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VEGETATION STRUCTURE IN A POST-FIRE SUCCESSIONAL GRADIENT OF *PINUS HALEPENSIS* FORESTS

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SUMMARY

The structure of vegetation in a post-fire successional gradient of Aleppo pine forests in Attica, Greece, was studied by a synchronic method. All study sites have typical Mediterranean climate and they form a post-fire chronosequence. The vegetation structure is described by means of the flora of the sites, its diversity, the growth and the life forms. The burned ecosystems recover quite rapidly. While the vegetation structure of the mature stage is reached by the 20th post-fire year, the flora practically remains the same from the 15th post-fire year on. During the first four years of the post-fire successional sequence, the herbaceous taxa dominate the flora of the forests, reaching their peak at the second year. The richest family in terms of the taxa it has is that of Leguminosae for the initial two critical years of the succession. The majority of those taxa are herbaceous. The relative contribution of legumes in the flora of the sequential stages of the post-fire succession is gradually restricted.

INTRODUCTION

Fire is known to be the main ecological factor affecting the vegetation of the Mediterranean -climate ecosystems (Naveh, 1967; 1973). The flora of those ecosystems have evolved certain mechanisms in order to overcome the stress caused by the fire incident (Naveh, 1973; Rundel 1981; Arianoutsou-Faraggitaki and Margaris, 1981a). According to their recovery behaviour after fire, plants are classified as "seeders", "resprouters" or plants with intermediate behaviour.

One of the main types of Mediterranean ecosystems in Greece are the Mediterranean pine forests. In the mainland of Greece the dominating pine tree is *Pinus halepensis* (Aleppo pine), while at the islands of East Aegean Sea and in Crete Aleppo pine is been replaced by *Pinus brutia* (East Mediterranean pine). They both cover 8.72% of the forested area of Greece.

About 24.10% of the area burned every year during the dry summer period in Greece refers to Aleppo and East Mediterranean pine forests (Kailidis, 1992). During the period between 1965 and 1989, 122015 ha of *Pinus halepensis* forests were burned. Considering that the Aleppo pine forests cover 371984 ha in Greece, this percentage is not negligible. The situation seems more severe near the urban areas and the tourist resorts where forests are subjected to :ontinuing land-use changes, especially when burned. In order to contribute towards the ıccumulation of the knowledge needed to form ecologically sound post-fire management plans, ve undertook a study on the effects of fire on the resilience of *Pinus halepensis* and *Pinus* ›*rutia* ecosystems. This paper reports on part of this study, specifically on the vegetation ;tructure in a post-fire succesional gradient of Aleppo pine forests in Attica, where they 'onstitute 39.83% of its forested cover and 17.83% of the overall *Pinus halepensis* cover in ;reece.

MATERIALS AND METHODS

All seven study sites are located on hillsides around Athens and they form a post-fire hronosequense of Aleppo pine forests. They all have typical Mediterranean climate, that is nild, subhumid winters and long, dry, hot summers . Data concerning the characteristics of the ites are inserted in Table 1. Although our effort was to select sites as much identical as possible e had to establish them in locations of relatively diffferent bedrock formations, since they are xtremely diverse even in adjacent areas, as long as the dominant woody flora was identical and ıe degree of human interference with the ecosystem was similar. Data for the study sites are iven in Table 1.

The study lasted for eight months, from October 1992 to June 1993. In order to describe the egetation structure we followed the "line-transect" method, which is supposed to be especially dvantageous and efficient in studies of contiguous stages in ecological succession or of ommunities at transition zones (Brower et al, 1990).

In every stand we have randonmly chosen three line transects of one hundred meters, eeping relatively adequate distance between them. On a monthly basis, we recorded all plants that were intercepted by an one-meter-long strip extended at every meter interval across the wire, counting at the same time the number of their individuals. Thus, we end up having 300 records per line transect.

Table 1. The characteristics of the sites studied (M= mature stand).

Stand Age (yr)	Date of Fire	Locality	Parent Rock Material	Slope
1	Sep 92	KAPANDRITI	Tertiary deposits	Steep to moderate
2	Sep 91	AVLONA	Limestone	Steep to moderate
3	Aug 90	STAMATA	Schists	Steep to moderate
4	Jul 89	FILI	Limestone	Steep to moderate
11	Aug 82	DIONISSOS	Schists	Moderate
15	Jul 78	PIKERMI	Tertiary deposits	Moderate to gentle
M		PIKERMI	Tertiary deposits	Gentle

Plant nomeclature follows Med - Checklist (Greuter et al, 1984-1989)

RESULTS

Table 2 presents the list of plant taxa found along the line transects at each study site. We must point out that propably some obscure taxa not growing exactly on the grid created by the transects are not included in the catalogue, since the sampling method, as foresaid, was designed in such way as to give not only qualitative but quantitative data as well.

