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Land-use interactions with fire in Mediterranean *Pinus halepensis* landscapes of Greece: patterns of biodiversity

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ABSTRACT: The landscapes of the Mediterranean have suffered major land-use transformations during the last 40 years. Fire, as an integral part of the Mediterranean environment has also experienced changes in its regime, mainly in its recurrent time. The aim of this paper is to tackle the influence of land-use interactions with fire on the patterns of plant diversity in Penteli mountainous region of Attica, Greece. Land cover maps for 1945, 1971 and 1995 were obtained from aerial photographs. The area has experienced several fire events, the two biggest and more recent with only 3 years difference. Sites studied are discriminated after their geological substrate, their post-fire age, the fire interval and the number of fires they have experienced. Land use history does not seem to affect sites ordination when data on vegetation composition are used.

1 INTRODUCTION

The landscapes of the Mediterranean Rim have a distinctive physical background that arises from geomorphological conditions and the prevailing climatic conditions. This physical background creates a mosaic of landscapes, which supports a broad array of habitats and a high number of plant and animal species (Cowling et al. 1996). It is broadly accepted that mediterranean-type ecosystems have evolved under the influence of environmental stresses, such as summer drought and that they have been under the periodic influence of natural hazards, such as fire (Rundel, 1998; Arianoutsou, 2001).

Man has early settled Mediterranean Basin. Indigenous agriculture and animal husbandry have been practiced here for more than 10000 years, in combination with deforestation practices and fire management (Le Houerou, 1981; Naveh, 1998). Plant community structure and diversity patterns have therefore being evolved under the influence of this interaction. These patterns were kept in a dynamic equilibrium at least till the Second World War (Caravello & Giacomin, 1993). It is since the decade of 1950 when major changes have occurred to the economies, the livelihood and hence the landscapes of the Mediterranean countries. Extensive rural migrations, agricultural intensification, land abandonment, tourism development, population concentration along the coast, the build of extended transportation networks characterizes late 80-90's (Burke & Thornes, 1998). The socio-economic changes encountered during these last decades are causing major changes in the landscape patterns and the biodiversity they support.

In this context, the aim of the current work, which was performed within the framework of the European project LUCIFER, was to identify the possible effects of land-use changes and fire history on plant diversity in Mediterranean Aleppo pine communities of Attica, Greece.

2 STUDY SITES

Mt Penteli is a mountain (1100m) found at the urban/forest interface of Athens metropolitan area. Until the early '70s, the largest part of the mountain was coverer by *Pinus halepensis* forests, while in the lowland peripheral zone other land cover types such as shrublands and agricultural lands were encountered. The situation of the mountain has changed dramatically since 1970, when urbanization hit Athens. Housing pressure on new lands and abandonment of traditional uses of the pine forest (such as grazing and resin collection) has induced major land use changes, some of them mediated through fires. As a result, the homogeneous forested landscape of Penteli Mt. has changed into a heterogeneous landscape consisted of patches of different fire history.
In summer of 1995 a large fire burst over this heterogeneous landscape and burned more than 7000 ha. A large part of this area was reburned during another large fire in summer of 1998. For the aim of the current work all study sites were selected within the periphery of the 1995-burned-area. The burned area studied consisted of two distinctive zones in terms of soil formation, a zone with schists and a lowland zone with soils derived from tertiary deposits. The altitude of the area varied from 170 to 900 m a.s.l., while the climate is typical mediterranean (Fig. 1).

