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Effects of fire on structure, dynamics and regeneration of Quercus pyrenaica ecosystems.

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SUMMARY - Post-fire regeneration is studied in forty-three communities of Quercus pyrenaica in the province of Leon (Spain) burned by surface fires from a few weeks up to 60 years before the sampling, and is compared with four zones which have not been burned. A greater similarity in floristic composition is clearly to be seen in the different phases of one same community than between different communities with the same age of regeneration. The vegetation prior to the fire conditions, therefore, is to a great extent the one which will arise after it, the process constituting a compensatory autosuccession of the regression suffered.

Specific diversity increases in the first years, due mainly to an increase in species richness, showing later values more in accordance with each specific zone than to the time which has elapsed since the fire. All the communities studied are very heterogeneous, but the action of the fire can be seen as an additional generating factor of heterogeneity a few weeks after the burning.

From all this, it can be deduced that these communities have been adapted to fire for a very long time and that most of the species have developed selective mechanisms to regenerate themselves quite effectively after the fires.

KEYWORDS : post-fire regeneration, Quercus pyrenaica, autosuccession, diversity, heterogeneity.

INTRODUCTION

Due to the increment of the great number of fires detected in the last few years, above all in the Mediterranean zones, the theme of forest fires has acquired a considerable importance nowadays. Nevertheless, this phenomenon, although it has increased in the last few decades, does not constitute something exceptional, rather it is a normal ecological factor, which has influenced the dynamics of the ecosystems of these zones for a very long time. Even before the appearance of man, fires were produced by lightning. Fire frequency increased later on by the action of farmers and shepherds. This has conditioned the development of a vegetation adapted to resist fire, and which usually resprouts immediately after the burning. The shrubby formations proper to the Mediterranean climates which are adapted to more or less periodical fires, are numerous, e.g. the Californian chaparral (BISWELL 1974, PARSONS 1976, KEELEY & KEELEY 1981) and the maquia and garrigue in France (TRABAUD 1980, TRABAUD & LEPART 1980), Israel (NAVEH 1974) and Greece (PAPANASTASIS 1977, 1978).

The communities of Quercus pyrenaica discussed here cannot really be considered as bushes, but in most cases they cannot be considered as real woods either, because they are usually very much altered and the shrubby forms are predominant. In the zone studied, they are situated between the phytogeographic Mediterranean region and the Eurosiberian region (RIVAS et al. 1984). Their present state of degradation is due mostly to human activity, which includes the frequent fires, some of which must have been accidental, which would have extended from the neighbouring pasture grounds, and others ignited on purpose to make the area more practicable for cattle.

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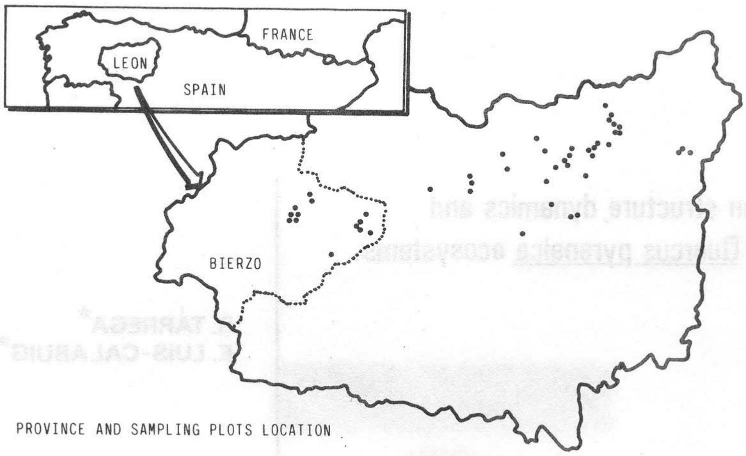

PROVINCE AND SAMPLING PLOTS LOCATION

The main aim of the present study is centred, therefore, on the effects of fire on the structure, dynamics and regeneration of these ecosystems with the view of determining their degree of adaptation to the fires. The ideal in this type of study is to follow the evolution of the same communities through time, but as this is often impossible, it is necessary to revert to space-temporal extrapolations. Nevertheless, we have at our disposal the real temporal evolution of the vegetation, for three consecutive years for some zones, and also including amongst them a spectrum ranging from a month to eight years.

