, forest environment, and wildlife. Crown characteristics are useful in predicting growth responses in spacing and thinning, and in relating growth to soil moisture availability. They are frequently required for growth modeling with tree growth being estimated from the crown and other characteristics. These studies emphasize the close relationship between the size of the crown and the amount of the photo-synthetically active foliage (Laar and Akca, 1997).

The surface area of the foliage of forest trees is a useful measurement for the study of precipitation interception, light transmission through forest canopies, forest litter accumulation, soil moisture loss, and transpiration rates (Husch, *et al.,* 1982). The size of a tree crown is strongly correlated to tree growth. The crown biomass and the quantity and quality of branch material, however, are also of direct interest to ecological studies and research into the effects of trees on pollution. Nowadays, knowledge concerning the crown structure is of great importance, in the sense that trees use this arboreal component as a source of absorption of carbon dioxide.

2. Objective

The objective of this investigation is to develop a method of characterizing the crown structure in the mixed, uneven-aged coniferous forests, through the application of tree dimensions, diameter distribution and crown indexes.

3. Study site and methods

In 1998 the Cerro El Potosí was decreed a natural protected area, containing natural forests of high biological value (3,675 m.a.s.l.) in north eastern Mexico (Jiménez, *et al.* 2002). The study area is located in Cerro El Potosí, in a mixed natural coniferous forest composed of *Abies vejari*, *Pseudotsuga menziesii*, *Pinus hartwegii* and *Pinus ayacahuite* (figure 1).

Figure 1. Location of the study area.

To obtain in a graphic manner the diametric distributions of the species, the Weibull method was employed, being one of the most widely used in the forest area because of its relative simplicity and flexibility, as well as being better adapted to mixed and uneven aged forests (Bailey and Dell, 1973; Rennolls *et al*., 1985; Maltamo, 1996, Nagel and Biging, 1998)

$$f(x) = \frac{c}{b} * \left(\frac{x-a}{b}\right)^{c-1} * e\left(\frac{x-a}{b}\right)^{c}$$

To characterize the crown structure, measurements were taken in different sections of the crown to determine the shape and area of occupation on an individual species basis, as well as on a complete site basis. In this sense the following parameters were determined: crown radius (*CR*), crown diameter (*CD*), crown length (*CL*) and light crown length (*LCL*).

4. Results and discussion

4.1 Size Structure

We completed an analysis of the dasometric parameters (Table 1) to understand the characteristics of the site. By analysis of the data collected, we determined the stems per hectare (*N*), basal area (*G*), average diameter (*d*) and average height (*h*). From this analysis we found that the stems, as well as the basal area are very different. There is a similarity between the stems of most species: *Pinus ayacahuite* (124), *Abies vejari* (120) and *Pseudotsuga menziesii* (102), most of them except *Pinus hartwegii* (60). *Pseudotsuga menziesii* shows the greatest dispersion in diameter with 77.2%. In general, there is a high variability between all the species with respect to age (14-126 years), diameter (5-65.4 cm) and height (2.2-22.4 m).

Table 1: Size structure of the uneven-aged stand.

Tree species	**Age (years) Mean**	**Range**	**Stems (N)**	**Basal Area (m^2)**	**Diameter (cm) Mean**	**Range**	**Height (m) Mean**	**Range**
Abies vejari	32	16 - 72	120	1.86	12.5	5.1-39.2	7.9	3.5-18.4
Pseudotsuga menziesii	38	16 - 105	102	3.65	17.1	5.0-61.2	8.9	2.5-20.1
Pinus ayacahuite	40	15 - 126	124	5.10	18.8	5.0-65.4	8.1	2.2-18.1
Pinus hartwegii	51	14 - 121	60	4.62	26.5	5.1-65.3	10.6	2.3-22.4
Stand	38	14 - 126	406	15.10	1 7.6	5.0-65.4	8.6	2.2-22.4

4.2 Diameter distribution

Considering the results of the size structure, we proceeded to analysis the diametric distribution of the species to locate the individual dimensional position within the forest, and to obtain in this manner its ecological value within the ecosystem structure. To complete this objective, the individuals were arranged by diametric classes of 10 cm in order to separate the individuals by ranges. In general, it was observed that most trees range in the diameters of 10-40 cm, the greatest proportion belonging to the 10 and 20 cm categories (398 trees) with only 106 trees remaining in the following categories. In particular, *Abies vejari* was found in the 10 and 20 cm diametric categories (143 trees), as was *Pseudotsuga menziesii* and *Pinus ayacahuite.* However, *Pinus hartwegii* showed a similarity in both 20 and 50 cm.

In order to process differentiation within the forest in a vertical structure. Wenk (1996) proposed calculating the parameters of the function of each strata. This study employed a method for describing bimodal diametric distribution using estimates of a maximum and minimum stand diameter (Figure 2).

