Ecology of Mexican fir *Abies durangensis* Martínez

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Abstract
The genus *Abies* has about 40 species, which are mainly distributed in boreal or subalpine areas. In Mexico as a diversity center for this genus, all eight species of *Abies* are protected. Six of them are endemic and mainly distributed in the Sierra Madre Occidental and Oriental. The often isolated relict *Abies durangensis* Martínez, also known as Durango Fir, is located in the states of Durango, Chihuahua, Sinaloa, and Jalisco and usually grows on slopes with well-drained and shallow lithosols, where the climate is humid and cool. *A. durangensis* is specifically associated with species such as *Pseudotsuga menziesii, Pseudotsuga lindleyana, Pinus strobiformis, Picea chihuahuana, Pinus durangensis, Cupressus lusitanica (lindleyi),* and *Juniperus deppeana*. In the state of Durango, the species has a restricted geographic distribution between 23.2° and 25.7°N and 105° to 107°W and elevations varying from 2,195 m to 2,955 m (mean 2,690 m). The species' habitat has a mean annual temperature that ranges from 8.6 °C to 12.2 °C (mean 10.6 °C) and a mean annual rainfall of 1,088 mm to 1,395 mm (mean 1,224 mm). According to the Red List of Threatened Species of the International Union for Conservation of Nature and Natural Resources, the species is in low risk and does not depend on conservation efforts.
Keywords: Sierra Madre Occidental, Conservation, Red list

Introduction

Pinaceae is one of the most prosperous families of gymnosperms. Approximately 200 species in 11 genera are distributed in the northern hemisphere. *Abies* Miller is a genus representative of the subfamily Abietoideae, and is the second largest genus of the Pinaceae family followed by the genus *Pinus* (Florin, 1963). The genus *Abies* Mill. has about 40 species, which are distributed mainly in boreal or subalpine areas (Liu, 1971). Mexico is a center of diversity for this genus because of the heterogeneity of its climate and orography. In Mexico there are eight species of *Abies*, six of them endemic, and five varieties, which are mainly distributed in the Sierra Madre Occidental and Sierra Madre Oriental (Martínez, 1948, 1953). The often isolated relict *Abies durangensis* Martínez (Martínez, 1953), also known as Durango Fir, is located in the states of Durango, Chihuahua, Sinaloa, and Jalisco, and usually grows on well-drained slopes or lithosols, where the climate is humid and cool. It can be associated with other rare conifers such as *Picea chihuahuana, Pseudotsuga menziesii, Pseudotsuga lindleyana, Pinus strobiformis, P. chihuahuana, P. durangensis, Cupressus lusitanica,* and *Juniperus deppeana* (Farjon, 1990). It has a very restricted distribution with very small populations. However, according to the Red List of Threatened Species of the International Union for Conservation of Nature and Natural Resources, its current status is of low risk, or minor concern (IUCN, 2011). Although *A. durangensis* is not included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora list, the species is registered in the NORMA Oficial Mexicana NOM-059-SEMARNAT-2010 (CITES, 2012; SEMARNAT, 2010).

Abies durangensis Martínez is a tree which can reach 48 m height and a diameter at the breast height (DBH) up to 150 cm. The species features a straight, round trunk, and bears long, horizontally-spreading first-order branches that form a narrowly conical to a rounded irregular crown. The bark is smooth with a grey or red-brown color on young trees, which darkens to black-brown and eventually becomes deeply, longitudinally fissured (Silba, 1986; Rushforth, 1987; Farjon, 1990 in http://www.conifers.org/pi/Abies_durangensis.php). Because there is little information about this species, the aim of this study was to determine the composition of forest tree communities with *Abies durangensis* and its

dendrometric variables in the state of Durango, Mexico.

Material and Methods

Study area and Sampling sites

The study area is located in Nearctic subtropical coniferous forests in the Sierra Madre Occidental (Ricketts et al., 1999) in the state of Durango, Mexico (within the geographical coordinates of 23.2° to 25.7°N and 105° to 107°W). The data were obtained from the National Forestry Commission, which is responsible of the National Forest and Soil Inventory in Mexico (CONAFOR, 2004). The sampling design was distributed throughout the country in a grid of 5 x 5 km. In order to analyze the composition of tree species communities with *Abies durangensis*, 1,590 conglomerates (6,390 plots) were used in the study (Figure 1). A conglomerate consists of four 400 m^2 circular plots as shown in Figure 2 (Silva-Flores and Wehenkel, 2012, unpublished). For each plot, the longitude (LONG), latitude (LAT), elevation (ELEV), mean annual temperature (MAT), and mean annual precipitation (MAP) were estimated using the climate model of Rehfeldt (2006; Rehfeldt et al., 2006), which is based on the thin plate splines of Hutchinson (1991, 2004).

