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Structure and Density Analysis of a Semi Desert Ecosystem Disturbed by Fire

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Abstract

In Mexico, forest ecosystems are disturbed by fires and generally these are considered to have negative impacts. However, it is important to consider that fire is an element of these ecosystems, and is important for its functionality. So it should be understood that in many cases the effects of a forest fire are beneficial, which can be determined through studies of population dynamics of these ecosystems. However, most of these studies currently focused only on aspects of species composition, with few cases concerning the analysis of the structure and density. In this study, a comparative analysis of the vegetation showed that conditions prevailing between burned and unburned areas of a site covered by microphyll desert species (shrubs and mesquite). The results suggest that the structure and density conditions of vegetation between burned and unburned areas are not statistically different. This is highlighted because one year after the fire occurred there is no evidence that fire had altered the structure and density of vegetation. Moreover, both in burned and unburned areas, vegetation had a healthy condition. Finally, although this may suggests that the fire was of low intensity, which resulted in a low impact on vegetation, in future studies it is recommended to determine if the same results are observed under different possible fire behavior and intensity.

Keywords

Population Dynamic, Forest Fire, Semi-Desert

1. Introduction

Fire has an important role in the dynamic of almost every forest and grasslands, as it is a factor that restarts the cycle of ecological succession (Flores & Rodríguez, 2006; Fitch, 2006; Jardel et al., 2009). Because of this, we want to understand and define under what conditions fire could have positive effects to support fire management objectives (Jardel et al., 2009; Sheuyange et al., 2005; Anaya, 1989). Generally, fire is seen as a destructive factor and a threat against forest ecosystems (Bakirci, 2010), therefore, they should be controlled (Villers, 2006; Pyne, 1995; Rodríguez et al., 2002). The rationale is that in some ecosystems, fire constitutes a limiting factor for species that are susceptible to it (Pausas & Keeley, 2014; Moretti et al., 2006; Pausas, 1998; Uhl & Kauffman, 1990). On the other hand, for fire dependent species, it's an alternative that guarantees their permanence (Ice et al., 2004; Flores & Benavides, 1994; Boerner, 1982; DeBano & Conrad, 1978). This fire dependency also is related to the intensity and frequency of the fires (Rodríguez & Sierra, 1995; Alexander, 1982; DeBano et al., 1970), under which condition the processes and the temporality of the recuperation of ecosystems perturbed by fire (Syphard et al., 2006; Varner et al., 2005). Fire perturbation can be determined through studies of population dynamics in forest ecosystems (Roques et al., 2001; Hoffmann, 1999; Young & Evans, 1978). However, the majority of population dynamics studies are focused only in aspects concerning to evaluate or monitor alterations in the species composition of forest ecosystems (Bergeron, 2000), through determining parameters, such as species similarity indices (e.g. Sorensen), measuring specific richness (e.g. diversity index of Simpson, Menhinick and Margalef), and species accumulation functions, etc. Nevertheless, there are few studies on alteration of the structure and density of ecosystems (Hall et al., 2005; Peterson & Reich, 2001). Moreover, the structure parameters are interpreted in terms of the composition, when the structure of communities is described in terms of proportional abundance of each species (Hickler et al., 2004; Moreno, 2001). Accordingly, in this study, I conducted a comparative analysis with regard to the vegetation in areas perturbed by a superficial fire and areas not perturbed, in a semi-desert ecosystem, considering the structure, and also the density of different vegetation forms of life (trees, bushes, grass and herb). My starting hypothesis is that fire does not alter the studied population dynamics.