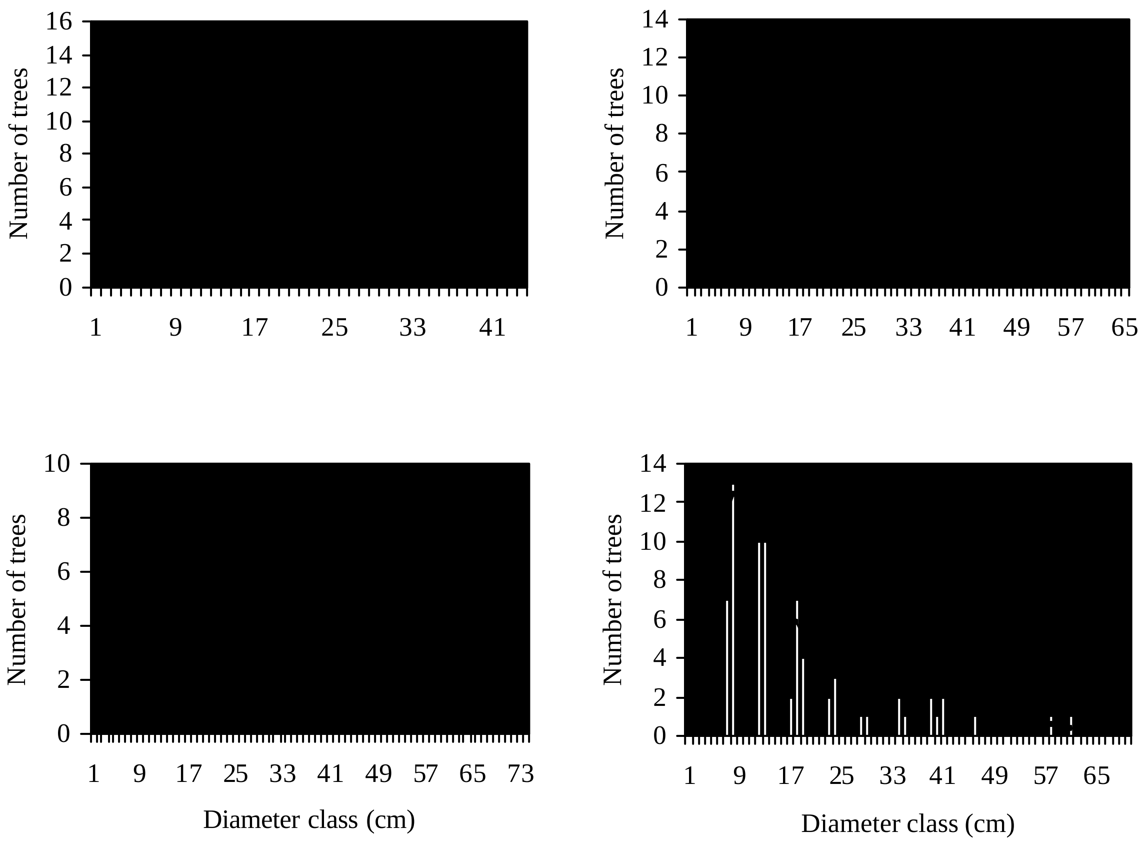

Figure 2: Fitted bimodal-Weibull distribution.

4.3 Crown analysis

We proceeded to separate high zone trees in accordance with the method proposed by Pretzch (1996), where the greatest height of the site was recorded (22.4 m) and the division of two zones was considered.

The study site was divided into two strata : high zone I and high zone II. Table 2 shows the trees by species and by high zones, 75% (376) corresponding to the individuals in high zone II, and only 25% (128) in high zone I. In the stratum of predominant and dominant trees (high zone I), *Pinus ayacahuite* and *Pinus hartwegii* show a remarkable similarity in their stem dimensions (d, h, t). *Abies vejari* and *Pseudotsuga menziesii* show a greater variability in their dendrometrical parameters, as well as an increase in their stabilizing values (51-61). This is due to the fact that they are shade-tolerant species, and for that reason their development is slower in their primary phases and with greater competition, which is why a positive stable relationship does not exist. However, in high zone II, the shade-tolerant species show a greater similarity in their diameter, height, and age values, thus observing a greater stability.

Table 2: Crown characteristics of the stand according to the height zone

Tree species	***n*** **stem**	***dbh*** **cm**	***h*** **m**	***t*** **year**	***CL*** **M**	***CR%*** **%**	***LCP*** **m**
High zone I (predominant and dominant trees)							
Abies vejari	21	23.9	13.	47	8.4	62	8.2
Pseudotsuga menziesii	35	33.6	15.2	63	8.9	58	7.9
Pinus ayacahuite	33	39.3	15.5	72	8.2	53	4.9
Pinus hartwegii	39	39.6	15.3	73	6.7	45	4.4
Strata	128	35.3	15.2	66	8.0	53	6.1
High zone II (suppressed trees)							
Abies vejari	128	10.7	6.9	29	4.9	72	4.3
Pseudotsuga menziesii	91	10.8	6.5	28	4.8	76	3.6
Pinus ayacahuite	121	13.2	6.1	31	4.2	71	2.8
Pinus hartwegii	36	12.2	5.6	28	4.2	78	2.6
Strata	376	11.7	6.4	29	4.6	73	3.5

CL= Crown length, *CR%*= Crown percent), *LCP*= Light crown length.

