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Regeneration in *Quercus Pyrenaica* Ecosystems After Surface Fires

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Abstract. Early post-fire structural dynamics in three *Quercus pyrenaica* communities after intense fires was studied. In the first year there is a marked domination of perennial species (herbaceous or woody); afterwards, herbaceous species tend to decrease in importance and ligneous species increase. Changes in species diversity were analysed as an indicator of recovery and stability in the communities. An increase was observed in the second year, and then diversity was maintained or reduced slightly in the third and fourth years. Spatial heterogeneity tends to diminish with time.

Keywords: Fire; Regeneration; *Quercus pyrenaica*; Species diversity; Spatial heterogeneity.

Introduction

At present, forest fires are considered to be the main cause of disturbances of the natural environment in the Mediterranean Basin countries. Because of its ecological and demographic conditions, Spain appears to represent one of the most serious cases in this part of the world.

Quercus pyrenaica is a species whose distribution area is basically the Iberian Peninsula (fig. 1). This species is of ecological importance because it has intermediate characteristics between the typical Mediterranean sclerophyllous species (*Quercus ilex*) and the clearly deciduous species (*Fagus sylvatica, Quercus petrea*). As far as the burnt surface area is concerned, the *Quercus pyrenaica* communities represent 0.1% of Spain (I.C.O.N.A. 1985). However, in the province of Leon they constitute one of the forests which are most affected by fires. In 1984 they accounted for 51% of burnt forest area and more than 81% if we exclude the conifer plantations. In the period 1974-83, a mean of 2850 ha of oak forest was burnt every year (Tarrega 1986).

Although forest fires have increased considerably over the last few years, they have always occurred in Mediterranean-type ecosystems (Naveh 1974, 1990). Frequently, the species composition after the fire is similar to that which existed previously (Casal 1987; Trabaud 1987a; Mazzoleni and Pizzolongo 1990). The majority of the species possess adaptative traits which allow them to regenerate after the fire, although it is often difficult to say which traits are specifically an adaptation to fire (Trabaud 1987b). Vegetative reproduction, for example, is also efficient in the face of cutting and grazing or browsing.

Since ancient times, *Quercus pyrenaica* communities have been subject to fire, cutting, and grazing pressures. Consequently, communities contain many species that sprout from belowground parts (Tarrega and Luis 1989). In those forests where the trees are well-developed and survive forest fires, a few years after the fire no differences in plant recovery and structure are noted with respect to forest which have not been burnt (Tarrega and Luis 1987).

This paper aims to analyse post-fire dynamics in *Quercus pyrenaica* ecosystems where small oak trees, whose above-ground parts were destroyed, are dominated.

Materials and Methods

Figure 1 includes the distribution of *Quercus pyrenaica* as well as the climate diagrams of Leon city and Cistierna village, two localities situated near the sampled areas. The plots are located in three areas in the province of Leon that were burned at different times. The first area is in Palacios de Rueda (M.T.U. 30TUN2324), situated near the mountainous region, on a very gentle slope, at an elevation of approximately 1150 m. This area was burnt in the summer of 1985. The second area, called Santovenia (M.T.U. 30TTN9526), is situated on a gentle slope facing S-SE, at an elevation of 970 m, that was burnt in the spring of 1986. The third study area, Santa María (M.T.U. 30TTN9830), is located on a steep north-facing slope at an elevation of approximately 950 m. The fire occurred in the summer of 1986.

