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Landscape changes in Mediterranean ecosystems of Greece: implications for fire and biodiversity issues

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Abstract

The landscapes of the Mediterranean rim have been under the influence of humans for at least 10,000 years. Most of the human activities were applied in a sustainable manner and they have resulted in a human-maintained dynamic equilibrium. The existing plant communities are particularly rich and host approximately 25,000 vascular plant species. The extensive rural migrations, the intensification of the agriculture and of irrigation networks were among the factors that created major changes in the landscape and biodiversity patterns throughout Mediterranean Europe. In this paper, three study cases are briefly reviewed; these present major landscape changes which have occurred in the Mediterranean parts of Greece, and aim to pinpoint the fire regime-related processes through which these changes might affect long-established biodiversity patterns.

The structure of Mediterranean landscapes – The natural history of the Mediterranean landscapes

The landscapes of the Mediterranean Rim have a distinctive character that arises from their physiography and the long history of human development. The Mediterranean region has a basin and range topography surrounding the Mediterranean Sea, as a consequence of which it has variable geomorphological conditions. Various geological substrates are closely alternating. producing a variety of soils. The prevailing climatic conditions, although falling in the general pattern of the Mediterraneity, vary considerably, even over short distances. This physical background creates a mosaic of landscapes, which supports a broad array of habitats and a high number of species.

It is broadly accepted that all mediterranean-type ecosystems evolved under the influence of environmental stresses, primarily summer drought and low soil nutrient availability. Furthermore, mediterranean-type ecosystems of the world have been under the periodic influence of natural hazards, such as fire and tectonic instability. Consequently, the plant communities of these systems have been forced to cope with all these environmental factors and natural perturbations. In particular, Mediterranean plant communities have evolved response mechanisms to cope with fire. These mechanisms are expressed through the morphological, physiological and phenological adaptations of the plant species (Arianoutsou, 1998). However, fire, as an environmental natural hazard, does not have the same regime in all five mediterranean-climate regions of the world (Rundel, 1998). In South Africa, for example, fynbos vegetation of the Cape region usually burns at intervals of 10-15 years (van Wilgen *et al.*, 1992), while in California and in the Mediterranean Basin natural frequencies are usually 30-50 years or more (Trabaud & Prodon, 1993; Rundel & Vankat, 1989).

The Mediterranean Basin has also experienced marked climate changes during the Quaternary, which has had profound effects on plant community structure and speciation (Cowling *et al.*, 1996).

Plant diversity in Mediterranean landscapes

Many references indicate that the Mediterranean rim is ranked first of the five Mediterranean regions of the world in terms of the plant species diversity (Cowling *et al.*, 1996). It hosts approximately 25,000 vascular plants (Cowling *et al.*, 1996), a large number of which are range-restricted taxa. A great portion of these range-res icted taxa is now considered as threatened. Within this frame, Greece has a special position, having approximately 6,000 plant taxa, a very high degree of endemism (–20%) and unfortunately a high number of plant taxa considered as threatened

(900; 600 of them endemics) (Georghiou & Delipetrou, 2000; Kokkoris & Arianoutsou, 2001). Mediterranean-type ecosystems constitute 40% of the terrestrial ecosystems of Greece. They extend from the coastline up to an altitude of 800 meters and they occur both in the continental country and in the islands. Approximately half of the Greek endemics (~600 taxa) occur mainly in the Mediterranean ecosystems of Greece and 307 of them occur exclusively in the fire-prone habitats of these ecosystems. More than half of these Mediterranean endemics are considered to be threatened (Kokkoris & Arianoutsou, 2001).

Man and the Mediterranean Landscapes

The Mediterranean Basin was settled by humans very early. Consequently, Mediterranean-type landscapes have long ago experienced the human impact. Indigenous agriculture and animal husbandry have been practiced here for more than 10000 years (Naveh & Dan, 1973; Le Houerou, 1981; Naveh, 1998), in combination with deforestation practices and fire management. Plant community structure and diversity patterns have therefore evolved under the influence of this interaction. These patterns were kept in a dynamic equilibrium at least until the Second World War (Caravello & Giacomin, 1993). Since 1950, when major changes have occurred to the economies, the livelihood and hence the landscapes of the Mediterranean countries. Initially, there were extensive rural migrations followed by agricultural intensification from the introduction of new farm machinery, new strains of cereals and tree crops and extensive application of fertilizers. The invention of new irrigation techniques made possible the use of hilly areas, so agriculture spread further. The European Community set the next milestone in this process by setting the general framework within which agricultural activities should unroll.

Current trends in landscape changes in Greece

The dynamic equilibrium between humans and the Mediterranean environment lasted until 1980 and resulted in a remarkably rich landscape. However, land abandonment, tourism development, population concentration along the coast, and the building of extended transportation networks characterized the last two decades of the 20th century (Burke & Thornes, 1998). Common Agricultural Policy (CAP) set by the European Union is also part of the puzzle. The accelerated socio-economic changes encountered during these two decades are causing major changes in the landscape patterns and the biodiversity they support.

This paper presents three cases of changes in landscape patterns of Greece -each one revealing a different set up of drivers and results- and discusses the implications that these changes might have for the long established patterns of plant diversity and fire regime.