2. Methods

2.1. The role of Fire in Forest Ecosystems

Fires are a recurrent natural phenomena in forest ecosystems; and historical analysis have determined that periodic fires have been present during millenniums (Gollberg et al., 2001). In addition to natural fires, humans have also been a cause of forest fires since prehistory (Stocks et al., 2002; Keeley & Fotheringham, 2002), defining in an important way the configuration of forest ecosystems. When a fire does not show up in a long period of time the vegetation's dynamics advances to very specific conditions (Varner et al., 2007; Briggs et al., 2005), such as: a) a higher density, which defines the poor illumination in the lower parts of the forest; b) a scarce defined structure, where there are different generations of the same species, forming mixed strata (intra or inter-specifically); and c) a mix of high species, which can implicate the gradual displacement of certain species. Thus, vegetation that initially conformed an ecosystem can be modified or displaced by more advance species of vegetation (Turner et al., 1997). Therefore, we can say that fire stops the plant succession cycle, allowing a characteristic forest vegetation to continue in a determined area (Verner et al., 2007; Uhl et al., 1981).

2.2. Description of the Study Area

The study area is located in the state of Jalisco, Mexico, approximately 22 km south of Guadalajara city (647,062.97 (X); 2250,434.90 (Y) (UTM 13)). The total area surface is 27.25 ha, of which 0.65 are covered by mezquital and 26.60 by microphyll desert shrub (deciduous tropical). A 2011 forest fire burned 18 ha in the area. This area is located in a region with a weather type (A)C(w0)(w) (García, 2004), which is tempered semi-warm, of the sub-humid with summer rains, mainly during the months of June to September. The average annual rainfall is 776 mm with winter rains representing less than 5 mm. The average annual temperature is 20.3˚C ranging from 16.2˚C to 23.7˚C. In the study area within the forest water basin, there are four types of dominant soil identified: feozem, vertisol, luvisol and solonetz.

Though the fire occurred in late February of 2011, a year later little evidence of such fire was found. However, we must consider two important periods of rain that occurred: 1) the 2011 raining season (from June to September); and 2) a series of rains during the month of January of 2012. This allowed the vegetation in the burnt area to regrow and to recuperate. Data for this comparative study between burned and unburned areas was collected during the first week of March 2012.

2.3. Design of the Comparative Analysis

Sampling design. The strategy used was to first establish, a series of areas with similar conditions. For this, I used satellite images, allowing us to define nine different homogeneous response areas (HRA) based on density, color, proximity and texture (**Figure 1**).

A stratified random sampling procedure was used to determine the distribution of the sample plots. The strata was defined by homogeneous response polygons and the sites were distributed completely randomly inside the polygon; trying to have at least two sites for each condition (burned/unburned) within each polygon. Three elements were used to structure the plots: a) a circle of 78.54 m^2, inside of which all vegetation was evaluated; b) a 30 × 30 cm square, located in the middle of the circle, which was used to take samples of biomass; and c) a point where floor samples were taken, located in the middle of the circle. The purpose of this design was to be able to estimate the average and the variance of the following variables measured for trees, shrubs, cactus and nopals:

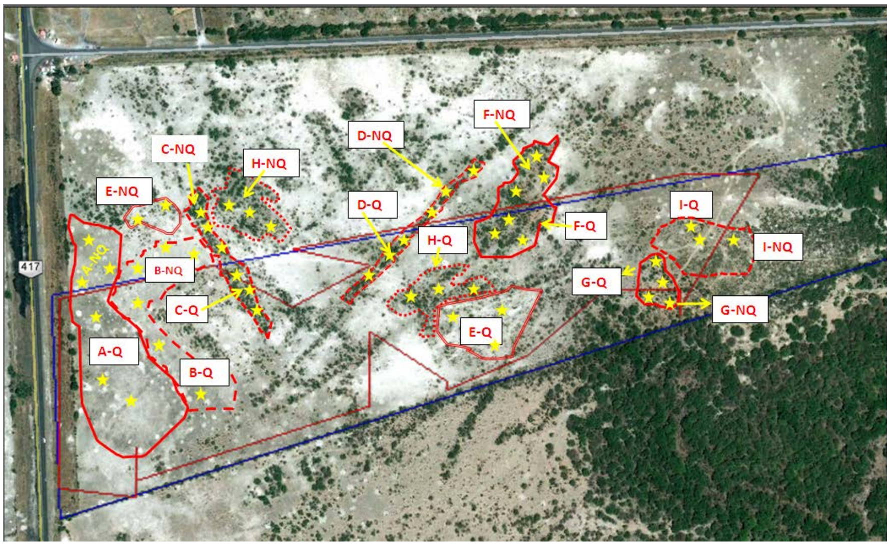

Figure 1. Distribution of the homogeneous response polygons along the burned area of the evaluated plots (Q = Burned, NQ = Unburned).

crown diameter, total height, condition (alive or dead), and damage. In the case of the herbs and grass, in addition to height, density was also evaluated (percentage of presence in the area of 78.54 m^2).