Table 2. List of plant taxa observed in all study sites. M refers to mature (>30 yr old) forest which is considered as the reference site. The classification of the plant taxa to life form (LF) follow the Raunkiaer's system. Ph= Phanerophytes, Ch= Chamaephytes, Cr= Cryptophytes, H= Hemicryptophytes, Th= Therophytes. From Ph only *Pinus halepensis* has growth form of a tree. The rest Ph and the Ch are classified as shrubs, while Cr. H and Th are all herbs.

	YEARS AFTER FIRE							
TAXA	1	2	3	4	11	15	M	LF
1. PINACEAE								
Pinus halepensis	+	+	+	+	+	+	+	Ph
2. FAGACEAE								
Quercus coccifera	-	+	+	+	+	+	+	Ph
3. CARYOPHYLACEAE								
Stellaria media	-	+	-	-	-	-	-	Th
Silene vulgaris	-	+	-	-	-	-	-	Th
Silene colorata	-	+	-	-	-	-	-	Th
4. RANUNCULACEAE								
Anemone blanda	-	-	+	-	-	-	-	H
Clematis vitalba	-	+	-	-	-	-	-	Ph
5. PAPAVERACEAE								
Papaver rhoeas	-	+	-	-	-	-	-	Th
Fumaria microcarpa	+	+	+	-	-	+	-	Th
6. CRUCIFERAE								
Hirshfeldia incanna	-	-	-	+	-	-	-	Th
Capsella bursa-pastoris	-	+	+	-	-	-	+	Th
Biscutella didyma	-	+	+	-	-	-	-	Th
7. ROSACEAE								
Sarcopoterium spinosum	-	-	-	+	+	+	_	Ch
8. LEGUMINOSAE								
Calicotome villosa	-	-	+	+	-	+	-	Ph
Genista acanthoclada	+	-	+	+	+	+	-	Ph
Anthyllis hermanniae	-	+	+	+	+	+	+	Ph
Anthyllis vulneraria	-	-	-	+	-	-	-	H

11. EUPHORBIACEAE								
Euphorbia taurinensis	-	-	-	+	-	-	-	Th
12. ANACARDIACEAE								
Pistacia lentiscus	+	+	+	+	-	+	+	Ph
Pisıacia terebinthus	+	+	-	-	+	-	-	Ph
13. MALVACEAE								
Malva sylvestris		+	+	-	+	+	+	H
14. THYMELEACEAE								
Thymelea tartonraira	-	-	-	+	-	-	-	Ch
15. HYPERICACEAE								
Hypericum empetrifolium		+	+	+	+	+	+	Ch
16. CISTACEAE								
Cistus creticus	+	+	-	+	+	-	+	Ph
Cistus salvifolius	-	-	+	+	+	+	-	Ph
Cistus monspeliensis	-	-	+	-	+	-	-	Ph
Fumana thymifolia	+	+	+	+	-	+	+	Ch
17. UMBELLIFERAE								
Tordyllium apulum	-	-	+	-	-	-	-	Th
Scandix pecten-jacobeus	-	+	-	-	-	-	-	Th
Daucus carota	-	+	-	-	-	-	-	Th
18. ERICACEAE								
Arbutus unedo	+	-	-	-	+	-	-	Ph
Arbutus adrachne	-	-	-	-	+	-	-	Ph
Erica arborea	-	-	+	-	+	-	-	Ph
Erica manipuliflora	-	-	-		+	-	+	Ph
19. PRIMULACEAE								
Cyclamen graecum	+	+	+	+	+	+	+	Cr
20. OLEACEAE								
Olea europea	-	+	-	+	+	+	+	Ph
Phillyrea latifolia	-	+	+	+	+	-	+	Ph
21. RUBIACEAE								
Gallium aparine	-	+	-	-	-	-	-	Th
Rubia peregrina	+	+	-	-	-	-	-	Ch