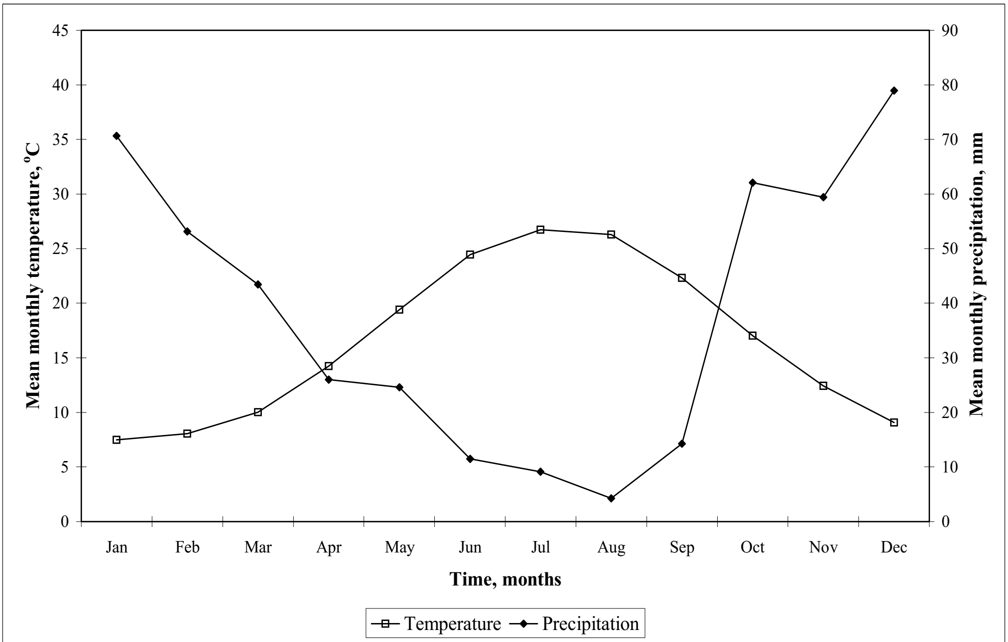

Figure 1. Climatic diagram for the area studied. Data are derived from the nearest meteorological station of Tatoi from 1951-1996.

3 METHODS

A number of sites were selected within the 1995-burned-area according to a specific design imposed by the needs of project LUCIFER, so as to reflect various combinations of land use changes, fire history and soil types. The history of land use changes, which have occurred during the last half of the 20th century, was reconstructed from land cover maps produced from aerial photographs of 3 time points (1945, 1971, and 1995) (Maroudi & Arianoutsou unpubl. data). Three general

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groups of land cover types were identified, cultivations (C), shrublands (S) and pine woodlands (W). Additional information was derived from all available data on fires, which have occurred over the area since 1970 and which were reasonably reliable.

From the initially selected number of sites, some were not included for sampling. The selection of sites was made on the condition that they should have been interpreted as *Pinus halepensis* woodlands (W) in the map of 1995, so as to have a unique final reference characteristic. Sixty sites were finally established for sampling.

Field campaign took place in late spring of 1999. At each study site a plot of 100 m^2 (5x20 m^2) was established. All plant taxa growing within the plot were recorded. Furthermore, woody and herbaceous vegetation cover was estimated from three 10 m^2 subplots established within the primary plot. Data on plant species presence/absence were analyzed with the use of CANOCO™ 4.0 for windows software. Direct gradient analysis was performed so as to identify the most influential variables.

4 RESULTS

Direct gradient analysis (CCA) was performed on the vegetation composition data. The environmental variables included in the analysis were soil type (SOIL), post-fire age (AGE), numbers of fires (FIRES), time interval in years between the two more recent fires (INTERVAL), woody vegetation cover (W.COVER), and the combination of land use changes encountered between 1945, 1971 and 1995 (CSW, CWW, WWW etc). From all those variables, combination of land use changes was finally excluded from the analysis after performing the Monte Carlo permutation test on the correlation of the variables.

The ordination of the study sites produced from the analysis is shown in Fig. 2. Canonical Eigenvalues reach 22.8% of all unconstrained eigenvalues (Table 1).

Table 1. Summary of the Canonical Correspondence Analysis.