Changing Mediterranean landscape patterns in Greece: case studies

Three study cases will be reported here in brief

- Western Crete island
- Western Lesvos island
- Mountain Penteli in Attica

Western Crete island

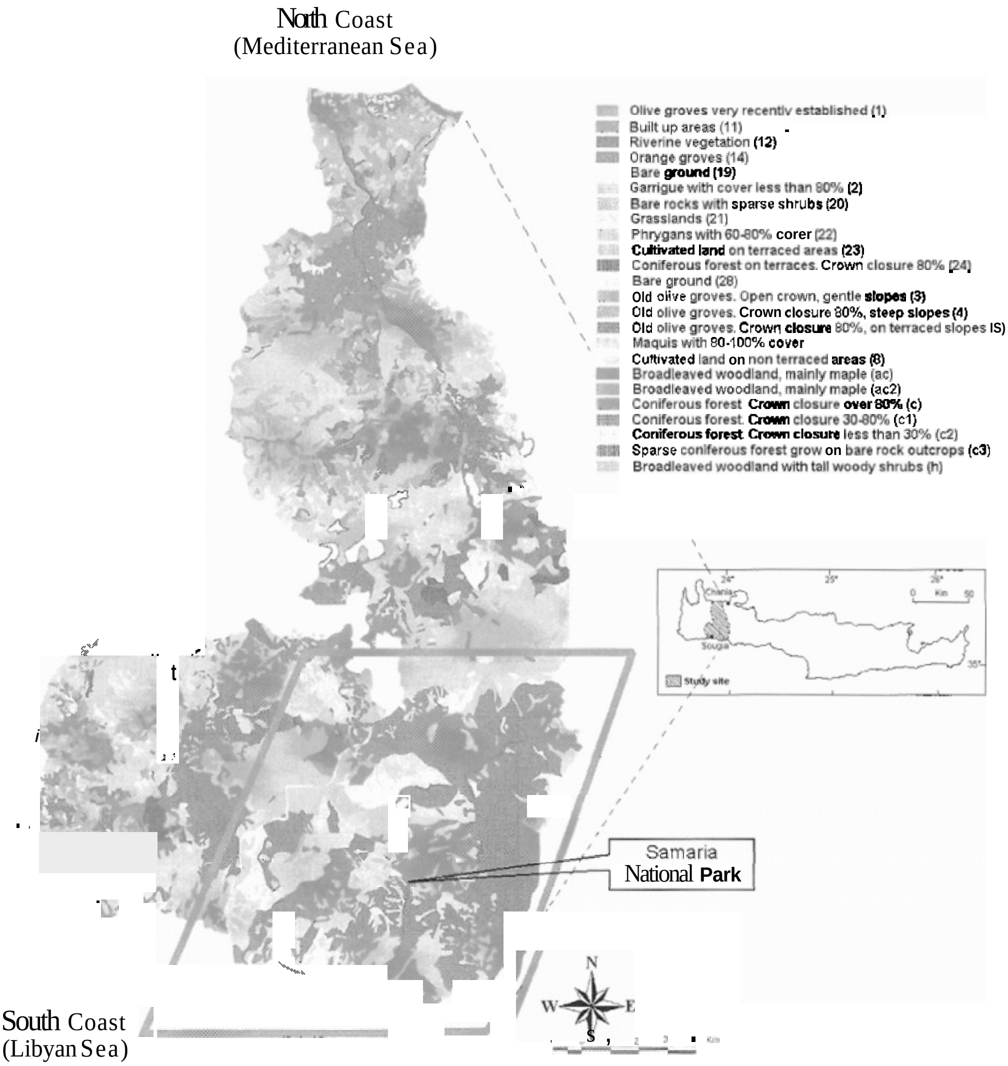
Crete reveals one of the most diverse systems of contrasting landscapes with an array of habitats ranging from subtropical palm groves in the south to alpine meadows, with high mountains and many gorges. Western Crete is characterised by a great variety of natural features, dissected physiography, parent rock material and soils, land cover types, high species and habitats diversity and cultural elements (Papanastasis *et al.*, in press). Crete has gone through sweeping changes in the last 20-30 years. It has been transformed from a traditional economy based on agricultural and pastoral activities to an open market. Millions of tourists visit Crete every year. As a result, large upland areas have been abandoned and people have moved to the urban centres. Development is largely concentrated along the coast, mainly to accommodate tourists (Papanastasis & Kazaklis, 1998; Papanastasis *et al.*, in press).

For the needs of this study, a strip of 424 km² was selected stretching across the island a few kilometres to the west of Chania, south to the Sougia river mouth and the Samaria National Park (Figure 1). This area was initially studied under the EU project entitled 'Threatened Mediterranean landscapes: the case of West Crete' (EV4C-CT90-0112), (Papanastasis & Kazaklis, 1998). Aerial photographs of the area taken in 1945 and 1989 were photo-interpreted to produce land use/land cover maps (Papanastasis & Kazaklis, 1998). Following this phase of the work and under the EU project 'Modelling Mediterranean Vegetation Dynamics' the maps were further analysed with GIS techniques and digitised maps were produced. In this paper, only the map of 1989 is presented (Figure 1).

Although the total area of the natural Mediterranean plant communities, that is phrygana, maquis, garrigues, other broad-leaved woodlands, *Pinus* brutia and *Cupressus sempervirens* forests, has not changed significantly, major transformations have been observed between the various communities (Table 1):

Table I. Major changes in the study site of W. Crete between 1945-1989 (adapted from Papanastasis et *al.*, in press).

Land use type	**Change between** 1945-1989 **(%)**
Olive groves	+80.00
Cereals	-61.54
Total agricultural *land*	*-38.71*
Phrygana	-6.97
Garrigues	-6.45
Maquis	-30.43
Total shrublands	*-8.50*
Dense forest (>71%)	+39.12
Open forest (30-70)	-28.97
Very open forest (<30%)	-2.12
Total forest land	*+9.17*



Land cover map of the study area in Western Crete. Mediterranean formations are shown within the framed region

The major landscape changes encountered are shown in Figure 2. Phrygana, garrigue and maquis formations, which were traditionally used as rangelands, have been reduced in favour of the *Pinus brutia* and *Cupressus sempervirens* forests (areas corresponding to light green in the map of Figure 2).

- Open forested areas (areas with crown densities <70%) have become much thicker and the canopy is now almost closed (area indicated in green with yellow polygons in Figure 2).
- Agricultural lands cultivated mainly with cereals are reduced; some of the lands have been transformed to olive groves.