The study was carried out on permanent plots so as to

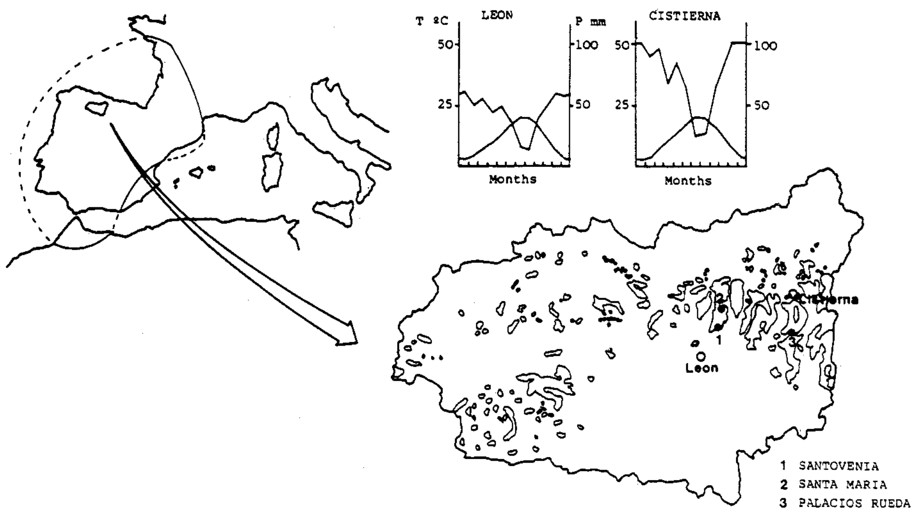

Figure 1. Distribution area of *Quercus pyrenaica* and approximate location in León province (Mapa Forestal de España, 1966). Climate diagrams of two sites situated near the sampling plots.

avoid the interference of spatial variability, and to be able to follow annually in July from 1986 to 1990 the temporal development of vegetation. In each area, a 25 x 5 m plot was established. In each plot, 25 one square metre inventories were made as percent cover of all the species and of bare ground.

Calculations included the species diversity (H'α), and the global diversity in the plot (H'γ), by means of Shannon-Weaver index (1949).

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

Where p_i = Probability of finding species i.
s = Number of species.

Diversity components: richness, or number of species, and evenness (H'/H'max) were also determined (Pielou, 1969). The annual values were compared by means of repeated measures analysis of variance.

Spatial heterogeneity (ß diversity) was calculated by Margalef formula (Margalef 1972).

$$\text{Het.} = H'\gamma - \sum_{i=1}^{n} H'\alpha i / n$$

Where H'γ = Total diversity in the plot.
H'αi= Diversity of each inventory of that plot.
n = Number of inventories in that plot (25).

The affinity values between the areas for each sampling year were calculated by means of an association analysis, using the index attibuted to Steinhous by Motyka et al. (1950).

$$S(x_1,x_2) = 2w\ 100 / A+B$$

Where w = Sum of the lowest cover value of the species present in the two samplings x_1 and x_2.
A = Total cover value in sampling x_1.
B = Total cover value in sampling x_2.

The results were grouped together using the arithmetic average clustering, or UPGMA method (Sokal and Michener 1958).

Results and Discussion

Since the fire occurred (Figure 2), post-fire life form percentage show a clear predominance of perennial species in the first sampling. The greatest number of annual species were found in the second year after the fire in Palacios de Rueda and Santá Maria, and in the first year in Santovenia, where the fire occurred in spring.

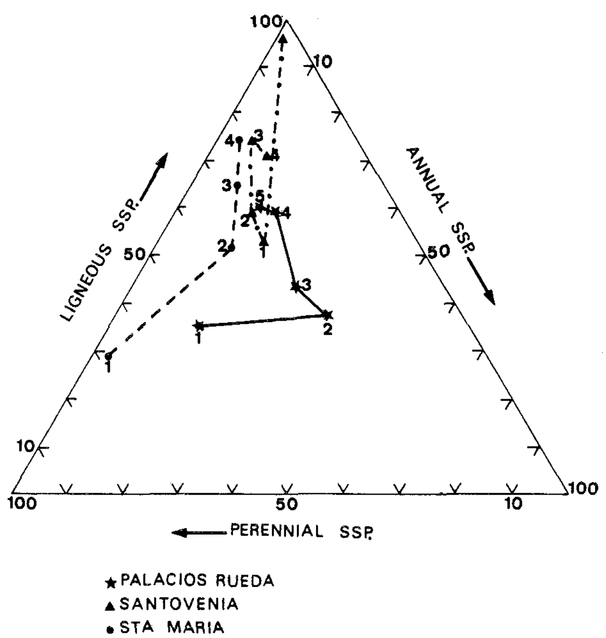

Figure 2. Percentage of plant life-forms in the three areas studied. The numbers indicate years after the fire.

In the first year, there was a predominance of species characteristics of the community, capable of rapid sprouting. By the end of one or two years, seed from pioneer species germinated and then were replaced. This coincides with the observations of several authors (Dymess 1973; Debussche et al. 1980; Trabaud 1980; Casal et al. 1984).