MATERIAL AND METHOD

Description of the study zone

A total of 47 communities were studied, all of them located in the province of Leon (Spain). Thirteen of them were situated in the region of El Bierzo, with a microclimate of its own, defined by a higher level of humidity and more temperate temperatures; they have been designated as BA, BB, BC, BD, BE, BF, BG, BH, BI, BJ, BK, BL and BM respectively. The other 28, in the North-west of the province, are coded with the letters of the alphabet from A to Z; 18 of these, the most recently burned or of a larger extension, were sampled for three consecutive years, placing before their code letter the numbers 1, 2 or 3, corresponding to the first, second or third sampling. In 1A' it was impossible to carry out inventories because no vegetation had sprouted. Those named as PA, PB and PC are those burned at an earlier date, though for the last two, part of them was burnt again recently, and both phases of each community have been sampled. The remaining three, NQ1, NQ2 and NQ3 belong to zones which, according to the information available, had never suffered a fire. The location of these zones can be seen in Fig. 1, and the UTM coordinates, the date of the fire and the sampling, as well as some general characteristics, in Table I. Zones BI, BJ and BK suffered two fires within the stated period.

All of them were surface fires allowing the survival of a great part of the trees.

Sampling method

In each zone, an average of ten inventories carried out at random were performed, with a square sampling unit of 50 cm a side. In each unit the data of the species present were collected, and their degree of importance was expressed in terms of cover average. The main aim of these inventories was the analysis of the herbaceous vegetation, theoretically the most sensitive to the perturbations and the post-fire dynamics unfortunately well known in these ecosystems. Nevertheless, the bushes of small size, even the sprouts of shrubby or arboreous species included in the sampling units, were also registered.

Table I - Definition of geographical characteristics and date of burning and sampling of the studied zones.

ZONES	SITE	UTM COORDINATES	YEAR OF BURNING	YEAR OF SAMPLING	EXPOSURE	ALTITUDE	SLOPE
BA	Sta. Ma. del Sil	29TQH057253	1970-1982	1982	NW	700-800	Quite pronounced
BB	Toreno	29TQH059294	1972	1982	W	700-800	Very pronounced
BC	Toreno	29TQH019352	1972	1982	NE	750-900	Very pronounced
BD	Pardamaza	29TQH069389	1973	1982	SE	1300	Light
BE	Pardamaza	29TQH086370	1970	1982	SW	1300-1400	Variable
BL	Valdelaloba	29TQH021277	-	1982	-	700	Imperceptible
BM	Toreno	29TQH028335	1970	1982	N-NE	700-800	Very light
BF	Almagarinos	29TQH254300	1966	1982	N-NE	900-1000	Very pronounced
BG	Almagarinos	29TQH251305	1975	1982	N-NW	950-1000	Quite pronounced
BH	Almagarinos	29TQH246306	1966	1982	E	1000	Variable
BI	Sta. Marina	29TQH156187	1973-1979	1982	N	700-800	Quite pronounced
BJ	Pobladura	29TQH280318	1958-1980	1982	NW	1000	Quite pronounced
BK	Tremor de Abajo	29TQH252233	1963-1978	1982	NE	900-1000	Very pronounced
V	La Omanuela	30TTN553404	1979?	1982	E	1100	Quite pronounced
NQ1	Quintanilla	30TTN682401	-	1982	N	1000-1100	Quite pronounced
X	Garano	30TTN699425	1978	1981-83	S-SW	1100	Very light
Y	Vega Caballeros	30TTN686445	1980?	1981-83	W-SW	1000-1100	Variable
Z	Carbajal	30TTN871240	1981	1981-83	W	900	Very light
A'	Sta. Ma.del Monte	30TTN996292	1981	1981-83	SE	960	Very light
A	Sta. Ma.del Monte	30TUN026306	1980?	1981-83	-	960	Imperceptible
P	Ruiforco	30TTN953347	1978	1981-83	W y N	950-1050	Variable
O	Pedun y Pardavé	30TTN947413	1978?	1981-83	E	1000	Variable
N	La Valcueva	30TTN977467	1978	1981-83	NW	1100-1200	Quite pronounced
NQ2	Vegaquemada	30TUN083421	-	1982	S	950	Very light
LL	Campohermoso	30TUN018469	1979	1981-83	N y NW	1100	Quite pronounced
M	Campohermoso	30TUN017846	1978 o 79?	1981	S	1200	Quite pronounced
B	Bonar	30TUN115520	1980	1981-83	E-NE y N	1000-1100	Very pronounced
NQ3	Oville	30TUN095520	-	1982	N	1100-1200	Very pronounced
C	Bonar	30TUN110525	1978?	1981	SE	1000-1100	Very pronounced
D	Valdecastillo	30TUN113540	1978?	1981	SE	1100	Quite pronounced
E	Vegamian	30TUN155557	1981	1981-83	NW	1300-1400	Very pronounced
F	Lodares	30TUN167576	1978?	1981-83	S	1200	Very pronounced
G	Pallide	30TUN176580	1978?	1981-83	SW	1100-1200	Quite pronounced
H	Pallide	30TUN179576	1978?	1981	NW y W	1150-1250	Quite pronounced
I	Orones	30TUN175588	1980 o 81?	1981	W	1250	Quite pronounced
J'	Orones	30TUN173595	1980?	1981	SW	1200-1300	Quite pronounced
J	Orones	30TUN173603	1979 o 80?	1981-83	W y W-SW	1400	Quite pronounced
Q	Cofinal	30TUN127666	1978 o 79?	1981	W y SW	1300-1400	Variable
K	Valdepiélago	30TUN038505	1979	1981-83	E-SE	1100-1250	Quite pronounced
L	Nocedo	30TUN036535	1980?	1981-83	S	1300-1450	Quite pronounced
R	Vegacervera	30TTN937524	1979?	1981	S	1150-1200	Light
S	Felmin	30TTN925552	1979?	1981	S-SE	1100-1200	Quite pronounced
T	Puente de Alba	30TTN244442	1979?	1981-83	N y E	1000-1100	Variable
U	Buiza	30TTN805521	1975	1981-83	E-NE	1200-1300	Variable
PA	Prioro	30TUN386539	1920?	1982	S	1200-1300	Very light
PB	Prioro	30TUN358501	1962-1978	1982	S y NE	1200	Variable
PC	Prioro	30TUN417514	1965-1978	1982	NW	1250-1400	Very pronounced