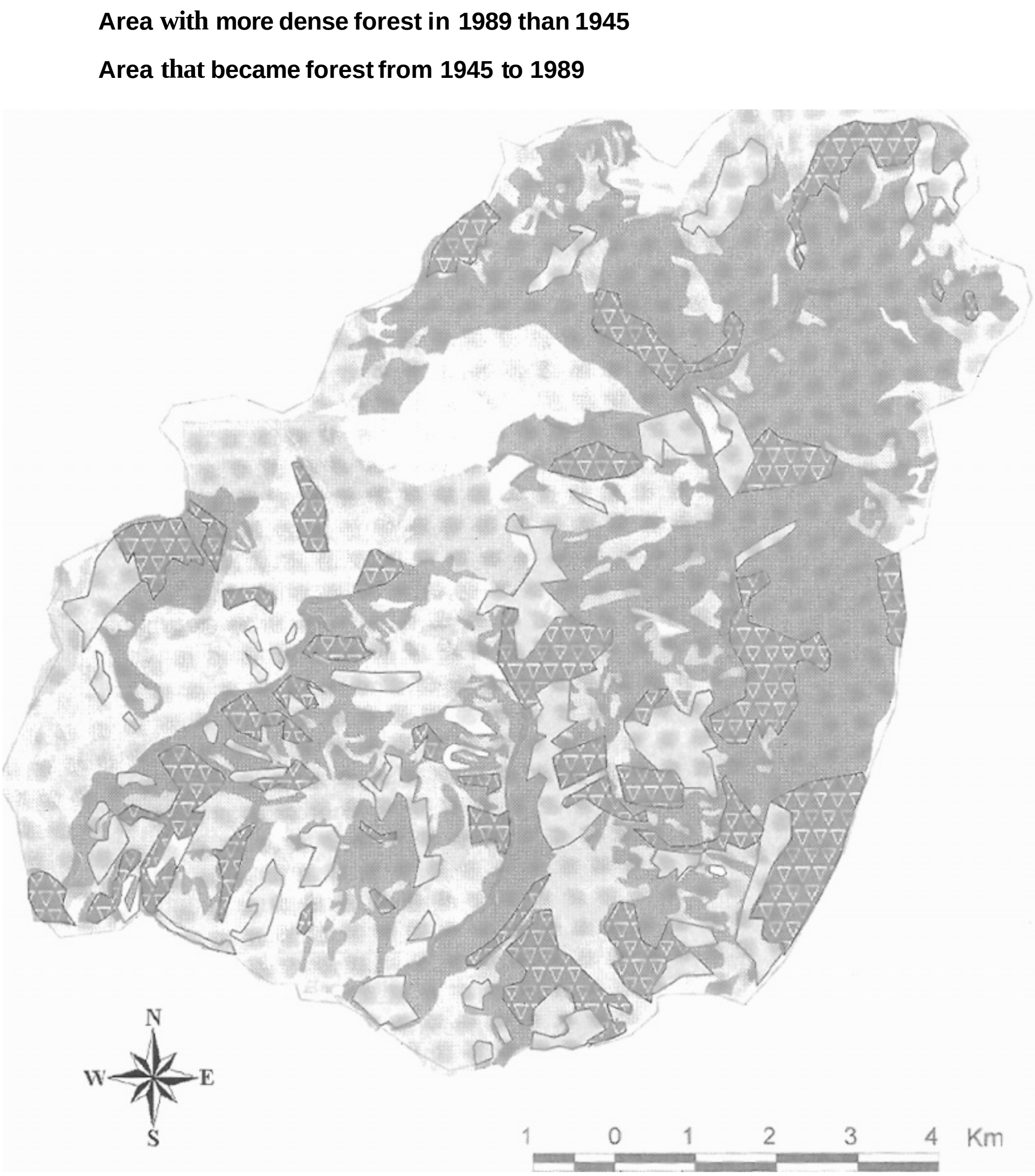


***Fig.* 2. Mediterranean formations of the study area in Western Crete with notable changes between 1945 and 1989.**

All these landscape changes are the consequences of the changes that have occurred in the livelihood of the Cretans. The human population has decreased between 36% and 47% in the mountainous villages of the region during the period 1951-1991 (Papanastasis & Kazaklis, 1998; Papanastasis et *al.*, in press), while it has changed very little in the plain. On the other hand the traditional activities in the area have been abandoned. Untill the late 1960s, farming of cereals and vineyards on terraces was a very common practice over the limestone areas of W. Crete, while extensive grazing with sheep and goats was also practised. Grazing activities in Greece are often combined with deliberate rotational burning of the sites in an effort to suppress the woody vegetation and promote the development of herbaceous plants, mainly legumes (Arianoutsou & Margaris, 1982). In the study area of Crete, all these activities were minimised by 1989, at least they were not so extended in space. Because of these shifts, most of the terraces that were abandoned and many grazing lands that had been left free of animals began a process of secondary succession leading to the potential vegetation that the area could support.

Field campaigns in several sites of the studied region were performed during the years of 1996-1997, for the needs of EU project entitled: "Environmental Response of Mediterranean Ecosystems – ERMES II". During these campaigns data on vegetation structure and floristic composition were gathered (Arianoutsou *et* al., 1998). These data revealed changes in the composition of the vegetation in relation to what it was expected. For example, it is reported in the literature that phrygana has a stronger therophytic component than maquis (Margaris, 1980; Ish-Shalon-Gordon, 1993; Kutiel et *al.*, 1995). However, fewer therophytes than expected were represented in the sites covered by phrygana (Arianoutsou & Kazanis, in preparation). In addition, legnmes, a key- functional group of the early post-fire succession (Kazanis & Arianoutsou, 1996; Arianoutsou & Thanos, 1996) were absent. Furthermore, according to field records (Arianoutsou & Kazanis, in preparation) 13 plant taxa were recorded in elevations higher than those reported in the literature (Turland et *al.,* 1993). It is noteworthy to mention that among the taxa registered in the field campaigns (Arianoutsou & Kazanis, in preparation) there was one adventitious taxon (*Centranthus ruber*).

Crete and in particular Western Crete, hosts an array of areas of European Community Interest, known as NATURA 2000 sites (Dafis, 1996; Arianoutsou et al., 1996). It is worthwhile to mention that Samaria National Gorge is one of them, together with the Omalos plain. The latter is one of the areas that has suffered the most dramatic changes.

Literature sources report the presence of several endemic plant taxa in the Mediterranean habitats of the study area (Georghiou & Delipetrou, 2000; Kokkoris & Arianoutsou, 2001). The majority of the endemic plant taxa reported for the Mediterranean habitats of the study site belong to the families of Liliaceae and Caryophyllaceae (Figure 3). Over 50% of them are perennial herbs (Figure 4), either geophytes or hemicryptophytes (Figure 5). Many of them are threatened (Georghiou & Delipetron, 2000), and six are included in the National Red Data Book (Phitos et al., 1995).