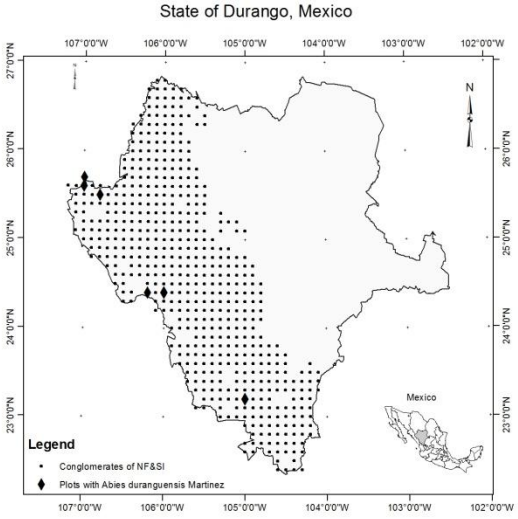

Figure 1. Map of the studied tree species communities with *Abies durangensis* (conglomerates).

3. The forest community of Durango fir trees is species-rich. The Durango fir was found

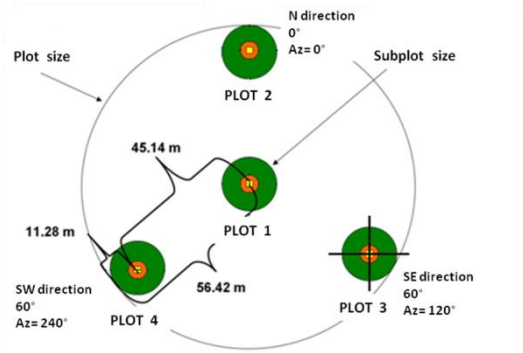

Figure 2. Design of a single conglomerate of the National Forest and Soil Inventory. Simbols: Az = Azimuth, N = North; SE = Southeast; SW = Southwest (from Silva-Flores and Wehenkel, 2012, unpublished).

Results and Discussion

1. Durango fir trees were found only in 13 plots (0.20 % of all analyzed plots) (Tables 1 and 2). That is not surprising because this species has a very restricted distribution with very small populations (Farjon, 1990).

2. In Durango, the species has a geographic distribution between 23.2°-25.7°N and 105°-107°W and in altitudes from 2,195 m to 2,955 m (mean 2,690 m). The habitat has a mean annual temperature ranging between 8.6 °C and 12.2 °C (mean 10.6 °C) and a mean annual rainfall range of 1,088 mm and 1,395 mm (mean 1,224 mm) (Table 1). Thus, *A. durangensis* is a tree species that thrives in cool and humid climates.

Table 1. Longitude (LONG), latitude (LAT), elevation (ELEV), mean annual temperature (MAT), mean annual precipitation (MAP) of the thirteen *Abies durangensis* Martínez plots

Plot	LONG	LAT	ELEV (m)	MAT (°C)	MAP (mm)
1	-106.0	24.4	2,198	12.1	1,218
2	-106.0	24.4	2,221	11.9	1,225
3	-106.0	24.4	2,223	11.9	1,226
4	-106.0	24.4	2,195	12.2	1,216
5	-106.0	24.4	2,823	8.6	1,312
6	-105.0	23.2	2,906	10.1	1,251
7	-105.0	23.2	2,955	9.9	1,261
8	-105.0	23.2	2,915	10.0	1,253
9	-107.0	25.6	2,845	9.8	1,151
10	-107.0	25.6	2,794	10.1	1,142
11	-107.0	25.7	2,657	10.8	1,088
12	-106.8	25.5	2,593	10.9	1,107
13	-106.2	24.4	2,613	9.9	1,395

along with at least 19 tree species, and is often associated with *Quercus scytophylla*,

Quercus sideroxyla, *Pinus durangensis*, and *Arbutus xalapensis* (Table 2). Thus, it is associated with more tree species than Farjon (1990) indicated.