<u>Statistic treatment</u>

Due to the enormous amount of data collected, a statistic analysis to quantify and thus clarify the information was considered necessary. For this, an average cover of the species in the total of the inventories belonging to each community and sampling is employed, except for those communities where we have no certainty about the year of the burning.

Three affinity analyses between the different groups of samplings are carried out: a temporal analysis, considering the samplings in order to their ages distinguishing between samplings with ages of post-fire regeneration ranging from one to three years; between samplings over three years after the fire; and a third analysis among communities located in El Bierzo, because of the peculiar characteristics of this region. For this, an index attributed to Steinhaus by MOTYKA *et al*. (1950), which is applied with quantitative variables, is used, and it is expressed with the formula:

$$S_{(x_1, x_2)} = \frac{2w}{A+B} 100$$

where w = summation of the lowest cover value of the species present in the two samplings x_1 and x_2.

A = summation of all the cover values of all the species present in sampling x_1.

B = summation of all the cover values of all the species present in sampling x_2.

The results obtained are grouped together by means of the UPGMA method (SOKAL & MICHENER 1958) and are represented graphically in form of dendrograms.

The specific diversity is also calculated by the information index of SHANNON-WEAVER (1949):

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

where p_i = probability of finding species i.

s = n° of species.

Their evolution over the course of time as well as their components, richness and uniformity are studied.

The heterogeneity of each sampling is also studied by means of a modified expression of the formula of MARGALEF (1972):

$$\text{Het.} = H'_T - \frac{\sum_{i=1}^{n} H'_{\alpha_i}}{n}$$

where H'_T = diversity of the sampling according to the Shannon-Weaver index.

$H'_{\alpha}i$ = diversity of each inventory of that sampling.

n = number of inventories performed in that sampling.

RESULTS AND DISCUSSION

In the affinity analysis of the samplings out from one month to three years after fire, we can see the biggest difference in the floristic composition of the other samplings compared with 1E and 1Z, where there were only a few weeks of regeneration, where the soil without vegetation is predominant, and with only a few perennial species, which differ in both cases as these 2 samplings do not associate with each other. The predominance of the vivacious species (TARREGA 1986), with only three annual species out of the 16 registered, suggests, in both cases, that most of them resisted the fire fundamentally by means of underground organs, from which plants rapidly sprouted. This is a phenomenon quoted by numerous authors (DEBUSSCHE et al. 1980, TRABAUD 1980, CASAL et al. 1984).