It is expected that the land use/land cover changes encountered, although they could be considered as beneficial because they bring back the systems to their potential vegetation, might be detrimental. This is because they 'shake' the traditional dynamic equilibrium between man – fire and natural plant communities, which was established for thousands of years (Naveb, 1998; Papanastasis & Kazaklis, 1998; Papanastasis et *al.,* in press).

It is mentioned in the literature (Naveh & Whittaker, 1979, among others) that the extensively grazed woodlands and shrublands of the Mediterranean Basin have perhaps the greatest alpha diversity of any temperate plant community. This diversity is derived from the large number of annuals capable of surviving the multiple stresses of drought, fire, grazing and cutting.

In the case of Western Crete, the alteration of the long-established dynamic equilibrium is expected to alter:

- the fire regime – more intense fires may burn over the areas, as the landscape has lost its mosaic structure and has become more homogeneous;
- the components of the habitats of the range restricted species, as for example, more dense crowns are now developing, less light and rain reach the lower layers.

Both alterations may directly or indirectly affect the function and the persistence of the species and thus the function of the systems themselves.

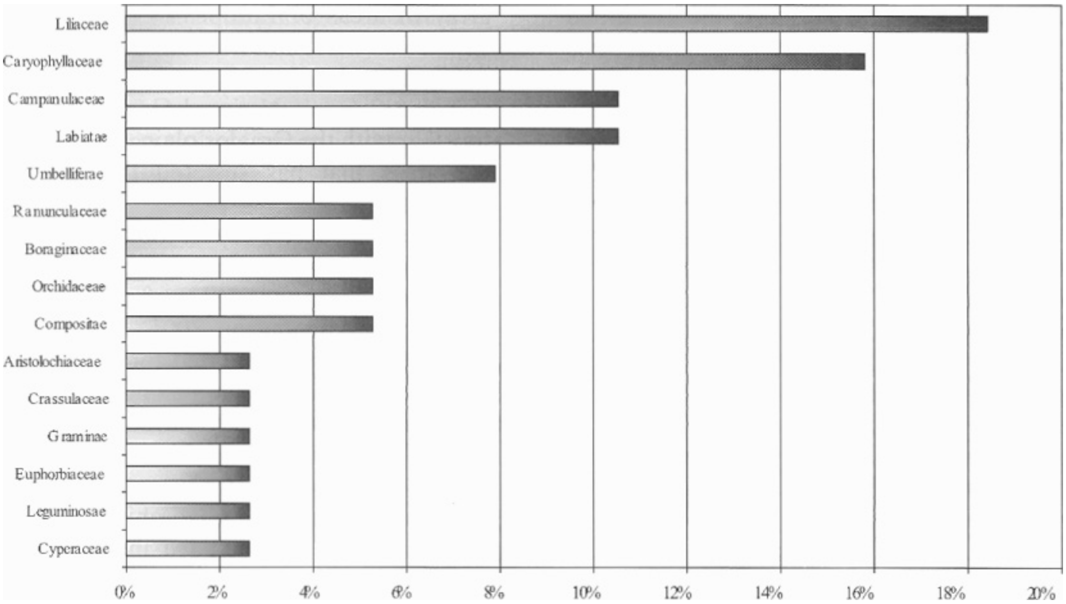


Fig. 3. The representation of plant families in the taxa endemic to the study area of Western Crete.

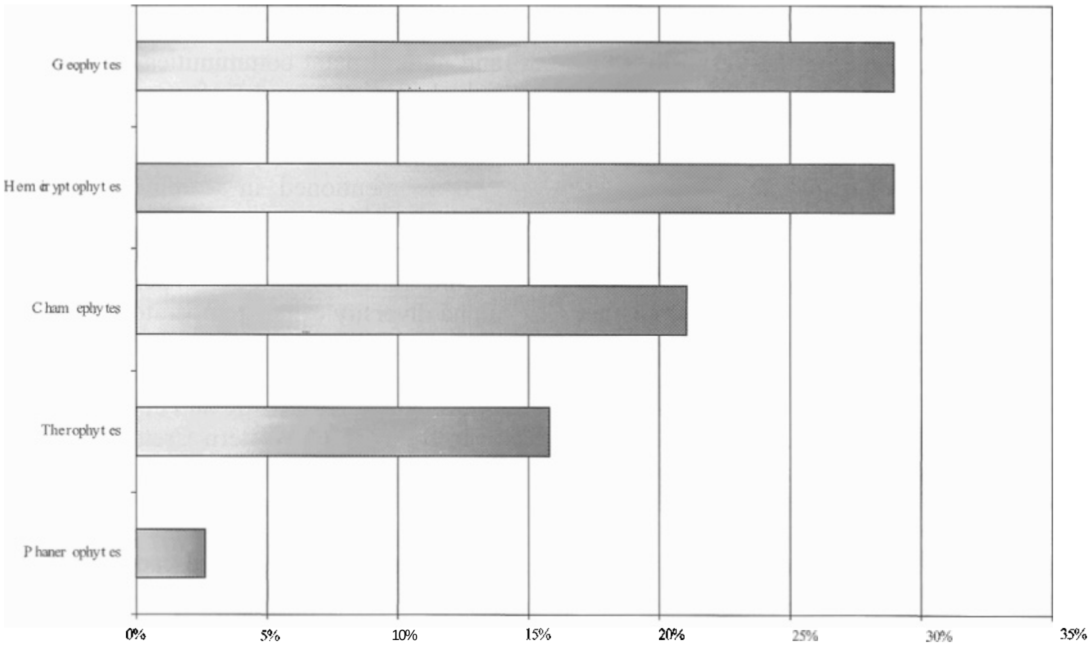


Fig. 4. Life forms of the taxa endemic to the study area of Western Crete.