In the last year of sampling, there was a clear tendency towards an increase of woody species. *Quercus pyrenaica* in Santa María and in Palacios de Rueda (Table 1) was predominant. In Santovenia, the most degraded area, few oak shoots were observed even before the fire, and the dominant ligneous species was *Chamaespartium tridentatum*. The high percentage of ligneous species a few months after the fire, is due to the pre-fire dominance of this species.

Mean values of diversity (average H'∝ values in the 25 inventories of each plot and sampling period) usually showed a maximum in the second year after the fire, although in Palacios de Rueda the values continued to increase until the fourth year (Table 1).

Species richness in the three areas was minimum for the first sampling and maximum in the fourth year. The temporal pattern for evenness was not so clear. It was very low a few weeks after the fire in Santovenia (the only area in which information was available on that date). However, in the following years, the fast growth and the dominance of the ligneous species led to a decrease in evenness. This was observed in Santa María and explained why diversity did not continue to increase after the second year, despite the increase in the number of species.

Comparisons by means of repeated measures analysis of variance and the application of the Tukey test detected significant differences (confidence interval of 95%) in the diversity, richness and evenness values between different areas with the same post-fire age (Table 2). This confirms that space-temporal extrapolations are not reliable in regeneration studies in these communities (Tarrega and Luis 1987).

Differences in the diversity values between the first sampling carried out in each plot (after a few months in

Table 1. Mean values over time (over 25 subplots) of species richness, evenness and diversity in the three study areas. Total cover in the plots and percentage of cover by *Quercus pyrenaica* and total species richness, evenness, diversity and heterogeneity are provided for each plot.

	MEAN VALUES			TOTAL VALUES IN THE PLOT					
	RICH.	EVEN.	DIV.	COV.	%Q.p.	RICH.	EVEN.	DIV.	HET
PALACIOS RUEDA									
1 year	4.8	0.78	1.73	11.6	31.0	23	0.74	3.36	1.63
2 years	10.6	0.69	2.24	63.4	29.9	35	0.64	3.27	1.03
3 years	14.7	0.71	2.72	94.3	31.0	33	0.73	3.68	0.93
4 years	18.4	0.73	3.01	81.8	33.5	42	0.70	3.78	0.72
5 years	17.4	0.73	2.99	81.2	30.8	42	0.73	3.86	0.87
STA. MARIA									
1 year	5.1	0.80	1.75	16.4	12.3	20	0.74	3.18	1.43
2 years	11.3	0.79	2.72	87.4	23.9	36	0.73	3.77	1.06
3 years	11.1	0.69	2.39	95.6	24.5	39	0.65	3.46	1.07
4 years	13.7	0.68	2.54	93.0	29.2	50	0.61	3.46	0.92
SANTOVENIA									
3 months	0.3	0.07	0.12	5.0	0.8	6	0.18	0.48	0.36
1 year	9.9	0.76	2.50	41.8	0.2	26	0.68	3.22	0.70
2 years	11.7	0.73	2.57	104.2	0.1	28	0.65	3.15	0.58
3 years	10.0	0.61	2.01	98.6	0.2	26	0.52	2.43	0.42
4 years	13.2	0.64	2.34	113.9	0.6	45	0.51	2.82	0.47

Table 2. Tables of Repeated Measures analysis of variance to compare richness, evenness and diversity values in the three study areas (only values from one to four years after the fire were used in the analysis).

RICHNESS

Source:	df:	Mean squ.:	F-test:	P value:
Site (A)	2	82.813	6.54	0.0025
Subjected w. groups	72	12.660		
Repeated Measure (B)	3	921.390	171.77	1.0E-4
AB	6	164.573	30.68	1.0E-4
B x Subjected w. groups	216	5.364		

EVENNESS

Source:	df:	Mean squ.:	F-test:	P value:
Site (A)	2	0.077	3.11	0.0509
Subjected w. groups	72	0.025		
Repeated Measure (B)	3	0.187	17.62	1.0E-4
AB	6	0.038	3.55	0.0022
B x Subjected w. groups	216	0.011		

DIVERSITY

Source:	df:	Mean squ.:	F-test:	P value:
Site (A)	2	0.180	0.39	0.6764
Subjected w. groups	72	0.459		
Repeated Measure (B)	3	5.707	34.64	1.0E-4
AB	6	4.051	24.59	1.0E-4
B x Subjected w. groups	216	0.165		

Santovenia and after a year in the other two areas) and all the others were statistically significant. The mean diversity value obtained in Santovenia in the sampling carried out one year after the fire, was almost as high as that corresponding to the second year, which did not occur in the other two areas. Thus, season of fire occurrence influences community regeneration, supporting the conclusions of Trabaud (1980).