Axes	1	2	3	4	Total inertia
Eigenvalues	0.243	0.216	0.155	0.092	3.419
Species-environment correlations	0.927	0.910	0.881	0.842	
Cumulative percentage variance					
of species data	7.1	13.4	17.9	20.6	
of species-environment relations	31.4	59.3	79.4	91.3	
Sum of all unconstrained eigenvalues					3.419
Sum of all canonical eigenvalues					0.772

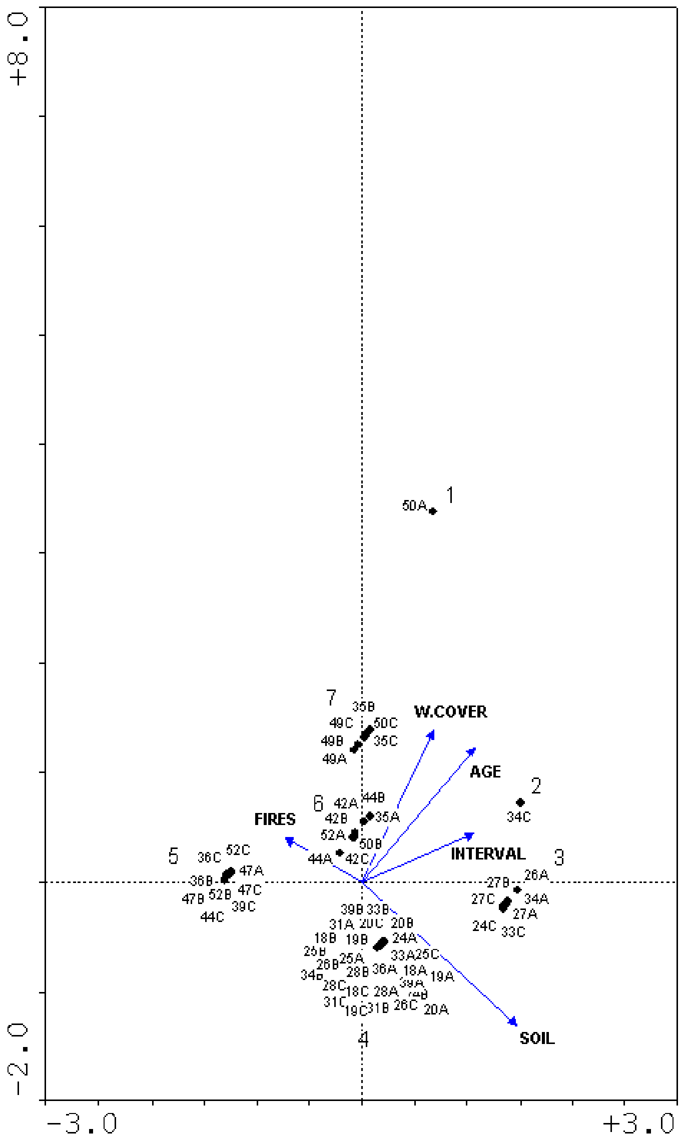

Figure 2. Ordination of the study sites after performing Canonical Correspondence Analysis on the vegetation composition data.

The study sites are divided into seven groups, according to the soil type and the fire regime in every case. Two of the groups are represented by only one site. The characteristics of each group are given in Table 2.

Table 2. Characteristics of the groups of sites that resulted from the performed CCA ordination.

Group No	Symbol	Soil type	Postfire Age (years)	Number of Fires	Last Fire Interval (years)
1	T (78, 87, 95)	Tertiary deposits	Four	Three	Eight
2	S (77, 95)	Schists	Four	Two	Eighteen
3	S (95)	Schists	Four	One	More than fifty
4	S (95, 98)	Schists	One	Two	Three
5	T (95, 98)	Tertiary deposits	One	Two	Three
6	T (95)	Tertiary deposits	Four	One	More than fifty
7	T (78, 95)	Tertiary deposits	four	Two	Seventeen

Fig. 3 represents the vegetation cover for each of the sites groups (see Table 2). Site groups are separated in two in regard to their post-fire age. Woody plants cover overall gives higher values in the 4th post-fire year as compared to the herbaceous cover and also as compared to that of the 1st post fire year. Number of fires experienced by the site seems to negatively affect the woody plants cover, regardless the post-fire age of the site. Fire interval seems also to act as a stressful agent at least for the woody vegetation component. The groups of sites which experienced 2 fire events of only 3 years apart produce the lowest woody vegetation cover between all sites studied. Among these two groups tertiary deposits seem to support higher vegetation cover, both woody and herbaceous.