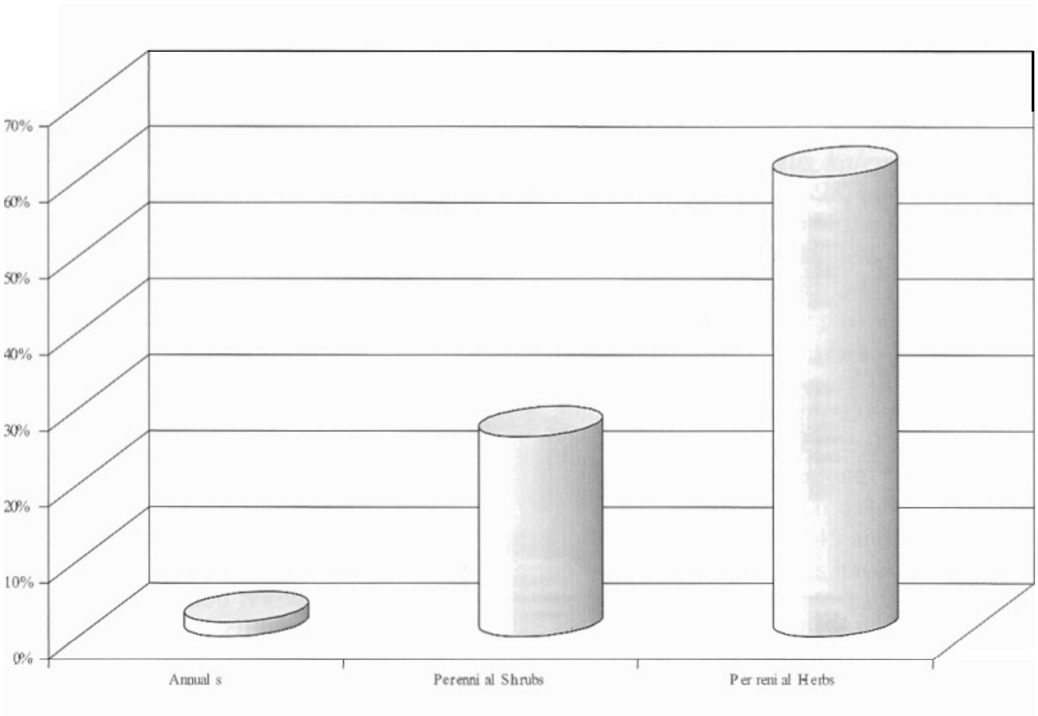


Fig 5. Growth forms of *the taxa endemic to the* study *area* of *Western Crete*

Western Lesvos island

The island of Lesvos, covering 1640 km^2, is situated in the northeastern Aegean Sea. The compact dominating mountain mass is located in the centre of the island and its highest peak reaches the 996m. The climate of the area is typical Mediterranean, with mild – humid winters alternating with hot – dry summers. On the mountaintops the climate is rather temperate. Lesvos has distinctive vegetation discriminating in two parts, that of the east and that of the west. ***Pinus brutia*** forests and garrigue formations dominate in the east on limestone and marls. Open forest stands of *Quercus macrolepis* (a deciduous oak) and extended phrygana communities characterise the west part, on igneous rocks. Olive groves occur over large areas on the island (Figure 6).

Agropastoral activities were the traditional occupation of the inhabitants of Lesvos until 30 years ago. Grazing pressure was moderate as animals were kept at low numbers. *Quercus macrolepis* forests growing on the west part of the island were used as the main rangelands. They were managed in that way so to preserve production of acorns, which were used in leather manufacturing. This traditional activity was moderately practised, thus keeping the plant community in a dynamic equilibrium. When chemicals replaced acorns in the leather industry, the land lost its value. Since then, grazing has been intensified and combined with too-frequent and deliberate fires (Arianoutsou, 1985). A total of 213,000 sheep and goats graze over the total area (1640 km^2), with 67% of them located on its western part, where the greatest utilisation occurs (Figure 7). Since grazing is unconstrained, continuous and not seasonal, theoretically, an area of 3500m^2 is available to each feeding animal. The degree of grazing pressure far exceeds the carrying capacity of the land. It is known that the minimum plant cover of an area – before deterioration starts – is estimated at about 60% (Orr, 1970). Given the fact that plant cover gradually diminishes in Lesvos' grazed lands and that strong winds are blowing over this part of the island it is not surprising that signs of land degradation are obvious. According to Kosmas *ef al.* (1999), 22% of the total area of the island – all concentrated over the specific region in reference – shows a high erosion risk because of the very low vegetation cover. The same authors also point out the dramatic effects that the irrational land management had on the area even 15 years later than it was firstly noticed (Arianoutsou, 1985).