Statistical analysis. The intent of the analysis was to determine if there was any difference in the structure and density of the vegetation in the burned unburned areas. I used the Student *t*-test as a statistic decision criterion because this test is used to contrast hypothesis about population means that are normally distributed. It also provides approximate results of the contrasts in the means of large enough samples when these populations are not normally distributed.

3. Comparative Analysis Results

Qualitative comparison by plot. Each one of the nine HRA polygons was characterized to compare between burned and unburned conditions. As an example, polygon F was located in the north-center part of the plot studied, and is composed by a shrub stand (Figure 2). The density of these shrubs was very similar between the burned and unburned areas. Although the dimensions of the vegetation found in this polygon were very similar, the shrubs in the areas burned were, on average, smaller. Nevertheless, in both cases some isolated trees and also grasses (15 to 20 cm) with a relatively low density can be observed. In the unburned area trees were taller than in the burned area. However, the structure and density of the vegetation were very similar between the both areas.

General comparison. Before presenting separate results for the burned and unburned conditions of the vegetation I calculated the averages of each of the variables measured (Table 1).

Table 2 presents the averages of the vegetation in the burned and unburned areas. In general the vegetation in both conditions is very similar. However, in the cases of trees, nopals and grasses, the vegetation is taller in the burned areas.

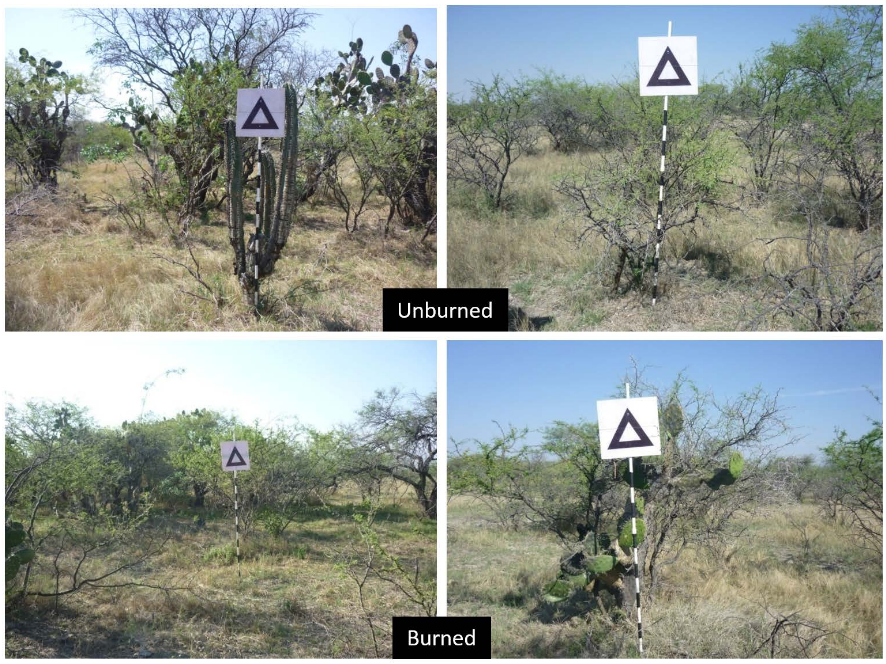

Figure 2. Mezquital and microphyll desert shrub of sites located in burned and unburned areas from polygon F.

Table 1. Variables averages (considering every sampled site) by vegetation type. NE = Not evaluated parameter.