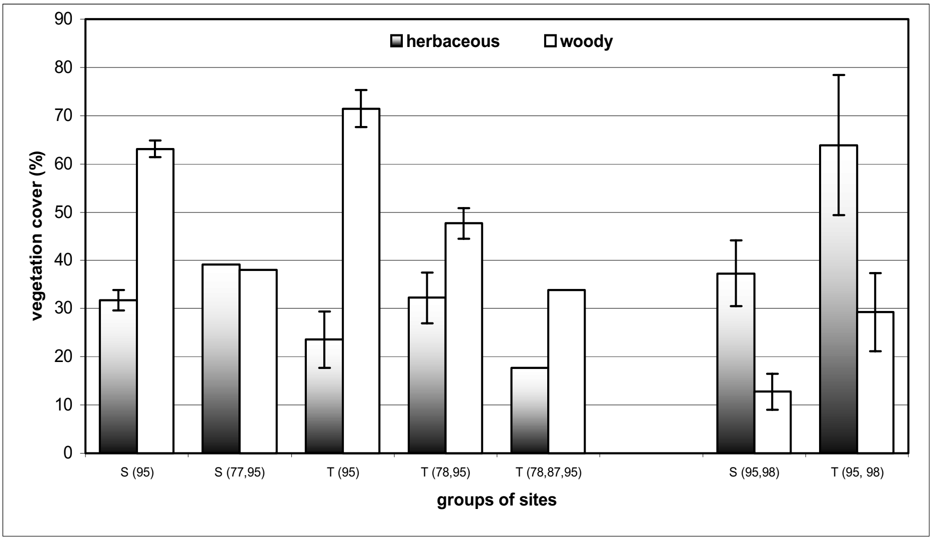

Figure 3. Vegetation cover for each of the sites groups shown in Table 2.

Fig. 4 presents data on plant species richness. Overall species richness shows its maximum at the one-year old communities on tertiary deposits regardless the fact that these sites have experienced two very frequent fire events.

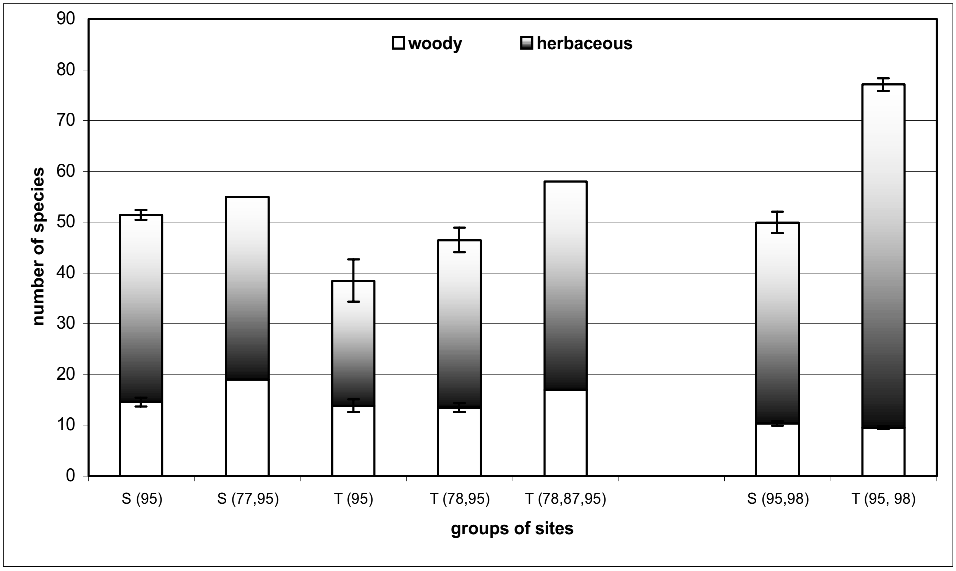

Figure 4. Species richness for each of the sites groups shown in Table 2.