The separation of the samplings belonging to zone A' can also be appreciated from the dendrogram, which can be explained by the great abundance of *Cistus laurifolius* and *Ornithopus compressus* in it, which practically do not appear in the others, as well as by the large predominance of annual species which penetrate from the neighbouring pasture grounds, due to the lesser density of trees in this community, and which conditions a quite different floristic composition (Fig. 1).

Taking into account the remaining areas, which have in common that small sprouts of oak trees are found in them, we can distinguish two sub-groups. The first one is characterized by the presence of *Chamaespartium tridentatum*, which does not appear in the areas which are part of the other sub-group. The great abundance of *Melampyrum pratense* also stands out, which conditions the union of 2E, 3E, 1LL and 2LL. In the second group the biggest similitude appears between group 2Z and 3Z, which are the only samplings in which *Thapsia villosa* is present.

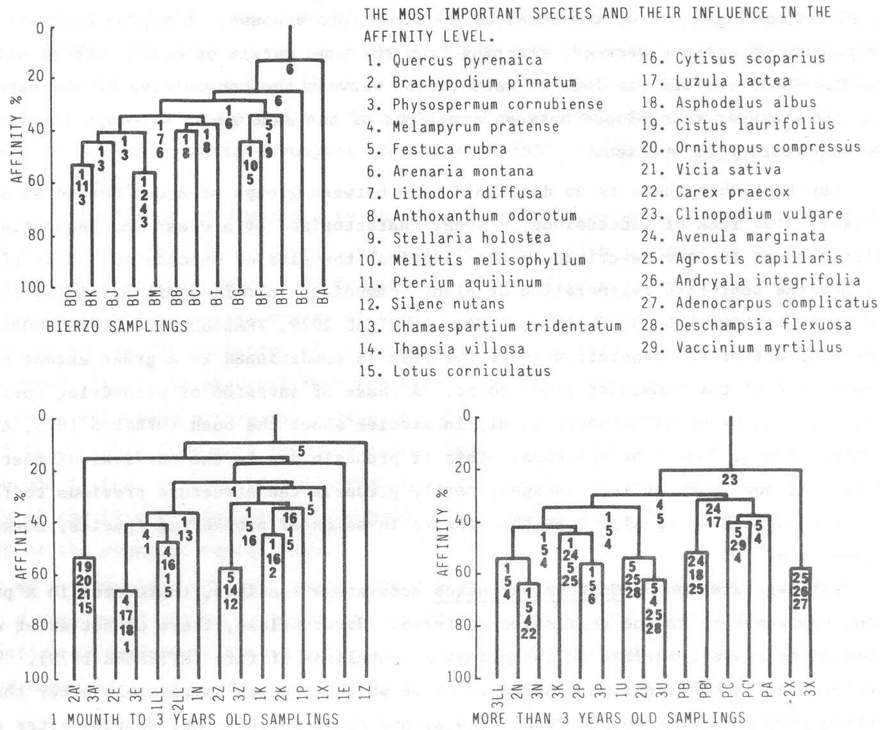

Fig. 1.- Affinity relations for three different analysis.

It can be appreciated that the association between the zones is not determined by the time that has elapsed since they suffered the fire, with the exception of the communities with only a few weeks of recovery which, for this reason, do not follow the same trend as the others. A preferential grouping can be detected in the other cases among the different samplings of a same area, which shows a greater resemblance among the different phases of a same community than among the samplings of the same age belonging to different zones.

In the dendrogram pertaining to the communities burnt at an earlier date (more than a three year post fire period) the connection between the samplings from a same zone is also apparent even where there are great differences in the age of regeneration, as in the case of PB and PC. The pair 2Z-3Z, differs from the others because it lacks Melampyrum pratense, a species highly abundant in the others. The influence of the geographic proximity in the associations can be observed, as in the group of areas located near the village of Prioro (PA, PB and PC) though this is not a general rule. The influence of many other factors which condition the floristic composition cannot be denied, the most important being connected to each specific area.

Similar results are obtained in the affinity analysis of the zones located in El Bierzo. The largest affinity group (BD, BK, BJ, BL and BM) is characterized by the presence of Physospermum cornubiense, a species which does not occur in the others. In the remaining groups the union is determined by the total of the species rather than by the exclusive apparition of one which makes them differ from the others. The association of the different zones in some cases is caused by the geographic proximity which conditions similar microclimatic and edaphic characteristics for vegetation, but in most cases it depends on the complex interaction of multiple factors, such as the orientation of the slope, the density and size of the trees, etc. It seems clear that the time elapsed since the attack of the fire is just one of the factors of this group. That it is not one of the most important factors is illustrated by the fact that no connection can be detected between the three areas which suffered a fire again more recently, (BI, BJ and BK) and the area which did not suffer the fire (BL) is not to be distinguished from the remaining ones (Fig. 1).