Vegetation type	Height (m)	Crown diameter (m)	Coverage (%)	Density (78.5 m^2)
Tree	2.91	2.85	NE	3.64
Shrub	1.82	1.54	NE	4.11
Cactus	1.65	1.01	NE	1.67
Creeper	3.80	1.10	NE	1.00
Herb	0.20	0.19	2.87	NE
Nopal	1.86	1.45	NE	2.46
Organ pipe catus	1.56	0.70	NE	1.00
Grass	0.17	0.23	32.57	NE

In terms of density, trees presented similar conditions. The same pattern was seen in herbs and grass. However, the density in shrubs was greater in burned areas. On the other hand, the density in cactus was greater in the unburned areas, which also happened with the nopals. Nevertheless, I cannot ascribe these conditions to the presence or absence of fire. But rather correspond to the way in which the natural distribution of the vegetation had prevailed in the region.

The quantitative comparative analysis suggests that, except for crown diameter ($p = 0.0152$), there is no statistically significant differences in vegetation between burned and unburned. However, the final criteria to decide the difference or similarity between conditions was through the results of the "t" test at a α level of 0.05 (**Table 3**). If the computed t-test value is less than the t-test table value

Table 2. Average of the evaluated variables, by vegetation type, corresponding to burned and not burned sites. The first value corresponds to unburned (UB) areas, while the second value corresponds to burned (B) areas. NE = not evaluated parameter; NP = Vegetation type not present.

Vegetation type	Height (m)	Diameter (cm)	Crown diameter (m)	Coverage (%)	Individuals (78.5 m^2)
Tree (UB)	2.68	27.11	2.79	NE	3.50
(B)	3.79	15.50	5.24	NE	3.40
Shrub (UB)	1.98	NE	2.19	NE	3.29
(B)	1.64	NE	1.67	NE	4.71
Cactus (UB)	1.28	NE	0.60	NE	2.00
(B)	1.90	NE	1.10	NE	1.33
Creeper (UB)	NP	NP	NP	NP	NP
(B)	3.80	NE	NE	NE	NE
Herb (UB)	0.24	NE	NE	3.41	NE
(B)	0.17	NE	0.18	2.52	NE
Nopal (UB)	1.69	14.00	1.46	NE	3.20
(B)	2.01	6.11	1.86	NE	1.93
Organ pipe cactus (UB)	1.56	19.00	0.70	NE	1.00
(B)	NP	NP	NP	NP	NP
Grass (UB)	0.15	NE	NE	34.34	NE
(B)	0.18	NE	NE	31.05	NE

Table 3. Results of the *t*-student test (at a 0.05 level) used as the decision criteria to test the hypothesis that there is no difference in vegetation conditions between burned and unburned areas.

Variable	Tree	Shrub	Herb	Grass	Nopal	Fules
Height	0.09147	0.37324	0.25645	0.34380	0.51640	-----
Crown	0.01515	0.38494	-----	-----	-----	-----
Individuals	0.91133	0.35021	-----	-----	0.36332	-----
Density	-----	-----	0.59480	0.40331	0.030896	-----
Weight	-----	-----	-----	-----	-----	0.21805

there is no significant statistical difference between the compared variables. From the values in Table 3, we can infer that in every case the statistic suggests that the vegetation variables between burned areas and unburned areas are the same.

Tree evaluation. A comparative analysis was also performed at the level of the principal vegetation type evaluated: trees. The dominant tree species of the area under study was *Acacia farnesiana* (huizache) In general, the largest trees were found in the burned areas (Table 4). The same is true for density and diameter; even though in the case of density, the number of individuals was very similar. Again, I believe that this was not the result of fire occurrence in the area, but of the natural population dynamics of trees.

Shrub evaluation. The shrub vegetation was represented mainly (99%) by *Acacia farnesiana* (huizache); even though there were some individuals of

Table 4. Statistics of the evaluated variables by vegetation type for the unburned and burned sites.