As for the life form representation in the flora of the studied sites, therophytes are the richest group in all sites (Fig. 5). The absolute number of therophytic taxa is the highest in the twice burned sites on tertiary deposits, regardless the fact that these sites were burned with only 3 years difference. The two life forms that correspond to woody species show different pattern in relation to fire number and fire interval. Species richness of phanerophytes is negatively correlated with these factors, while the opposite stands for the number of species falling to the chamaephytes.

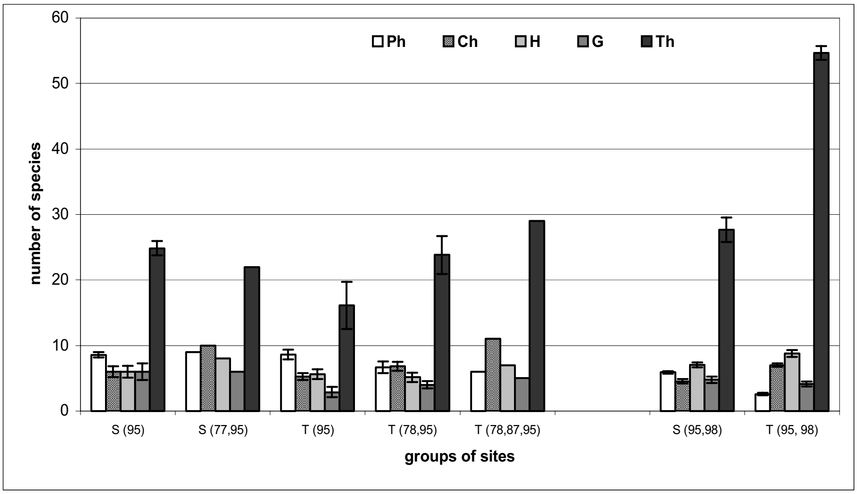

Figure 5. Plant species richness according to the Raunkiaer's life form classification for each of the sites groups of Table 2 (Ph: phanerophytes, Ch: chamaephytes, H: hemicryptophytes, G: geophytes, Th: therophytes).

Fig. 6 represents data on species richness in regard to their regeneration mode. Obligate resprouters are the species which regenerate vegetatively after fire; seeders are the species which overcome fire's action through seed germination and facultative resprouters are those species that can recover through seed germination but also occasionally they may resprout. As colonizers we characterize those species whose establishment depends on seed sources outside the burned site. As it is deduced from Fig. 6 colonizers is the group with the higher number of species throughout the studied sites.