The increase in species richness in the fourth year was statistically significant in all cases. However, in Palacios de Rueda, in the fifth year, a tendency towards stabilization was observed, although it was not possible to generalize since data from the other two areas were still not available.

A considerable increase in plant cover until the second year was observed as far as the global values were concerned (Table 1). This continued in the following year in Palacios de Rueda and Santa María, although to a lesser extent. Global diversity (H'γ) reached its maximum value in the second year after the fire in Santa María. In Santovenia global diversity reached its maximum value in the first year, which was very similar to that of the second year. In Palacios de Rueda global diversity gradually increased until the fifth year. The total number of species in all the plots reached its maximum in the fourth year.

The values corresponding to spatial heterogeneity decreased with time in all three areas. Fire usually increases spatial heterogeneity (Anderson 1982), since it burns with different degrees of intensity in different patches.

In the cluster analysis, samples from different years, but the same area, were more similar to each other than they were to samples from the same year, but different sites (Figure 3). This agrees with what had been observed in post-fire regeneration in this type of community, when surviving trees predominate (Tarrega and Luis 1987). Nevertheless, the similarity between the results after one year after the fire in Palacios de Rueda and Santa Maria must be emphasized. These two areas were the most similar, whereas the results of Santovenia formed a separated group. The samplings which showed greater affinity were those carried out in the last years, which indicated that the main changes in the communities occurred in the first years after the fire.

Conclusion

Post-fire regeneration follows an autosuccession process, thus species composition quickly assumes pre-fire species composition. This is similar to observations of several authors working in Mediterranean-type ecosystems (Tarrega and Luis 1987, 1989; Trabaud, 1987a; Mazzoleni and Pizzolongo 1990).

Although it is difficult to establish comparisons since we are dealing with very heterogeneous ecosystems, the greater removal of biomass, the greater is the time of

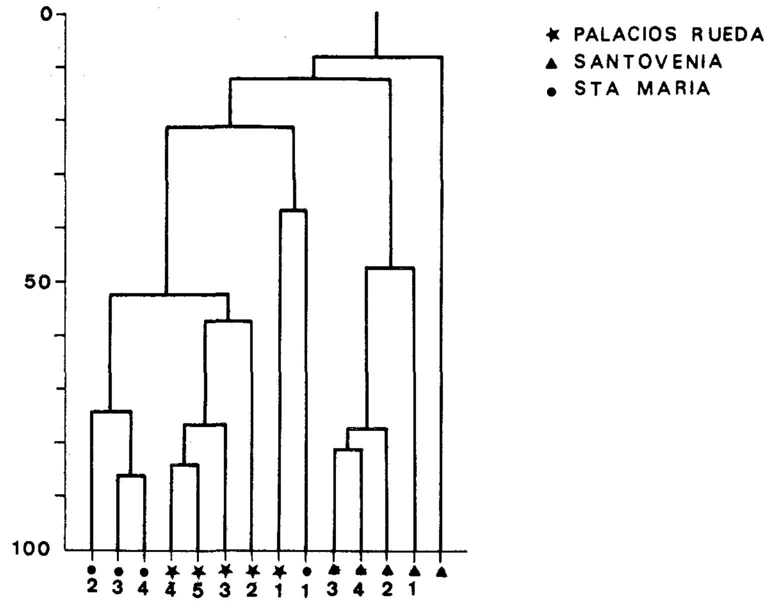

Figure 3. Affinity relations between the surveys in the studied areas. The numbers on the x axis indicate years after the fire in each survey.

recovery. This is detected, not only in its physiognomic aspect (the oak shoots do not normally exceed 2 m in height) but also in the species richness values, which continue to increase until the fourth year. In areas with surviving aboveground parts of the oaks and less biomass removal, the greater number of species are found in the second or third year after the fire (Tarrega and Luis 1989).