Condition	Vegetation type	Statistic	Height (m)	Crown diameter (m)	Individuals (78.5 m^2)	Density (%)
Unburned	Tree	Mean	2.460	1.696	3.182	---
		Variance	4.370	1.711	7.364	---
	Shrub	Mean	2.095	1.570	4.182	---
		Variance	0.824	0.613	14.96	---
	Herbs	Mean	0.239	---	---	3.178
		Variance	0.063	---	---	35.63
	Grass	Mean	0.153	---	---	34.28
		Variance	0.017	---	---	806.8
	Nopal	Mean	2.17	1.072	3.200	---
		Variance	1.581	0.223	11.51	---
Burned	Tree	Mean	3.786	2.920	3.400	---
		Variance	0.691	0.201	14.30	---
	Shrub	Mean	1.804	1.330	5.524	---
		Variance	0.562	0.352	12.66	---
	Herb	Mean	0.171	---	---	2.471
		Variance	0.0.41	---	---	16.135
	Grass	Mean	0.181	---	---	29.697
		Variance	0.022	---	---	487.97
	Nopal	Mean	2.530	1.624	2.090	---
		Variance	1.538	0.369	2.491	---

Nicotianaglauca. In this case, shrub vegetation was taller in burned areas, which is the opposite from trees. Nevertheless, the dimensions of the crown diameter were similar. On the other hand, the shrubs density was greater in the burned areas. However, as in previous cases, I believe that this is not the result of fire occurrence in the area, but of the natural population dynamics of shrubs.

Herb evaluation. The herb vegetation was represented by various species (Table 5). As in the case of the shrubs, the height and density measurements of herbs were greater in burned areas (Table 4). Once more I note that this is not the result of fire occurrence in the area; though evaluated, I think that it could be due to the presence of cattle. Nevertheless, in general, burned and unburned areas are considered similar.

Grass evaluation. The grass vegetation is dominated by the species listed in Table 6. On average, grasses were taller in the burned areas. However, this vegetation density was slightly greater in the unburned areas. Though grass height was slightly taller in the burned area, statistically there was no difference between burned and unburned areas. On the contrary, the major variability of

Table 5. Floristic list of herbaceous species present in the area of study.

Family	Gender	Species
Acantaceae	*Tetramerium*	*nervosum*
Aizoaceae	*Sesuvium*	*portulacastrum*
Asteraceae	*Dyssodia*	*papposa*
Asteraceae	*Eupathorium*	*sp.*
Asteraceae	*Tithonia*	*sp.*
Asteraceae	*Galinsoga*	*sp.*
Brassicaceae	*Lepidium*	*oblongum*
Cucurbitaceae	*Apodanthera*	*undulata*
Euphorbiaceae	*Croton*	*ciliato-glandulosus*
Euphorbiaceae	*Ricinus*	*comunis*
Fabaceae	*Trifolium*	*repens*
Lamiaceae	*Salvia*	*tiliifolia*
Lamiaceae	*Leonotis*	*nepetifolia*
Lemnaceae	*Lemna*	*sp.*
Malvaceae	*Sida*	*rhombifolia*
Malvaceae	*Anoda*	*acerifolia*
Musaceae	*Musa*	*sapientum*
Plantaginaceae	*Plantago*	*lanceolata*
Poaceae	*Phragmites*	*australis*
Polemoniaceae	*Loeselia*	*glandulosa*
Polygonaceae	*Polygonum*	*amphibium*
Pontederiaceae	*Eichhornia*	*sp.*
Solanaceae	*Capsicum*	*annuum*
Solanaceae	*Nicotiana*	*glauca*
Solanaceae	*Physalis*	*lagascae*
Solanaceae	*Datura*	*stramonium*
Solanaceae	*Jaltomata*	*procumbens*
Solanaceae	*Solanum*	*elaeagnifolium*
Typhaceae	*Typha*	*domingensis*

Table 6. Floristic list of herbaceous grass species present in the study area.

Family	Gender	Species
Cyperaceae	*Cyperus*	*esculentus*
Cyperaceae	*Schoenoplectus*	*sp.*
Poaceae	*Sporobolus*	*pyramidatus*
Poaceae	*Distichlis*	*spicata*
Poaceae	*Brachiaria*	*mutica*

density was found in unburned areas. This result cannot be attributed to fire occurrence in the area, but to the natural population dynamics of grass.