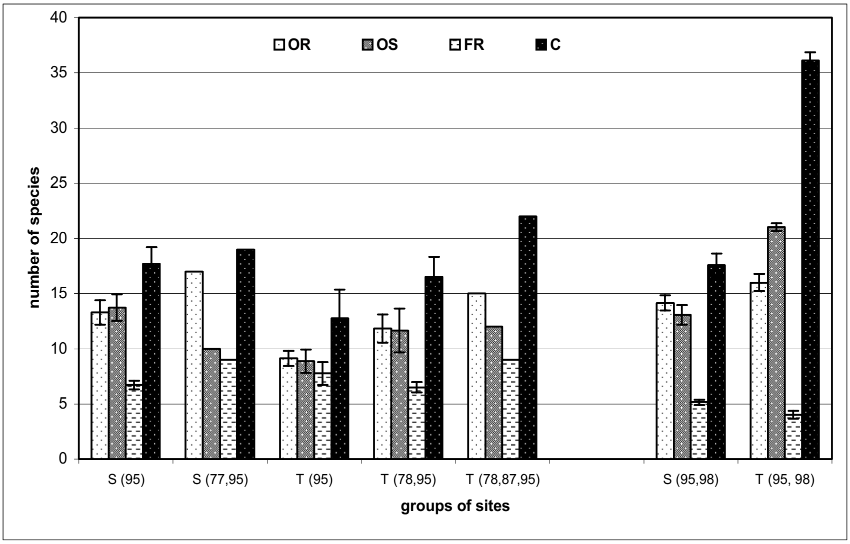

Figure 6. Number of species of obligate resprouters (OR), obligate seeders (OS), facultative resprouters (FR) and colonizers (C).

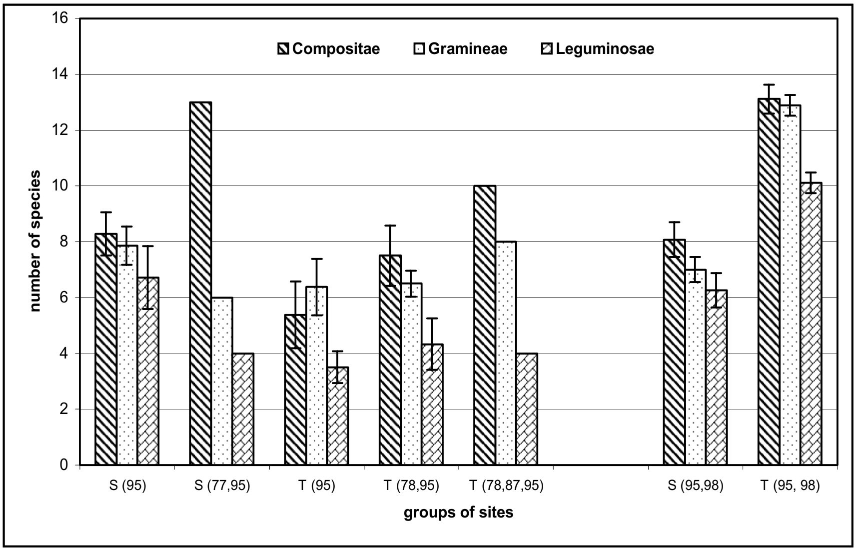

Figure 7. Species number of the plant families of Compositae, Gramineae and Leguminosae.

Fig. 7 reveals data on the most abundant plant families in terms of species richness. These are the families of Compositae, Gramineae and Leguminosae. Compositae are at the top of the ranking in almost all cases.

5 DISCUSSION

Throughout the Mediterranean Rim plant species distributions and community patterns have developed in response to heterogeneous environmental conditions and a wide range of historical factors, including complex histories of natural and anthropogenic disturbances (Cowling et al. 1996, Naveh 1998, Rundel 1998, Arianoutsou 2001). During the last 50 years these distributions are under the influence of increased human pressure, which is expressed in the urbanization of former wild areas, the abandonment of cultivations, the constructions of extended transportation networks etc. These alterations in the livelihood of the population are expected to strongly affect biodiversity patterns at all levels (Arianoutsou 2001). As a direct consequence of this transformation a homogenization of the landscape postulated, which in the case of the Mediterranean, is expected to promote large wildfires (Moreno et al. 1998).