Table 2. Relative frequencies of tree species that were detected in 13 plots along with tree species communities of *Abies durangensis* M. in Durango, Mexico

Species	Plot no													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Mean**
Abies durangensis Martínez	21	25	6	91	19	100	100	93	38	53	27	2	7	40.9
Alnus firmifolia Fernald	-	-	-	-	-	-	-	-	-	-	-	6	-	1.1
Alnus jorullensis Kunth	-	-	-	-	-	-	-	-	-	-	-	-	21	1.1
Arbutus xalapensis Kunth	11	4	-	-	-	-	-	-	10	-	-	24	-	6.3
Cornus spp.	-	-	-	9	-	-	-	-	-	-	-	-	-	0.7
Cupressus lindleyi Klotzsch ex Endl.	-	-	-	-	-	-	-	-	5	-	7	-	-	0.7
Juniperus deppeana Stend	-	-	-	-	19	-	-	-	5	-	-	4	-	2.2
Juniperus monosperma Engelm.	-	-	-	-	-	-	-	-	-	-	-	2	-	0.4
Pinus ayacahuite Ehrenb.	-	-	-	-	6	-	-	-	-	6	-	14	7	3.7
Pinus lumholtzii B.L. Rob & Fernald	-	4	-	-	-	-	-	-	-	-	-	-	-	0.4
Pinus teocote Schltdl & Cham	-	-	-	-	-	-	-	7	-	-	-	-	-	0.4
Pinus arizonica Engelm	-	-	-	-	-	-	-	-	5	-	-	6	-	1.5
Pinus durangensis Martínez	-	-	-	-	-	-	-	-	29	6	60	4	29	8.2
Pinus herrerae Martínez	-	17	6	-	-	-	-	-	-	-	-	-	-	1.9
Pinus luzmariae Pérez de la Rosa	5	17	-	-	-	-	-	-	-	-	-	-	-	1.9
Pseudotusa menziesii Mirb. Franco	-	-	-	-	25	-	-	-	5	12	-	-	-	2.6
Quercus candicans Née	16	-	12	-	-	-	-	-	-	-	-	-	-	1.9
Quercus crassifolia Humb and Bonpl.	-	-	-	-	-	-	-	-	-	-	-	-	29	1.5
Quercus scytophylla Liebm.	47	29	77	-	-	-	-	-	-	-	-	-	-	10.8
Quercus sideroxyla Humb and Bonpl.	-	-	-	-	31	-	-	-	-	6	7	30	7	8.6
Unidentified tree species	-	4	-	-	-	-	-	-	5	12	-	6	-	3.3

1. The forest tree community of *A. durangensis* has a low stand density (mean of 42 m^2*ha^{-1} and 517 $tree*ha^{-1}$) compared to unthinned white fir (*Abies concolor*) forests in northeast California, USA (Zhang et al., 2007). Per hectare, the mean tree number (DBH > 7 cm) of *A. durangensis* amounted to 212 (Table 3) while the mean basal area is 19.9 m^2 (maximum 84 m^2) (Table 4). The mean DBH is 28 cm, and the mean total height is 16 m (Table 5). The biggest tree in the study area had a DBH of 150 cm and a total height of 48 m.

Table 3. Number of *Abies durangensis* M. trees per ha (DBH > 7 cm) in the 13 studied plots in Durango, Mexico

Plot no													
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Mean**
100	150	25	500	75	300	675	350	200	225	100	25	25	212

Table 4. Basal area of all species (total) and *A. durangensis* in m^2*ha^{-1} in the 13 studied plots in Durango, Mexico

	All species	***A. durangensis***
plot	**G*ha^{-1}**	**G*ha^{-1}**
1	48.2	2.6
2	46.4	2.7
3	36.2	0.5
4	44.9	44.2
5	19	0.8
6	84.1	84.1
7	49.1	49.1
8	44	43.8
9	20.9	10.7
10	37.9	16.3
11	49.5	2.8
12	26.1	0.3
13	43.5	0.2

Table 5. Mean diameter at breast height (DBH), mean total height of all species (total), and *A. durangensis* per plot among the 13 studied plots, as well as the maximum DBH and total height of *A. durangensis* among all studied plots in Durango, Mexico

	All species		***A. durangensis***	
Plot	**DBH (cm)**	**Height (m)**	**DBH (cm)**	**Height (m)**
1	32.3	16.3	17.3	14.1
2	23.9	13.5	14.7	11.1
3	28.2	17.2	16	13.5
4	27.6	19	29.1	20.4
5	20.8	13.7	10.9	9.4
6	48.9	15.4	48.9	15.4
7	26.7	13	26.7	13
8	34	20.5	35.7	21.4
9	19.7	11	22.1	14.2
10	29.8	17.3	26.2	17.7
11	33.9	14.6	18.5	10.9
12	13.9	7.6	12.7	8.6
13	28.6	13.9	10.4	10
Mean			28	16
Max			150	48

2. Since (i) the populations are very small (with the lowest number found in Durango), and (ii) its cool and humid habitat further decreasing due to a warming climate, *A. durangensis* should be included in the Red List and more intensively monitored.

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