Bituminaria bituminosa	-	+	-	-	-	-	-	H
Dorycnium hirsutum	-	-	-	+	-	-	-	H
Onobrychis ebenoides	-	-	-	+	-	-	-	H
Trifolium uniflorum	-	-	+	-	-	-	-	H
Trifolium fragiferum	-	+	-	-	-	-	-	H
Trifolium campestre	+	+	+	+	-	+	+	Th
Trifolium arvense	+	+	+	-	-	+	+	Th
Trifollium stellatum	+	+	+	-	-	+	-	Th
Trifolium lappaceum	+	-	-	-	-	-	-	Th
Vicia villosa	-	+	-	-	-	-	-	Th
Vivia disperma	+	+	+	-	-	-	-	Th
Vicia tetrasperma	+	-	+	+	-	-	-	Th
Vicia sativa	+	-	-	-	-	-	-	Th
Lathyrus setifolius	-	+	-	-	-	-	-	Th
Lathyrus cicera	+	-	-	-	-	-	-	Th
Lathyrus aphaca	+	+	-	-	-	-	-	Th
Ononis variegata	-	+	-	-	-	-	-	Th
Medicago lupulina	-	+	-	-	-	-	-	Th
Medicago orbicularis	+	+	-	+	-	-	-	Th
Medicago littoralis	+	-	-	-	-	-	-	Th
Medicago polymorpha	-	+	-	-	-	-	-	Th
Medicago minima	+	-	-	-	-	-	-	Th
Lotus ornithopodioides	+	+	-	-	-	-	-	Th
Securigera securidaca	-	+	-	-	-	-	-	Th
Securigera cretica	-	+	-	-	-	-	-	Th
Hippocrepis unisiliquosa	+	+	-	-	-	-	-	Th
Scorpiurus muricatus	+	+	-	-	-	-	-	Th
9. GERANIACEAE								
Geranium molle	-	+	-	-	-	+	+	Th
Erodium mallacoides	+	-	-	-	-	-	-	Th
10. LINACEAE								
Linum pubescens	+	+	-	-	-	-	-	Th

table continued....

22. CONVOLVULACEAE								
Convolvulus elegentissimus	+	+	+	+	-	+	+	Th
23. BORAGINACEAE								
Alkanna tinctoria	-	-	-	-	-	+	+	H
24. LABIATAE								
Ajuga chamaepitys	+	-	-	-	-	-	-	H
Teucrium polium	-	-	-	+	-	+	+	Ch
Prassium majus	-	+	-	-	-	-	+	Ch
Ballota acetabulosa	-	+	-	-	-	-	-	Ch
Stachys spruneri	-	+	-	-	+	+	-	H
Satureja thymbra	-	-	+	+	+	+	-	Ch
Coridothymus capitatus	-	-	-	-	+	+	+	Ch
25. SCROPHULARIACEAE								
Veronica cymballaria	+	+	-	-	-	-	-	Th
26. GLOBULARIACEAE								
Glogularia alypum	-	-	-	-	-	+	-	Ch
27. PLANTAGINACEAE								
Plantago sp.	-	-	+	-	-	-	-	H
28. CAPRIFOLIACEAE								
Lonicera etrusca	+	-	-	-	-	-	-	Ph
29. VALERIANELLACEAE								
Valerianella sp.	-	-	-	+	-	-	-	Th
30. DIPSACACEAE								
Tremastelma pallestinium	-	+	+	+	-	-	-	Th
31. CAMPANULACEAE								
Campanula drabiflora	-	+	-	-	-	-	-	Th
32. COMPOSITAE								
Helichrysum sp.	-	-	-	+	-	-	-	H
Phagnalon graecum	-	-	-	-	+	+	+	H
Anthemis chia	-	+	+	-	-	-	-	Th
Senecio vulgaris	-	+	-	+	-	-	-	Th

table continued....

Calendula arvensis	-	+	+	+	-	-	+	Th
Carduus pycnocephalus	-	+	-	+	-	-	-	Th
Hypochoeris achyrophorus	-	+	+	+	-	+	+	Th
Atractylis cancellta	-	+	-	+	-	-	-	Th
Centaurea mixta	+	+	+	+	-	-	+	H
Tragopogon sp.	-	+	+	+	+	+	+	H
Scorzonera sp.	+	-	+	+	+	-	+	H
Reichardia picroides	+	+	-	+	+	+	+	H
Inula viscosa	-	-	-	+	-	-	-	Ch
33. LILIACEAE								
Asphodelus aestivus	-	-	+	+	-	+	+	Cr
Asphodeline lutea	-	-	-	+	-	-	-	Cr
Gagea graeca	-	-	-	-	-	-	+	Cr
Scilla autumnalis	-	-	-	-	-	-	+	Cr
Ornithogallum divergens	-	+	-	-	-	-	-	Cr
Muscari commosum	+	+	+	+	-	+	+	Cr
Asparagus aphyllus	+	+	+	-	-	+	+	Ch
Ruscus aculeatus	-	+	-	-	-	-	-	Ch
Smilax aspera	+	+	+	+	-	-	-	Ph
34. IRIDACEAE								
Crocus cartwrightianus	-	+	+	+	+	+	+	Cr
Romulea sp.	-	-	-	-	-	+	-	Cr
Gladiolus italicus	+	-	-	-	-	-	-	Cr
35. GRAMINAE								
Cynosurus echinatus	+	-	-	-	-	-	-	Th
Briza maxima	-	+	-	-	-	+	-	Th
Aegilops ovata	-	-	-	+	+	-	-	Th
Lagurus ovatus	-	+	-	+	+	+	-	Th
Bromus ramosus	-	+	+	+	-	-	-	Th
Avena sterilis	-	-	-	+	-	-	-	Th
Brachypodium pinnatum	-	+	+	+	+	+	+	H