Despite increased recognition of the importance of disturbance in determining forest composition and structure, few studies have assessed the relative influence of land use changes and fire history. For each of these two parameters series of studies have been reported (Motzkin et al. 1999, Farina 2000, Giovannini et al. 2001, Moreira et al. 2001), but only few for their combination (Perez et al. 1997) for the Mediterranean vegetation of Sierra de Gredos, Spain). These studies have shown a homogenization of differences in landscape and ecosystem attributes related to previous land-use history –and especially vegetation characteristics- and they have attributed it to the action of fire. Our data seem to be along the same line with the above as it can be deduced from the ordination of sites (Fig. 2). No significant effect of land-use changes was detected in the pattern of sites discrimination. This can be attributed mainly to the reason that land cover type of all studied sites at the time of their last burn was pine woodland (W). It is therefore reasonable to claim that all the potential effects, which shifts between the previous land cover types might had on plant biodiversity patterns have been 'absorbed' and compensated by the time elapsed. On the contrary, the sites studied were discriminated according to the characteristics of the fire regime studied, that is number of fires and fire interval and their geological substrate. The results of Canonical correspondence analysis (CCA) revealed that that a relatively high percentage of variance of the taxa data (22.8%) can be explained by the four canonical axes (Ter Braak 1986).

According to their post-fire age, there exist two groups of plant communities studied in this work. The first consists of 4-yr-old communities and the second of 1-yr-old communities. In the post-fire regeneration pattern of *Pinus halepensis* forests of Central Greece, the age of 4 years reflects important changes in the composition and structure of vegetation (Kazanis & Arianoutsou 2002b). It is then that woody cover (with *Cistus* spp. populations as the most important component) over dominates herbaceous vegetation which was dominant during the first three years. This fact forces us to discuss our findings for the two groups of sites separately.

<u>4-yr-old communities:</u>

Despite the dominance of woody cover at the 4-yr-old communities (Fig. 3), there was a negative correlation between this parameter and number of fires. On the contrary, for the same group of communities overall woody species richness seems not to be affected by the number of fires (Fig. 4). This is explained by the fact that despite that species richness of the woody phanerophytes is negatively affected by number of fires, the number of chamaephytic species increases with increased number of fires (Fig. 5).

Phanerophytes are the most important species for the structure of Mediterranean pine communities, since key-species such as *Pinus halepensis*, *Quercus coccifera, Cistus* spp. etc. are included in this life form. These species are either obligate resprouters (*Q. coccifera)* or obligate seeders *(Pinus halepensis*, *Cistus* spp) (Kazanis & Arianoutsou 2002a). Obligate resprouters seemed not to be affected, but this was not the case for obligate seeders, similarly to what is reported for *Quercus*

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coccifera garrigue in the Valencia region of Spain (Ferran et al. 1998). *Pinus halepensis* together with other important species, such as *Cistus* spp., *Genista acanthoclada, Anthyllis hermannaie* and *Satureja thymbra* were either absent or under-populated in the frequently burned sites, resulting in low values of woody cover. *Pinus halepensis* is known to form a canopy seed bank (Daskalakou & Thanos 1994) and produces the first cones at the age of 6 years, while *Cistus* species form an actual soil seed bank of hard-coated seeds 5 years after the fire event (Skourou & Arianoutsou unpubl. data). On the other hand, chamaephytes, which are attributed to a small proportion of woody cover, include many species classified as "colonizers" (members of the Compositae and Labiatae families). It is quite possible that low cover of phanerophytes enable the chamaephytic species to establish in the available gaps.

Data on post-fire regeneration of *Pinus halepensis* forests show that eventhough woody component dominates vegetation structure at the age of 4, vegetation composition is still dominated by herbaceous species and in particular therophytic annuals (Kazanis & Arianoutsou 2002b). Fire frequency hasn't altered this pattern. What was altered was the ratio between the richest families, and in particular Compositae and Leguminosae, in favor of the former family. The reason of this alteration is once more related to the regeneration attributes of the species in question. Members of the Leguminosae family are obligate seeders, producing hard-coated seeds and forming soil seed banks (Papavassiliou & Arianoutsou 1998), while members of the Compositae family are typical colonizers, producing light, wind-dispersed seeds.