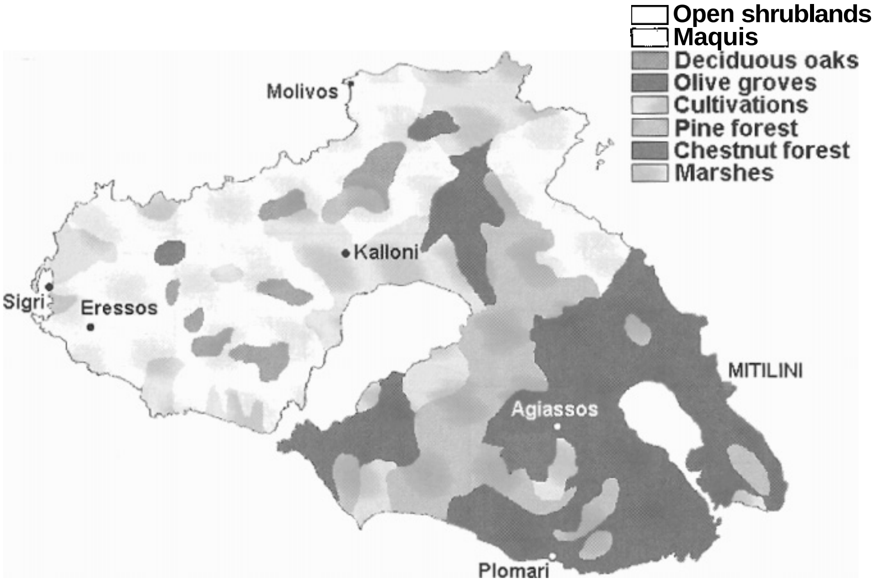
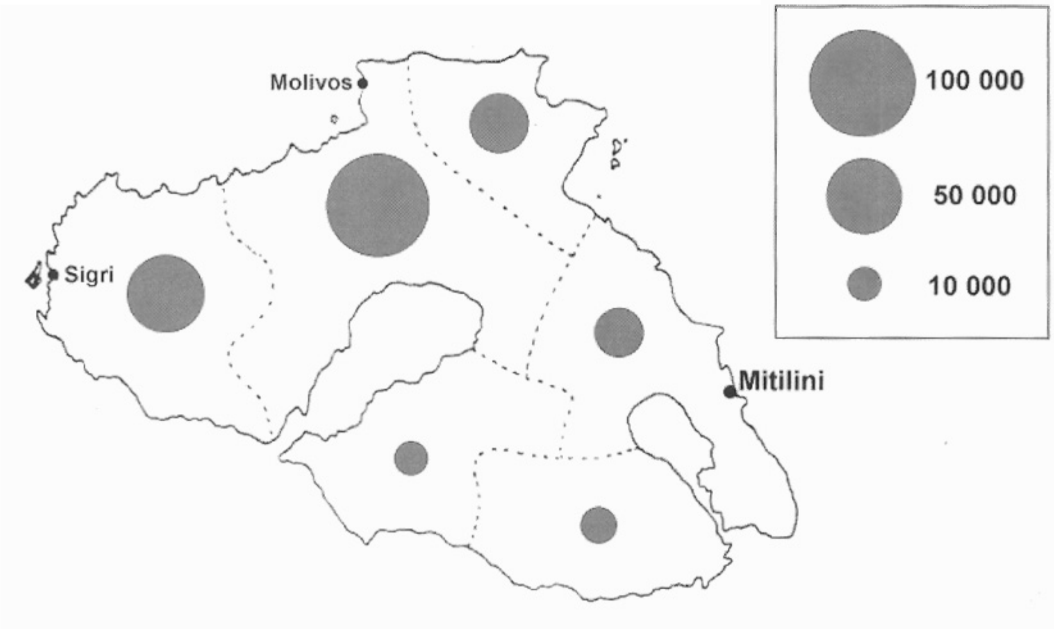


Fig. 6. Vegetation map of Lesvos island.



Stocking rates of grazing animals on Lesvos island.

Western Lesvos has special paleoecological features that make the region important. The Petrified Forest of the island is a unique geological monument of high scientific interest. By the Presidential Decree 443/1985 the area has been declared a protected Natural Monument and it is also protected by the Barcelona Convention. From the floristic point of view, the fossils – spread all over the rangelands of West Lesvos – belong to the following genera: *Pinus, Taxodioxylon, Pinoxylon, Cedroxylon, Pityoxylon, Alnus, Carpinus, Populus, Quercus, Platanus, Palmoxylon* etc (Dafis *et al.*, 1996). It is obvious that of these plant taxa those having tropical origin nowadays are found only in the tropical and subtropical biomes.

Three threatened endemic orchid species used to occur in the area (*Ophrys lesbis, 0. bucephala* and *O. minutula*; Georghiou & Delipetrou, 2000) all perennial geophytes characterised as rare and protected by the Presidential Decree 6711981 and the CITES convention.

For all these reasons Western Lesvos is considered as one of the regions of Greece threatened by desertification and it has been classified as an Environmentally Sensitive Area (Kosmas *et al.,* 1999).

Mountain Penteli

Mountain Penteli is one of the four mountains that surround the metropolitan area of Athens. It is on the northeastern part of the city and it reaches an altitude of 1200m. Three types of parent rock material are present at Mt. Penteli. The southern and western plains comprise tertiary deposits. The main body of the mountain has schists, while parts of the north-facing slopes comprise limestone.

During the middle of the 20th century, the majority of the mountain was covered by *Pinus halepensis* (Aleppo pine) forests. Since then, repeated fire events and urbanisation led to changes in the vegetation cover and the land use of the area.

An area of 10,500 ha was mapped at three time points (1945, 1971, 1995) by means of aerial photographs and the maps were further analysed using GIS (Varela *et al.,* 1999; Maroudi & Arianoutsou, 2001).

The results of photo-interpretation and GIS application are shown in Figure 8. Traditional vineyard cultivation and grazing activities have been abandoned since 1945 to 1971 an4 as in Crete, these systems have been transformed into forests. From 1971 onwards the major change has been urbanisation (Figure 8c). A large fire occurred in the area in July 1995, consuming over 7,000 ha of the *Pinus halepensis* forest cover. A second large fire in 1998, burnt more than 10,000 ha of land and reburned the 1995 fire. These two fires were among the largest in Attica in the recent historical period. Several smaller fires have occurred in area in the past, some of which within the periphery of the study site.

Unfortunately there are no reliable data available for the causes of fire, but the mapping of the fire ignition points (Figure 9) indicates an impressive concentration close to the settlements. Urbanisation has led to a 12-fold increase in the population between 1945 and 1995!

Several of these fires have intervals, less than 5 years. Recent field data have revealed that plant community structure and diversity are greatly affected by such frequent fires (Arianoutsou *et al.*, 2001). Only 30% of the taxa normally occurring in early post-fire regenerating communities are indifferent to the fact that more than one fire event has occurred, 33% of the species normally occurring in early post-fire regenerating communities are disappearing under the frequent fires regime, while 16% new taxa are appearing. These new taxa are mostly herbaceous Compositae. This wind-dispersed plant group is a strong competitor easily colonising open areas. Leguminosae, a plant family which is normally expected to be the first in the early post-fire regenerating Mediterranean communities (Kazanis & Arianoutsou, 1996; Arianoutsou & Thanos, 1996) is underrepresented in the frequently burned areas (Arianoutsou *et al.*, 2001). Furthermore, no natural regeneration of the Aleppo pine is occurring. Repeated fires have homogenised not only the landscape patterns but also the floristic composition of existing plant communities. It was proved that the numbers of fires experienced by the sites and fire interval are among the most important environmental variables that discriminate the field sites.