Global analysis of all zones (those with an approximate date of burning as well) were carried out, determining the similitude in relation to the Euclidean distance and using a computer for that purpose. Because of the great magnitude of the species found in all zones (339) which exceeded the capacity of the computer, it was necessary to leave aside the species which were found in less than five samplings, out of the total of 80 taken into account. A factor analysis in the principal components was also performed, starting from the same matrix of data. The results obtained (TARREGA 1986) confirm the lack of association between the communities of the same age of regeneration, and a bigger resemblance between samplings of the same zone, although the latter is masked by the suppression of species.

The fact that there is no discrimination between groups of areas burned at similar dates shows clearly the lack of successional stages, characterized by a clear and sequential floristic relay such as the one described in the classical theories of succession. Most of the authors who study the post-fire regeneration of plant communities obtain similar results (METHVEN et al. 1975, PURDIE & SLATYER 1976, SAUER 1977, OHMANN & GRIGAL 1979, TRABAUD 1980, 1986, NOBLE 1981, etc.). The development of the vegetation after the fire is conditioned to a great extent by the floristic composition of the community prior to it. A phase of invasion of pioneering species, mostly annual, detected by other authors, mainly in studies about the bush (DYRNESS 1973, ANDERSON & BAILEY 1979, CASAL 1984), cannot be detected. This is probably due to the survival of most of the oak trees which, although more or less damaged, partly preserve the structure previous to the fire, and usually give enough shade to slow down the massive invasion of pioneering species, normally of the heliophilous type.

The regeneration of Quercus pyrenaica ecosystems consists, therefore, in a process of autosuccession, compensatory to the regression suffered. Nevertheless, there do not exist cyclical changes of species as those described in the climax or subclimax of fire (MYTINGER 1979). To the surviving species, mostly oak trees, are added to those which resprout immediately after the burning, starting from persistant underground organs, and those which sprout shortly after springing from seeds which were already in the zone and resisted thanks to the bad diffusion of the heat in the soil, or due to seeds coming from the neighbouring communities.

This progressive incorporation of species conditions an increment of the diversity during the first two years (Fig. 2), although later on this tendency is not general in all the