Nopals evaluation. The nopals vegetation in the study area correspond to the specie *Opuntia atropes*. The measurements of all three variables (density, height, and crown diameter) were very similar. However, the measurements for height and crown diameter were slightly greater in the burned areas. The number of nopals per area (density) was larger in the burned areas. I believe this finding is not the result of fire occurrence in the area, but of the natural manifestation of population dynamics of nopals.

Fuel material evaluation. Forests fuels are composed by woody material of many sizes that vary from small grass and herbs up to big shrubs and trees (Brown et al., 1982), and that may be burn. Prevailing environmental conditions also influence forest fuels and its burnability (Rodriguez, 1996). All the fuel material collected in the 30 × 30 cm squares was evaluated. The material was dried until a constant weight, and measurement in tons per hectare was estimated. This fuel material contains mainly light fuels, formed by grass, dead twigs, dead leaves, herbs (dry and green) and humus (vegetable material in decomposition).

Initially we would expect a decrease of the fuel loads in burned areas. As expected fuel loads were slightly greater in unburned areas. However, the fuel loads means for the unburned and burned areas were very similar (2.704 tn/ha and 2148 tn/ha correspondingly). But the variance values (2.672 tn/ha and 0.821 tn/ha respectively) imply a greater variability in the burned areas. However, I remark that this is not result of the fire occurrence in the area. But rather as product of the distribution of the different vegetation types that are located in the area; which contribute to the production of fuels.

4. Conclusion

The main objective of this research was to determine if fire affected the study area ecosystem to the point in which the structure and density of the vegetation would be different between the burned and unburned sites. Based on our study results, I can conclude that there is no difference in vegetation structure and density conditions between the burned and unburned areas. I could not find any evidence that a fire occurring a year earlier in the study area had permanently altered the vegetation in the area. Though the fire could initially affect the vegetation of grasses and herbs, this vegetation recovered completely after about a year of the fire occurrence. Similarly, from the observed results and the level of impact of the fire evaluated in the study area I can conclude that it was a low intensity fire, which allowed a rapid recovery of the burned vegetation. In addition, after a year, there was no evidence or traces, of the occurrence of a fire in the study area. Finally, in general, the vegetation in both burned areas and unburned areas, showed a healthy condition. It was impossible to appreciate any damage caused by the fire, or any other agent of disturbance.

References

Alexander, M. E. (1982). Calculating and Interpreting Forest Fires Intensities. *Canadian Journal of Botany, 60,* 349-357. https://doi.org/10.1139/b82-048

Anaya, C. M. (1989). *El fuego en la regeneración natural del bosque de Pinus-Quercus en la Sierra de Manantlán, Jalisco*. Bachelor Thesis, Guadalajara: Universidad de Guadalajara.

Bakirci, M. (2010). Negative Impacts of Forest Fires on Ecological Balance and Environmental Sustainability: Case of Turkey. *Journal of Geography, 5,* 15-32.

Bergeron, Y. (2000). Species and Stand Dynamics in the Mixed Woods of Quebec's Southern Boreal Forest. *Ecology, 81,* 1500-1516. https://doi.org/10.1890/0012-9658(2000)081[1500:SASDIT]2.0.CO;2

Boerner, R. (1982). Fire and Nutrient Cycling in Temperate Ecosystems. *BioScience, 32,* 187-192. https://doi.org/10.2307/1308941

Briggs, J. M., Knapp, A. K., Blair, J. M., Heisler, J. L., Hoch, G. A., Lett, M. S., &. McCarron, J. K. (2005). An Ecosystem in Transition: Causes and Consequences of the Conversion of Mesic Grassland to Shrubland. *BioScience, 55,* 243-254. https://doi.org/10.1641/0006-3568(2005)055[0243:AEITCA]2.0.CO;2

Brown, J. K., Oberheu, R. D., & Johnston, C. M. (1982). *Handbook for Inventorying Surface Fuels and Biomass in the Interior West.* USDA Forest Service, General Technical Report INT-129, 48 p.