Previous field campaigns on the same region (Kazanis & Arianoutsou, unpuhl. data) have revealed the existence of 3 endemic plant taxa: *Campanula drabifolia,* a biennial hemicryptophyte, *Erysimum graecum* a biennial hemicryptophyte and *Onobrychis ebenoides,* a perennial pubescent chamaephyte, protected by the Presidential Decree 67/1981. None of these taxa were found after the second large fire of 1998.

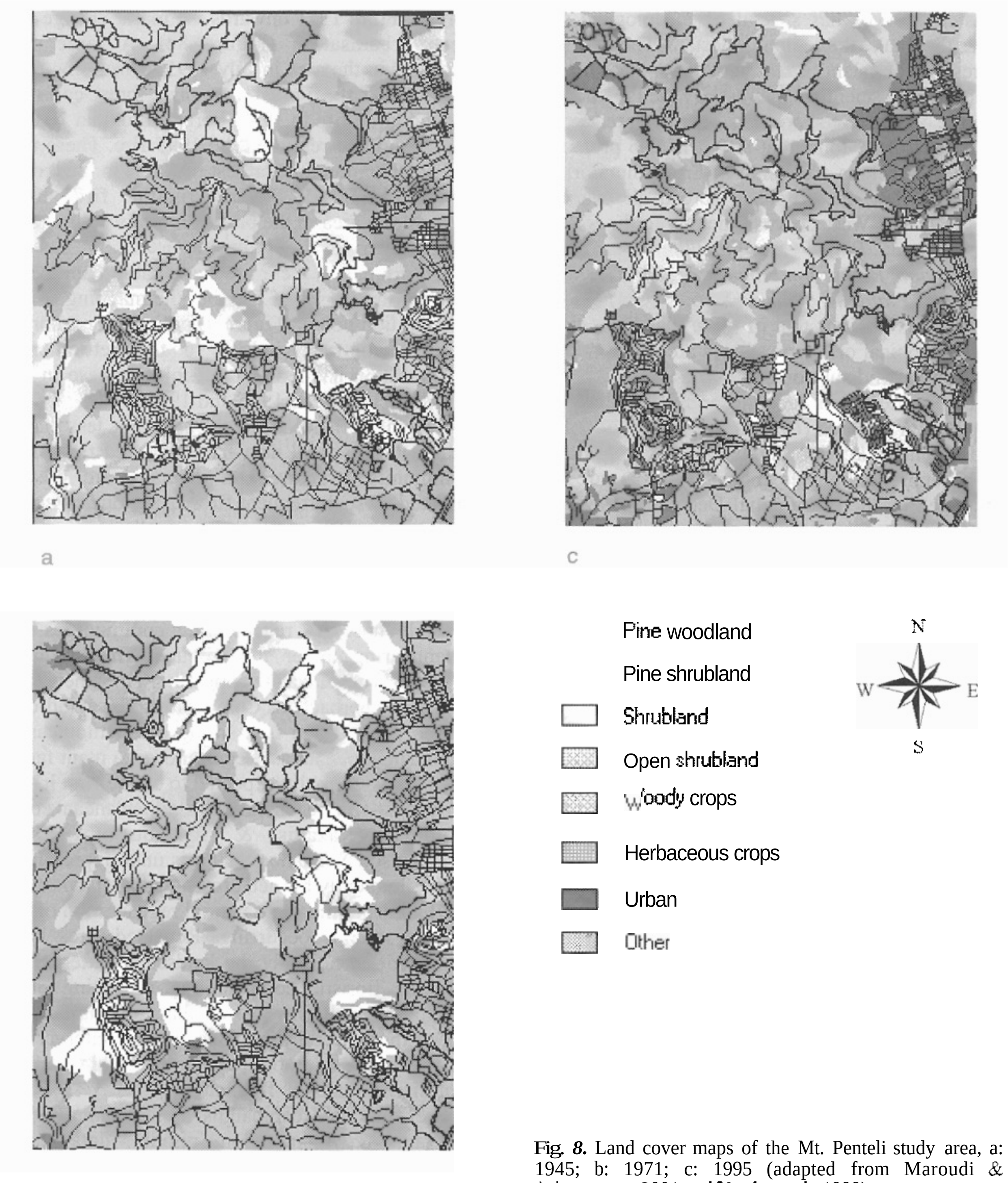


Fig. 8. Land cover maps of the Mt. Penteli study area, a: 1945; b: 1971; c: 1995 (adapted from Maroudi & Arianoutsou, 2001 and Varela *et al.*, 1999).