<u>1-yr-old communities:</u>

The alterations recorded within the previous group are emphasized in this group of burned communities that were burned twice within three years, the shorter fire interval that has ever been reported from those forest ecosystems. The composition of the plant community during the first post-fire year is dominated by the presence of herbaceous legumes (Kazanis & Arianoutsou 1996, 2002b) and thus, in terms of regeneration mode, obligate seeders dominate the flora. This was not the case in this study. The richest plant family was that of Compositae, and accordingly, colonizers were the dominant group in the composition of the communities.

In addition to the legumes, other obligate seeders were negatively affected by the 3-yr-long fire interval. *Pinus halepensis* wasn't recorded at any community of this group, nor was *Cistus monspeliensis*, *Anthyllis hermanniae* and *Genista acanthoclada*.

Post-fire regeneration of Mediterranean pine forests has been documented from several studies throughout the Mediterranean Basin (Arianoutsou & Neeman 2000, Thanos & Doussi 2000, Trabaud 2000). All studies agree that the vast majority of the plant species that inhabit these ecosystems have evolutionary developed specific adaptations to cope with fire. Still, the resilience of these ecosystems is strongly depended on fire regime and especially on its recurrent time, for the simple reason that plants need adequate time to build those biological structures that will enable them to regenerate successfully after a new fire event. Resprouters need time to store resources at those organs that will support their regeneration form new vegetative organs, while seeders need time to mature and produce an adequate seed bank. Consequently, changes in fire frequency and fire interval may result in changes related to vegetation composition and structure. Vegetation composition is affected when species that were unable to regenerate become locally extinct after fire. Still, some species may be able to regenerate but less vigorously than expected, thus producing smaller populations. According to the results of our study both vegetation composition and structure were affected by fire frequency and fire interval.

Trabaud & Galtie (1996) working with *Quercus ilex* and *Quercus suber* woodlands in Southern France concluded that fire does affect landscape features in the sense that frequent fires produce an homogenization of the plant communities, while less frequent fires lead to the opposite. Our data support the same only for what it concerns vegetation structure but not vegetation composition. Vegetation composition is primarily defined by the geological substrate as it is seen in Fig. 2. The influence of the edaphic factors on the vegetation is very well documented and it seems that it remains a driving force when acting with other environmental variables (Copenheaver et al. 2000, current study).

Ecosystems of the Mediterranean Basin have been suggested as model regions for global change research, particularly in relation to the importance of land use changes (Hobbs et al. 1995, Lavorel et al. 1998, Arianoutsou 2001). In this light the development of ecological models which will be able to predict plant community responses under various scenarios becomes quite an intriguing task. Mediterranean plant vital attributes are already being suggested to be used in this effort and they have been proved quite promising tools (Arianoutsou 1998, Pausas, 1999, Lavorel 1999, Arianoutsou 1999, Kazanis & Arianoutsou 2002b).

6 CONCLUSIONS

Land use changes encountered in the mountainous region of Penteli, Attica, Greece between 1945 and 1995 seem not to affect drastically the patterns of plant diversity. This can be attributed mainly to the reason that the most recent land cover type was pine woodland (W) for all studied sites. It is therefore reasonable to claim that all the potential effects, which shifts between the previous land cover types might had on plant biodiversity patterns have been ‘absorbed’ and compensated by the time elapsed.

From the other landscape parameters tested, the geological substrate seems to be the primary discriminating factor for the sites as they are represented by their floristic composition, followed by the post-fire age and the two components of fire regime that is, fire interval and number of fires experienced by the sites.

Among the most important conclusions of this work is that woody component of the vegetation is dramatically diminished in cover as a response to number and frequency of fires, while woody plants species richness is obviously affected by the short fire interval. On the contrary, no obvious trend is revealed for herbaceous vegetation cover in regard to number of fires, but a remarkable increase is recorded in the herbaceous species richness in the frequently burned sites. This is attributed to the high presence of ‘colonizing’ species, mainly of the families of Compositae and Graminae. Overall, it seems that under the cases of the observed land-use cover changes, fire regime still plays the most significant role in shaping plant communities.

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