DeBano, L. F., & Conrad, C. E. (1978). The Effect of Fire on Nutrients in a Chaparral Ecosystem. *Ecology, 59,* 489-497. https://doi.org/10.2307/1936579

DeBano, L. F., Mann,L. D., & Hamilton, D. A.(1970). Translocation of Hydrophobic Substances into Soil by Burning Organic Litter. *Soil Science Society of America, 34,* 130-133. https://doi.org/10.2136/sssaj1970.03615995003400010035x

Fitch, H. S. (2006). Ecological Succession on a Natural Area in Northeastern Kansas from 1948 to 2006. *Herpetological Conservation and Biology, 1,* 1-5.

Flores G., J. G., & Benavides S., J. de D. (1994). Efecto de las quemas prescritas sobre algunas características del suelo en un rodal de pino. *Revista Terra, 12,* 393-400.

Flores G., J.G., & Rodríguez T., D. A. (2006). Incendios Forestales. Definiendo el problema, ecología y manejo, participación social, fortalecimiento de capacidades, educación y divulgación (p. 241). Mundi Prensa.

García, E. (2004). *Modificaciones al sistema de clasificación climática de Köppen* (p. 77). UNAM.

Gollberg, G. E., Neuenschwander, L. F., & Ryan, K. C. (2001). Introduction: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management. *International Journal of Wildland Fire, 10,* 263-265. https://doi.org/10.1071/WF01047

Hall, S. A., Burke, I. C., Box, D. O., Kaufmann, M. R., & Stoker, J. M. (2005). Estimating Stand Structure Using Discrete-Return LiDAR: An Example from Low Density, Fire Prone Ponderosa Pine Forests. *Forest Ecology and Management, 208,* 189-209.

Hickler, T, Smith, B., Sykes, M. T., Davis, M. B., Sugita, S., & Walker, K. (2004). Using a Generalized Vegetation Model to Simulate Vegetation Dynamics in Northeastern USA. *Ecology, 85,* 519-530. https://doi.org/10.1890/02-0344

Hoffmann, W. A. (1999). Fire and Population Dynamics of Woody Plants in a Neotropical Savanna: Matrix Model Projections. *Ecology, 80,* 1354-1369. https://doi.org/10.1890/0012-9658(1999)080[1354:FAPDOW]2.0.CO;2

Ice, G. G., Neary, D. G., & Adams, P. W. (2004). Effects of Wildfire on Soils and Watershed Processes. *Journal of Forestry, 102,* 16-20.

Jardel, P. E. J., Alvarado, E., Morfin, R. J. E., Castillo, N., F., & Flores G. J. G. (2009). Regímenes de fuego en ecosistemas forestales de México. In J. G. Flores, & G. Impacto (Eds.), *Ambiental de Incendios Forestales* (pp. 73-100). Mundi-Prensa.

Keeley, J. E., & Fotheringham, C. J. (2002). Historic Fire Regime in Southern California Shrublands. *Ecology, 15,* 1536-1548.

Moreno, C. E. (2001). *Métodos para medir la biodiversidad*. M&T-Manuales y Tesis SEA.

Moretti, M., Conedera, M., Moresi, R., & Guisan, A. (2006). Modelling the Influence of Change in Fire Regime on the Local Distribution of a *Mediterranean pyrophytic* Plant Species (*Cistus salviifolius*) at Its Northern Range Limit. *Journal of Biogeography, 33,* 1492-1502. https://doi.org/10.1111/j.1365-2699.2006.01535.x

Pausas, J. G. (1998). Modelling Fire-Prone Vegetation Dynamics. In L. Trabaud (Ed.), *Fire and Landscape Ecology* (pp. 327-334). Washington DC: International Association of Wildland Fire, Fairland.

Pausas, J. G., & Keeley, J. E. (2014). Evolutionary Ecology of Esprouting and Seeding in Fire-Prone Ecosystems. *New Phytologist, 204,* 55-65. https://doi.org/10.1111/nph.12921

Peterson, D. W., & Reich, P. B. (2001). Prescribed Fire in Oak Savanna: Fire Frequency Effects on Stand Structure and Dynamics. *Ecological Applications, 11,* 914-927.