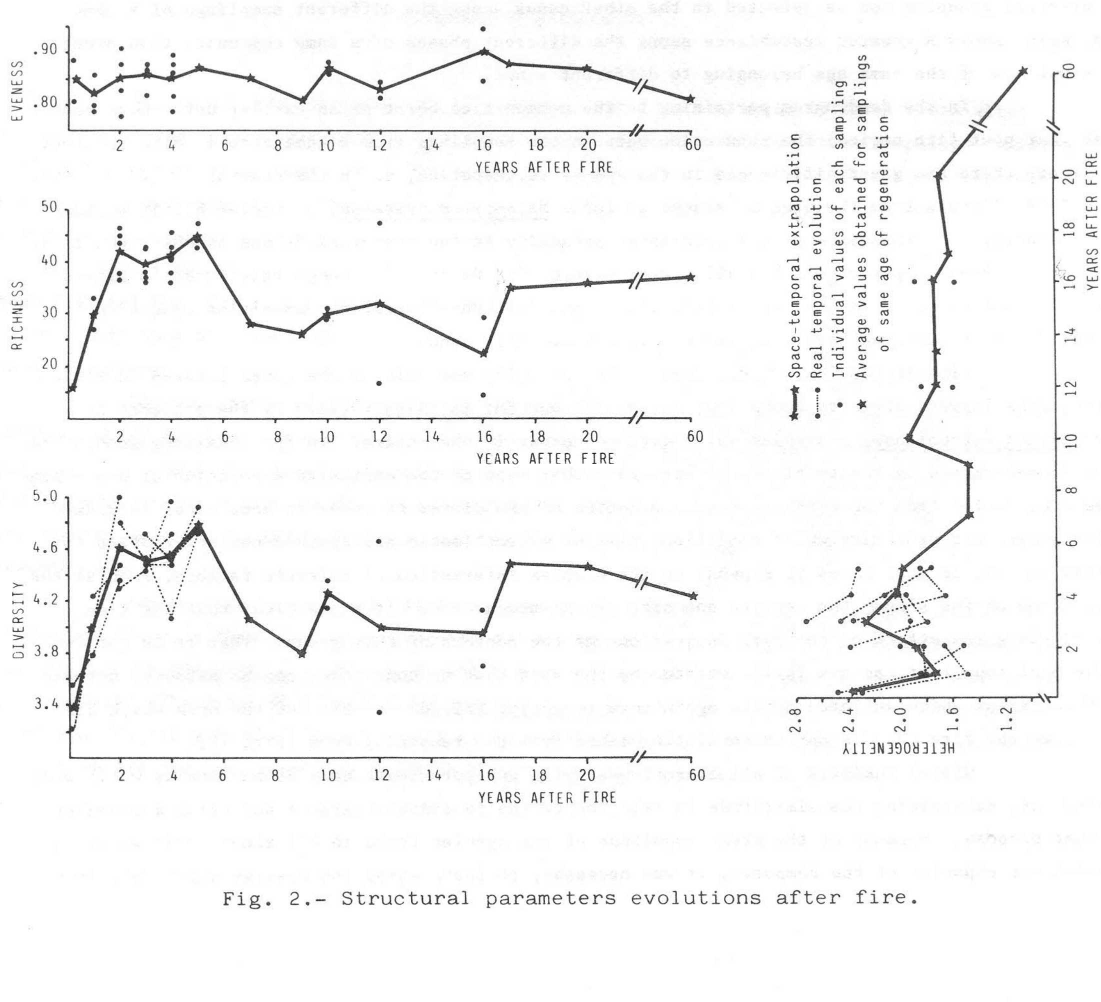

Fig. 2.- Structural parameters evolutions after fire.

zones. If the average value of the diversities of the zones of the same age is taken into account, a stabilization during the period up to five years can be noted, showing thereafter an irregular evolution, partly due to the fact that there are less data available. The progressive increment of the diversity in the first years after the fire followed by a posterior descent or stabilization is evident in most of the works on this subject (BELL & KOCH 1980, DEBUSSCHE et al. 1980, TRABAUD & LEPART 1980, CASAL 1982).

The increment of diversity is mostly due to the increment in the number of species (richness) as the great similarity between the 2 graphs shows, with a similar evolution. SHAFY & YARRANTON (1973) agree on this point. Uniformity has a more irregular behaviour, although with very small irregular oscillations in the course of time.

As far as the evolution of heterogeneity is concerned, if the average values are taken into account, it can be observed that the highest heterogeneity belongs to the communities just burned, the graph being afterwards irregular, although with an overall tendency to decrease (Fig. 2). It is probable that this tendency cannot be generalized because the oscillations can be better understood if they are considered linked to the heterogeneity values of each specific area, independently of the time elapsed since it burned. What really seems to be meaningful is the high heterogeneity of the youngest communities.

Fire can act as a perturbing element, exercising a more intense effect in some plots than in others depending to a very small extent on the microclimatic and topographic conditions. This determines if the vegetation is influenced to a greater or lesser extent and enables small, almost intact, mosaics to be observed in the same zone, surrounded by areas completely burned.

All the ecosystems studied show a great heterogeneity independently of their age of post-fire regeneration. Besides, they offer remarkable differences between each other, as can be verified by observing the deviation of some values from the average (for example, zones BE and BM, burnt twelve years before the study was carried out). Because of this, space-temporal extrapolations are not commendable in this type of community, and they must be only given an approximate value, backed by the temporal dynamics of the same communities.

CONCLUSION

The ecosystems of Quercus pyrenaica do generally recover well after the action of surface fires in a process of autosuccession which shows the presence of species adapted for a very long time to these perturbations. A progressive increment of the specific diversity of the herbaceous stratum up to two years after the burning can be observed. From that moment onwards it is difficult to detect structural differences caused by fire, and due to the survival of most of the oak trees, the passage of fire can only be recognized because of some burnt remains.

Nevertheless, it seems clear that the increment in the frequency of fires registered in the last few years constitutes an enormous factor of risk (TARREGA 1986). The fact that a system in a stage of recovery is again damaged after a very short time by a new fire, results in an increasingly greater degradation of the environment, which can lead to an irreversible alteration of the ecosystem.

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