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References

Anderson, S.H. 1982. Effects of the 1976 Seney National Wildlife Refuge wildfire on wildlife and wildlife habitat. U.S. Department of Interior, Fish and Wildlife Service Resource Publication. 146 p.

Casal, M. 1987. Post-fire dynamics of shrublands dominated by Papilionacea plants. Ecologia Maditerranea XIII (4): 87-89.

Casal, M., M. Basanta and F. Garcia-Novo. 1984. La regeneracion de los montes incendiados en Galicia. Monografias de la Universidad de Santiago. 99 p.

Debusche, M., J. Escarre and J. Lepart. 1980. Changes in mediterranean shrub communities with Cytisus purgans and Genista scorpius. Vegetatio 43: 73-82.

Dyrness, C.T. 1973. Early stages of plant succession following logging and burning in the Western Cascades of Oregon. Ecology 54: 57-69.

I.C.O.N.A. 1985. Los incendios forestales en España durante 1984. Ministerio de Agricultura, Pesca y Alimentacion.

Margalef, R. 1972. El ecosistema. In: Ecologia marina. Ed. Dossat.

Mazzoleni, S. and P. Pizzolongo. 1990. Post-fire regeneration patterns of Mediterranean shrubs in the Campania Region, Southern Italy. In: Fire and ecosystems dynamics. Ed. J.G. Goldammer and M.J. Jenkins. SPB Academic Publishing. The Hague. p. 43-51.

Motyka, J., B. Dobrzanski and S. Zawadski. 1950. Preliminary studies on meadows in the Southeast of the Province Lublin. Ann. Univ. Mariae Cirie Sklodowska. Sect. E: Agricultura 5: 367-447.

Naveh, Z. 1974. Effects of fire in Mediterranean Region, In: Fire and Ecosystems. Editor T.T. Kozlowski and C.E. Ahlgren. Academic Press. New York. p. 401-434

Naveh, Z. 1990. Fire in the Mediterranean - A landscape ecological perspective. p. 1-20, In: Fire and ecosystems dynamics. Editor J.G. Goldammer and M.J. Jenkins. SPB Academic Publishing. The Hague.

Pielou, E.C. 1969. An introduction to mathematical ecology. John Wiley, New York.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, Illinois.

Sokal, R.R. and C.D. Michener. 1958. A statistical method for evaluating systematic relationships. University of Kansas Science Bulletin 38: 1409-1438.

Tarrega, R. 1986. Regeneracion post-fuego del estrato herbaceo en robledales de *Quercus pyrenaica* en la provincia de Leon. Doctoral dissertation, University de Leon.

Tarrega, R. and E. Luis. 1987. Effects of fire on structure, dynamic and regeneration of *Quercus pyrenaica* ecosystems. Ecologia Mediterranea 13(4): 79-86.

Tarrega, R. and E. Luis. 1989. Sucesion post-fuego y mecanismos de supervivencia en comunidades de *Quercus pyrenaica* de la provincia de Leon. Options Mediterraneennes - Serie Seminaires 3: 137-140.

Tarrega, R., L. Calvo and E. Luis. 1989. Fire as a stressor. Comparative effects on climax and degraded *Quercus pyrenaica* communities. International Congress on Forest Decline Research. Friedrichshafen (F.R.G.). p.179-180.

Trabaud, L. 1980. Impact biologique et ecologique des feux de vegetation sur l'organisation, la structure et l'evolution de la vgtation des zones de garrigue du Bas Languedoc. These de Doctorat d'Etat. Univ. des Sciences et Techniques du Languedoc.

Trabaud, L. 1987a. Natural and prescribed fire: survival strategies of plants and equilibrium in mediterrenean ecosystems. In: Plant Response to Stress. Editor J.D. Tenhunen, F.M. Catarino, J.L. Lange and W.C. Oechel. Springer-Verlag. Berlin. p. 607-621.

Trabaud, L. 1987b. Fire and survival traits of plants. In: The role of fire in ecological systems. SPB Academic Publishing. The Hague. p. 65-89.