Pyne, S. J. (1995). *World Fire; the Culture of Fire on Earth*. Washington DC: University of Washington Press.

Rodríguez, T. D. A. (1996). *Incendios Forestales*. Mundi-Prensa.

Rodríguez, T. D. A., & Sierra, P. A. (1995). Evaluación de los combustibles forestales en los bosques del Distrito Federal. *Ciencia Forestal en México, 20,* 193-218.

Rodríguez, T. D. A., Rodríguez, A. M., Fernández, S. F., & Pyne, S. J. (2002). *Educación e incendios forestales*. Segunda edición, MundiPrensa.

Roques, K. G., O'Connor, T. G., & Watkinson, A. R. (2001). Dynamics of Shrub Encroachment in an African Savanna: Relative Influences of Fire, Herbivory, Rainfall and Density Dependence. *Journal of Applied Ecology, 38,* 268-280. https://doi.org/10.1046/j.1365-2664.2001.00567.x

Sheuyange, A., Oba, G., & Weladji, R. B. (2005). Effects of Anthropogenic Fire History on Savanna Vegetation in Northeastern Namibia. *Journal of Environmental Management, 75,* 189-198. https://doi.org/10.1016/j.jenvman.2004.11.004

Stocks, B. J., Mason, J. A., Todd, J. B., Bosch, E. M., Wotton, B. M., Amiro, B. D., Flannigan, M. D., Hirsch, K. G., Logan, K. A., Martell, D. L., & Skinner, W. R. (2002). Large Forest Fires in Canada, 1959-1997. *Journal of Geophysical Research, 107,* 1-12.

Syphard, A. D., Franklin, J., & Keeley, J. E. (2006). Simulating the Effects of Frequent Fire on Southern California Coastal Shrublands. *Ecological Applications, 16,* 1744-1756. https://doi.org/10.1890/1051-0761(2006)016[1744:STEOFF]2.0.CO;2

Turner, M. G., Romme, W. H., Gardner, R. H., & Hargrove, W. W. (1997). Effects of Fire Size and Pattern on Early Succession in Yellowstone National Park. *Ecological Monographs, 67,* 411-433. https://doi.org/10.1890/0012-9615(1997)067[0411:EOFSAP]2.0.CO;2

Uhl, C., & Kauffman, J. B. (1990). Deforestation, Fire Susceptibility, and Potential Tree Responses to Fire in the Eastern Amazon. *Ecology, 71,* 437-449. https://doi.org/10.2307/1940299

Uhl, C., Clark, K., Clark, H., & Murphy, P. (1981). Early Plant Succession after Cutting and Burning in the Upper Rio Negro Region of the Amazon Basin. *Journal of Ecology, 69,* 631-649. https://doi.org/10.2307/2259689

Varner, J. M., Gordon, D. R., Putz, F. E., & Hiers, J. K. (2005). Restoring Fire to Long-Unburned *Pinuspalustris* Ecosystems: Novel Fire Effects and Consequences for Long-Unburned Ecosystems. *Restoration Ecology, 13,* 536-544. https://doi.org/10.1111/j.1526-100X.2005.00067.x

Varner, J. M., Hiers, J. K., Ottmar, R. D., Gordon, D. R., Putz, F. E., & Wade, D. D. (2007). Overstory Tree Mortality Resulting from Reintroducing Fire to Long-Unburned Longleaf Pine Forests: The Importance of Duff Moisture. *Canadian Journal of Forest Research, 37,* 1349-1358. https://doi.org/10.1139/X06-315

Villers Ruíz, M. de L. (2006). Incendios Forestales. *Ciencias, 81,* 60-66.

Young, J. A., & Evans, R. A. (1978). Population Dynamics after Wildfires in Sagebrush Grasslands. *Journal of Range Management, 31,* 283-289. https://doi.org/10.2307/3897603