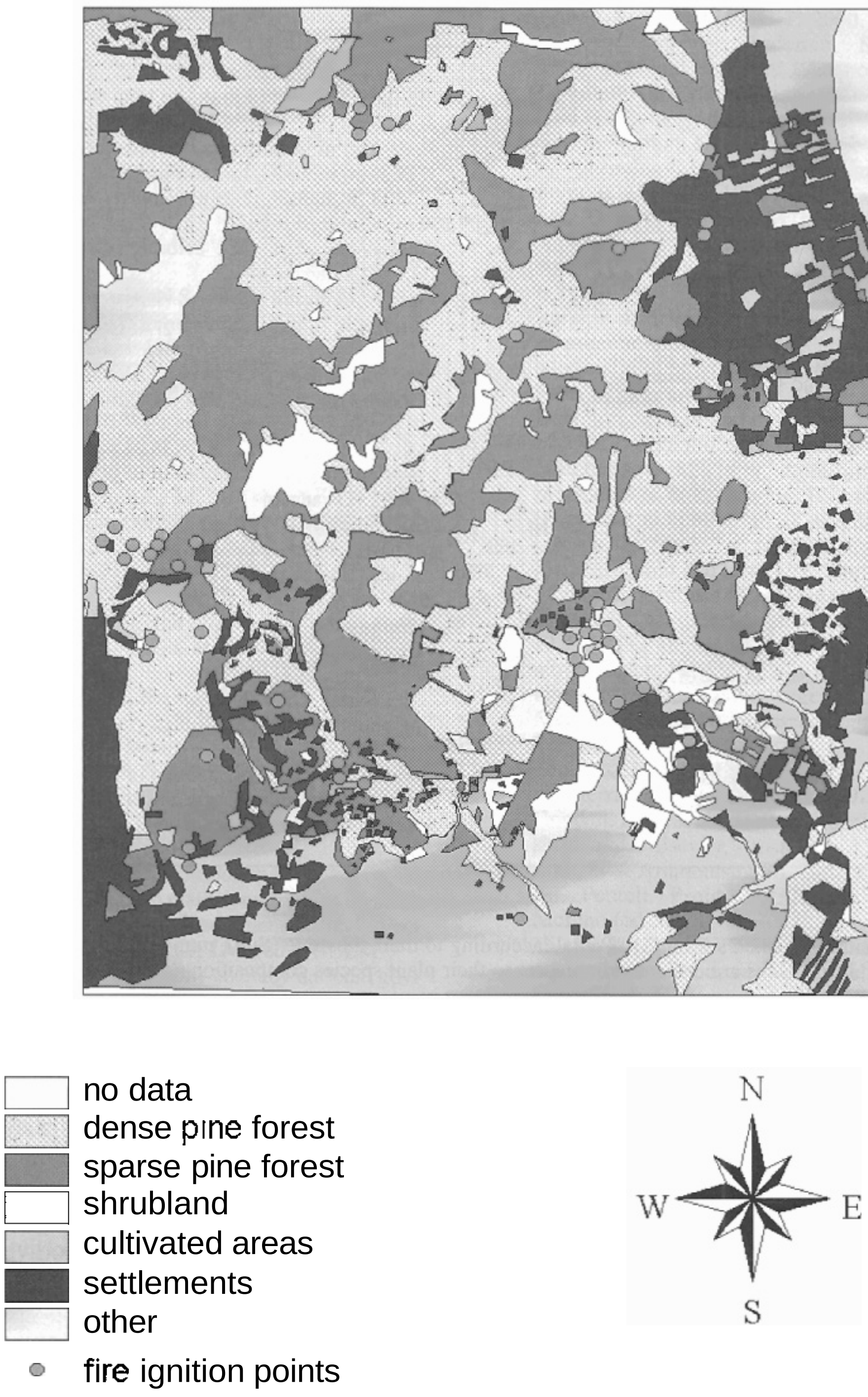


Fig. 9. Fire ignition points in Mt. Penteli since 1971 – from Varela *et al.*, 1999. The area presented coven a slightly broader region that that indicated in Fig. 8.

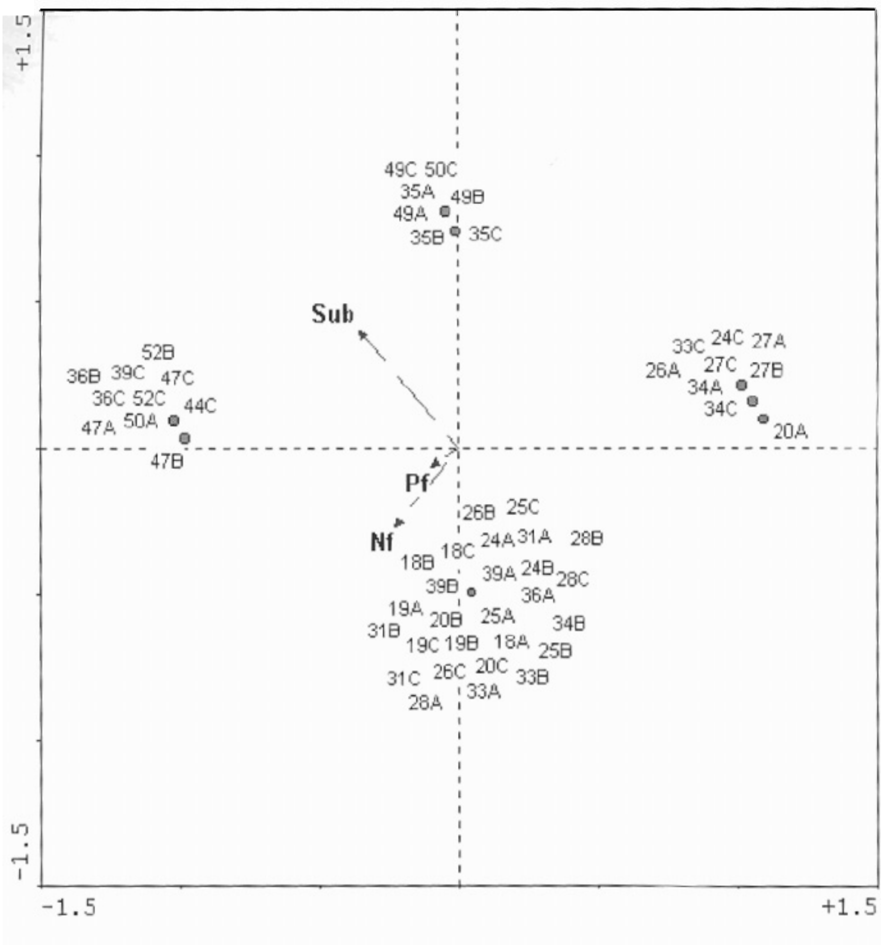


Fig. 10. CCA ordination of burned sites in Mt. Penteli according to their substrate (Sub), number of fires (Nf) they have experienced and fire interval (Pf). Sites are ordinated in respect to their plant species composition, (after Arianoutsou *et al.*, 2001)

Conclusions

There has been an increasing interest in many terrestrial biomes on issues relating biological diversity and ecosystem function (Schulze & Mooney, 1994; Tilman et *al.*, 1997; Chapin *et al.*, 1998). Mediterranean-type ecosystems of the world have been proposed as critical in this scientific effort in the sense that they provide important models for searching new paradigms relating biodiversity with ecosystem stability and resilience (Davis & Richardson, 1995). Given the fact that these unique systems, that had early drawn the attention of scientists from all over the world, are under the threat of severe and progressing landscape changes – especially in the Mediterranean Basin, the need of full understanding the processes underlying these links is essential. This paper has briefly presented three study cases of major landscape changes, which have occurred in the Mediterranean parts of Greece, and has pinpointed fire regime-related processes through which these changes might affect long-established biodiversity patterns.

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