Table 2 shows in a global way that, in the upper stratum, the crown percentage covers 53% of the tree, while in the lower stratum it covers 73%. At a species level, it was observed in high zone I that crown percentage decreases while the age increases (*Pinus hartwegii* t = 73; CR% = 45%, *Abies vejari* t = 47; CR% = 62). However, in high zone II there exists a great similarity between the age (28-31 years) and CR% (71-78%) values.

Table 3 shows the values for the crown parameters. In high zone II no considerable difference is observed among these parameters, however, *Pinus hartwegii* shows a slighter tendency in comparison to the other species. *Abies vejari* shows the same tendency in stratum I. In the same high zone (I), the pine species, while having similar values in age and stem dimensions, show a differentiation in their crown variables.

Table 3: Crown characteristics of the stand according to height zone.

Tree species	*CD* m	*CTI*	*CSR*	*CPA* m^2	*CSA* m^2	*LCS* m^2
High zone I (predominant and dominant trees)						
Abies vejari	4.22	0.51	0.31	14.91	76.41	73.83
Pseudotsuga menziesii	5.31	0.61	0.34	23.98	102.97	69.59
Pinus ayacahuite	5.91	0.75	0.38	28.59	102.13	61.53
Pinus hartwegii	6.31	0.96	0.41	33.90	90.87	59.32
Strata	5.59	0.74	0.37	26.71	94.71	71.21
High zone I (suppressed trees)						
Abies vejari	2.96	0.63	0.44	7.52	32.44	28.77
Pseudotsuga menziesii	2.76	0.59	0.45	6.57	30.88	23.14
Pinus ayacahuite	2.92	0.68	0.48	7.82	29.35	19.44
Pinus hartwegii	2.16	0.50	0.39	4.66	21.92	13.37
Strata	2.82	0.63	0.45	7.12	30.06	22.93

CD = Crown diameter, *CTI*= Crown thickness index, *CSR*= Crown spread ratio, *CPA*= Crown projection area, *CSA*= Crown surface area, *LCS*= Surface area of the light crown

The crown thickness index shows a certain differentiation between the dominant trees (0.74) and the suppressed trees (0.63). This differentiation is due to the fact that the trees in high zone I suffer less from competition - especially *Abies vejari* (0.51) and *Pseudotsuga menziesii* (0.61) which have a conoid crown, in contrast to pine trees which have a paraboloidal aspect.

With respect to the crown projection area it was observed, *Pinus hartwegii* shows a higher CPA (16%) than *Pinus ayacahuite*, this being due to its wider crown diameter. The highest CPA was held by the species in high zone I, ranging between the 14.91 and 33.90 m^2. The crown surface area (11%) is lower in *Pinus hartwegii*. This is due to the fact that it is 1.5 m (18%) shorter than *Pinus ayacahuite*. The maximum CSA was found in *Pseudotsuga menziesii* (102.97 m^2) and *Pinus ayacahuite* (102.13 m^2), due to the presence of a greater *CL* (8.9m and 8.2m).

5 Conclusions

In accordance with the heterogeneous structure of this mixed and uneven aged coniferous stand, it was observed that there is a great variability in stem dimensions and crown parameters, not only at a site level, but also in the species that are found in the ecosystem.

There is a bimodal type Weibull distribution for the arboreal species of the ecosystem. *Abies vejari*, *Pseudotsuga menziesii* and *Pinus ayacahuite* show a higher slope in the curve in the first diametric categories, due to a greater amount of trees, while *Pinus hartwegii* shows a similar tendency among the higher and lower diametric categories, which results in a similar curve slope. In general, it is observed that there is a good adjustment in the bimodal type Weibull distribution for all species.

One of the important objectives in this investigation was the analysis of the crown parameters. The crown indexes were defined: crown length, crown percentage, light crown length, light crown percentage, crown thickness index, crown spread ratio, crown projection area, and crown surface area. It was concluded from tables 2 and 3 that there exists a great heterogeneity in the values corresponding to the crown indexes (CL, CTI, CSR, CPA and CSA) in high zone I and high zone II; the discrepancy among the species within each of the high zones is even greater.

The conclusion of this study is that the uneven mixed stands presents a specific structure, in accordance with its stem parameters, diameter distribution, and crown parameters and indexes, proving that this methodology of evaluation can be reliably used in uneven aged mixed stands.

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