table continued....

36. ARACEAE						
Arisarum vulgare	+	+	-	-	-	Cr
37. ORCHIDACEAE						
Ophrys lutea	-	-	-	+	-	Cr
Serapias sp.	-	-	-	-	+	Cr

During the first three years after the fire the richest family, in terms of number of taxa, is the legume family (Leguminosae). At the more mature stands of the post-fire chronosequence other families, such as Compositae, Graminae and Liliaceae, appear to have rather more representatives than the rest families (Table 3). As it is obvious, the richest flora is observed on the second post-fire year, while the fewer taxa were noted on the eleventh year after fire event (Table 3).

The percentage contribution of the various life forms in the plant taxa recorded at the study sites is shown in Table 4.

Table 3. Number of taxa per family along the post fire chronosequence.

Families	Years after fire						
	1	2	3	4	11	15	M
Pinaceae	1	1	1	1	1	1	1
Fagaceae	-	1	1	1	1	1	1
Caryophyllaceae	-	3	-	-	-	-	-
Ranunculaceae	-	1	1	-	-	-	-
Papaveraceae	1	2	1	-	-	1	-
Cruciferae	-	2	2	1	-	-	1
Rosaceae	-	-	-	1	1	1	-
Leguminosae	16	19	9	10	2	5	3
Geraniaceae	1	1	-	-	-	1	1
Linaceae	1	1	-	-	-	-	-
Euphorbiaceae	-	-	-	1	-	-	-
Anacardiaceae	2	2	1	1	1	1	1

Malvaceae	-	1	1	-	1	1	1
Thymelaeceae	-	-	-	1	-	-	-
Hypericaceae	-	1	1	1	1	1	1
Cistaceae	2	2	3	3	3	2	2
Umbelliferae	-	2	1	-	-	-	-
Ericaceae	1	-	1	-	4	-	1
Primulaceae	1	1	1	1	1	1	1
Oleaceae	-	2	1	2	2	1	2
Rubiaceae	1	2	-	-	-	-	-
Convolvulaceae	1	1	1	1	1	1	1
Boraginaceae	-	-	-	-	-	2	2
Labiatae	1	3	1	2	3	4	3
Scrophulariaceae	1	1	-	-	-	-	-
Globulariaceae	-	-	-	-	-	1	-
Plantaginaceae	-	-	3	-	-	-	-
Caprifoliaceae	1	-	-	-	-	-	-
Valerianellaceae	-	-	-	4	-	-	-
Dipsacaceae	-	1	1	1	-	-	-
Campanulaceae	-	2	-	-	-	-	-
Compositae	3	9	6	11	4	4	7
Liliaceae	3	5	4	4	-	3	5
Iridaceae	1	1	1	1	1	2	1
Graminae	2	4	2	5	3	3	1
Araceae	1	1	-	-	-	-	-
Orchidaceae	-	-	-	-	-	-	1
TOTAL	41	71	41	50	32	35	35

Table 4. Life forms of the plant taxa recorded at the study sites

Years after fire	Plant Life Forms (% contribution)				
	Ph	Ch	Cr	H	Th
1	19.5	7.3	9.8	12.2	51.2
2	14.1	8.5	7.0	12.7	57.7
3	26.8	7.3	9.8	19.5	36.6
4	21.6	11.8	11.8	19.6	35.3
11	43.8	15.6	6.3	25.0	9.4
15	22.9	22.9	14.3	17.1	22.9
Mature	22.9	17.1	20.0	22.9	17.1

DISCUSSION

Since 1934, when Raunkiaer introduced his life form system, it has met with a great deal of application in all the fields of terrestrial ecology. That system can be successfully applied in the study of post-fire succession, as a tool that allow us to predict the post-fire behaviour of a plant according to its life form (Chapman and Crow, 1981). Of course in many cases things might not be so simple. For example, phanerophytes in general are regarded as resprouters but *Pinus halepensis* and *Cistus* spp. are obligative seeders. Chamaephytes and hemicryptophytes also seem to perform a diverse post-fire behaviour. On the other hand, therophytes are obligative seeders and cryptophytes seem to be obligative resprouters.

