Environmental influences on forest structure and woody species diversity after forest fires in Mexican pine-oak forest.

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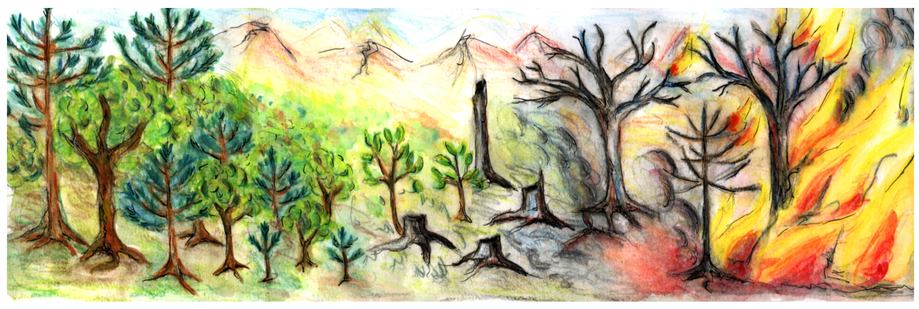


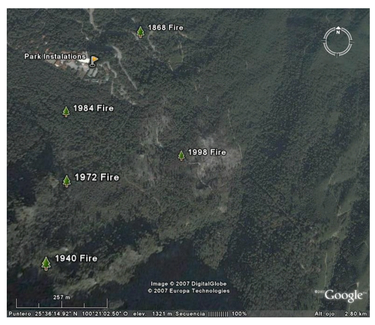
INTRODUCTION:

Forest fires in pine-oak forest in Mexico's Sierra Madre Oriental have had a remarkable relevance since the extraordinary fire season in 1998, due to their direct contribution to (1) deforestation, (2) changes in forest structure, species composition, and recently to their impact to the (3) increment of carbon dioxide in the atmosphere. Nevertheless, few studies have investigated post-fire stand dynamics or natural regeneration. The influence of environment, fire year and stand location on natural regeneration was studied in 23 post-fire stands in the Mixed pine-oak forest of Nuevo Leon state.

Our goal was to describe the present forest structure and woody plant species composition along a fire chronosequence in pine-oak forest in the SMO to (1) increase the understanding of succesional patterns in mixed pine-oak forest in this region, and (2) to relate succesional patterns to environmental variability. Besides as using time sin fire as a control variable, other parametres may also have an impact on forest succesion and woody plant species composition, thus we included analyses os site, aspect, elevation, slope and potential solar radiation.

MATERIALS and METHODS

The investigation was carried out in the Ecological Park Chipinque (PECH) in the northern part of the Sierra Madre Oriental (SMO) in Northeast Mexico. The Pech is located in the state of Nuevo Leon and extends over an area of 1624 ha (25° 34'' to 25° 38'' N and 100° 18'' to 100° 24''W) between 650 and 1800 msnm.



Based on their fire history 23 plots were selected in the Parque Ecológico Chipinque (PECH). Changes in forest structure across the chronosequence of burned stands were deduced from density, height and diameter measurements of trees and shrubs (>5 cmin diameter) in all plots of 1000 m2. Differences in woody plant species composition among the plots were evaluated using Shannon evenness measure and the Whittaker's measure and by Hierarchical cluster analysis and Detrended Correspondence Analysis. Hierarchical cluster analysis showed a high similarity among all recently burned plots, independed of the aspect. Multivariate analysis showed that local environmental factors, including time since fire, continue to structure species composition.

Table 1
Environmental characteristics of the stands in the PECH

Stands	Number of plots per stand	Fire	TSF	Aspect	Slope (°)	Elevation (m)	Burned area (ha^{-1})	PSR
PECH98	3	1998	4	NE	23	1125	500	72.3 ± 11.0
	2			SE	36	1220		79.2 ± 1.7
PECH84	3	1984	18	N	36	1300	–	77.3 ± 1.2
	2			S	30	1332		73.5 ± 5.9
PECH72	2	1972	30	N	23	1380	–	76.1 ± 0.1
	4			S	22	1370		73.9 ± 2.7
PECH40	3	1940	62	NE	27	1300	–	78.0 ± 3.9
	1			S	26	1206		80.2
PECH868	3	1868	134	N	28	1195	–	82.0 ± 0.1

TSF: time since fire; PSR: mean potential solar radiation during growing season (May–December); (–) information not available.

Environmental parameters.
Environmental parameters (aspect, slope, elevation, time since fire, and potential solar radiation) were obtained and their influences on woody plant species richness were examined.