During the early post-fire years herbaceous flora dominates the Aleppo pine forest ecosystems. The same is true for other Mediterranean climate ecosystems (Hanes, 1971; Naveh 1973, Arianoutsou-Faraggitaki and Margaris, 1981a; Arianoutsou- Faraggitaki, 1984; De Lillis and Testi, 1992; Faraco et al, 1993). The majority of those taxa are restricted only to the first few years after fire and they are obligate seeders. Their seeds, which are long-vitable and form soil seed bank, can only be germinated after the influence of fire (Keeley and Zedler, 1978; Arianoutsou and Margaris, 1981b; Papavassiliou et al, in the same volume).

Between the first and the second post-fire year sites an increase in the species richness is observed. It cannot be attributed to the enrichment of the flora of the burned forest by any dormant seeds, since it is expected that all of the hard-coated seeds have already germinated by the first year. Increase in numbers of individuals (density) during the second post-fire year.

have been observed. After the second post-fire year a decrease is noted in the flora of the Aleppo pine forests. This is mainly due to the restriction of the therophytes represented in the flora of the sites. This can be possibly explained by the hypothesis, that the absent herbaceous species have seeds the germination of which is directly or indirectly induced by fire. The direct induction can be seen to the mechanical eruption of the hard seed coat (Arianoutsou and Margaris, 1981b; Roy and Sonie, 1992; Thanos et al, 1992), while the indirect one can be related to the removal of the canopy (Roy and Arianoutsou-Faraggitaki, 1985). Once a fire consumes the vegetation, the incident light coming to the soil surface has different spectrum, since there is no leafy filter to intercept it. This leads to a change in the R:FR ratio which reaches the light sensitive seeds, which therefore germinate. It is possible that some of the soft coated seeds do germinate this way. We assume that further decrease in the herbaceous taxa that is observed in the more mature stands (3 yr old burn and onwards) is propably due to restriction imposed by the competition for light and nutrients with the woody species which are costantly extented. Although we expected that the species richness will be lower and lower from year to year, we found that in Fili (4 yr old burn site) the flora was richer than that of Stamata (3 yr old burn site). This happens because in Stamata existed a thick layer of bryophytes that might have possibly affected in a negative way the plant community. In the 11 year old stand the woody species dominate the ecosystem. The vegetation is quite dense and the participation of the herbaceous flora is limited. Finally in the 15 year old stand the vegetation appears less dense, the canopy opens slightly again and some herbaceous species reappear.

The richest plant family during the first years of the post-fire chronosequense is the family of Leguminosae. This has been referred also by previous researchers (Naveh, 1973; Chen et al, 1975; Arianoutsou, 1979; Rundel, 1981; Thanos et al, 1989; Papavassiliou and Arianoutsou, 1993, Arianoutsou and Thanos, in the same volume) for Mediterranean climate ecosystems. The importance of this family for the burned ecosystem is high, since the plants of that family are able to form symbiotic relations with nitrogen-fixing soil bacteria, thus contributing to the soil enrichment with nitrogen (Rundel, 1981; Arianoutsou-Faraggitaki and Margaris, 1981a, c; Papavassiliou and Arianoutsou, 1993; Arianoutsou and Thanos, in the same volume). The vast majority of the species noted were herbaceous and their presence was restricted to the first post-fire stages. Only three woody species were recorded: *Calicotome villosa*, *Genista acanthoclada* and *Anthyllis hermanniae*.

Other families which are rich both in number of taxa and in therophytes (possibly seeders) are those of Compositae and Graminae. They both show their peak of presence at the fourth post-fire year.

Our results show that the post-fire succession at the Allepo pine forests of Attica has similar characteristics with the succession of other Meditteranean ecosystems (Arianoutsou-Faraggitaki, 1984; Espirito-Santo et al, 1993; Lucchesi and Giovannini, 1993; Ne'eman et al, 1993). Still, there are not adequate data available in the Meditteranean countries per se, in order to furnish a strong theory on species replacement during post-fire succession. The main reason for that is that it is almost impossible to have long-term diachronic data on the same permanent plots in these human threatened areas. Most people use the synchronic method, which has the expected shortcomings. It is our aim to contribute towards the filling of this gap by a combination of both methods under the framework of the current project.

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