Cluster and detrended correspondence analysis.
Multivariate hierarchical cluster analysis was used to compare the between-plot similarity in terms of woody plant species composition (Oksanen et al., 2002). Detrended correspondence analysis (DCA, Hill and Gauch, 1980) was used to examine the major

RESULTS and DISCUSSION

Forest structure and woody plant species composition

Table 2
Structural characteristics of the stands in the PECH

Stand	Aspect	PECH98	PECH84	PECH72	PECH40	PECH868
Density ($trees\ ha^{-1}$)	N	3400 ± 701	1620 ± 780	1175 ± 247	753 ± 169	1066 ± 120
	S	1265 ± 248	1125 ± 417	1417 ± 140	850	
Diameter (cm)	N	3.1 ± 1.3	7.7 ± 2.5	8.9 ± 3.7	22.7 ± 10.6	14.1 ± 9.8
	S	3.8 ± 2.4	7.0 ± 1.9	9.0 ± 3.2	22.0 ± 10.1	
Height (m)	N	2.1 ± 0.7	6.5 ± 1.6	7.0 ± 1.9	13.1 ± 5.5	8.1 ± 9.8
	S	2.7 ± 1.2	5.3 ± 1.3	6.7 ± 1.9	8.9 ± 3.6	
Basal area ($m^2\ ha^{-1}$)	N	3.4 ± 0.6	8.3 ± 4.1	8.5 ± 0.7	37.3 ± 5.3	28.3 ± 2.9
	S	2.2 ± 0.3	4.7 ± 2.2	10.2 ± 4.2	38.9 ± 0.5	
CV	N	0.46	0.31	0.41	0.46	0.69
	S	0.63	0.24	0.36	0.45	

The values are mean values per post-fire cohort ± standard deviation (S.D.). CV: coefficient of variation of tree diameter.

The woody species composition and abundance in post-fire stands appeared to be determinate by a complex of environmental factors, including fire (TSF). Different species were clearly favored in stands with different topographic and different fire histories. Fire history varied with elevation, implying that topography and fire may exert mutual influences.

Woody plant species richness and diversity
On the north aspect we found five different post-fire cohorts with 16 woody plant species, whereas on the south aspect four post-fire cohorts were identified with 12 woody plant species (table 4).

As fires have been occurred frequently within the park and even the succession is leading to pine–oak stands similar to pre-fire conditions, in our opinion a fire management system should be integrated in the park. In addition, the exact role of fire in promotes natural regeneration in different site types need to be established and the impacts of forest suppression determinate

Table 4
Species richness (S), Shannon evenness index (J') and Whittaker's measure (β_W) of the stands in the PECH

Index	PECH98	PECH84	PECH72	PECH40	PECH868	P
North						
S	7.3 ± 1.5	6.7 ± 0.6	8.5 ± 0.7	3.7 ± 1.2*	10.7 ± 0.6*	0.02
J'	0.6 ± 0.07	0.4 ± 0.2*	0.6 ± 0.1	0.8 ± 0.1*	0.6 ± 0.01	0.03
β_W	1.2	1.3	0.8	3.3	0.5	
South						
S	5.0 ± 1.4	6.0 ± 1.4	5.9 ± 1.0	6		0.811
J'	0.7 ± 0.06	0.6 ± 0.1	0.6 ± 0.1	0.70		0.525
β_W	1.4	1.0	1.0	1.0		

Values are mean values ± S.D. Differences in these indices along aspects were tested with a Kruskall–Wallis analysis followed by Dunn's test (*P = 0.05) for multiple comparisons of unbalanced data.

Detrended correspondence analysis
Fig. 1 illustrates the results of analyzing the proportion of species variance explained by environmental factors, TSF, and topographic factors. After deducting all sources of covariance, five environmental variables explained 45% of the species variance. Two out of seven environmental variables emerged as significant.

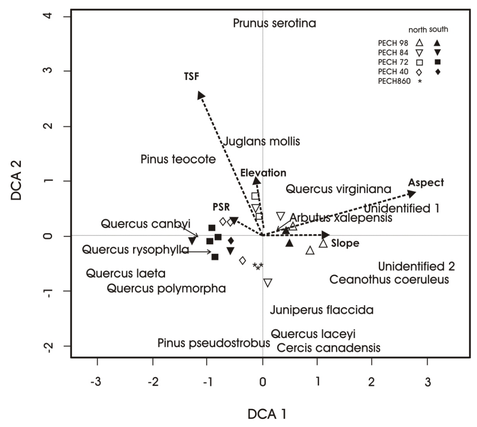


Fig. 1. DCA ordination diagram with log transformed data in the PECH. The scale refers to multiples of standar deviations (S.D.) T.S.F Tioime since fire, PSR. Potential solar radiation

Implications for management
The historical documentation of wildland fire events in the PECH showed that several fires have occurred over the past 134 years (Gonza´ lez-Tagle et al., 2005). Furthermore, our data indicate that fire was one of the factors governing forest structure and woody plant species composition in the PECH. Oak species recolonized the burned sites within 4 years after the fire. Although pine species establishment took almost 20 years, this study showed that in older stands, both pine and oak species were found in the upper canopy. Nevertheless, the foresters and technicians of the PECH would like to be able to concentrates its fire management resources on control and suppression, but has no integrated fire management system.

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