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# Effect of two successive wildfires in *Pinus halepensis* stands of central Greece

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We estimated differences, five years after a wildfire, in soil and vegetation between *Pinus halepensis* stands that were once burnt (1998) and stands that were burnt twice in a short time interval (1995 and 1998), in the area of Penteli, central Greece. The parameters monitored were the physical and chemical attributes of upper soil layer and the vegetation composition, density and height. The results showed that five years after the wildfire, soil pH did not differ between areas burnt once and twice, while the organic matter was higher in the once-burnt areas. The vegetation composition was similar in the two areas and the dominant species were those pre-existing the fire. On the contrary, vegetation density was considerably lower in the twice-burnt areas. The height of woody species oscillated in the same levels in the two areas. The plant community was composed mainly by resprouting species, like *Quercus coccifera, Pistacia lentiscus*, or *Phillyrea latifolia*, and less individuals from seed-regenerated species, like *Pinus halepensis*, *Cistus monspeliensis*, and C. *creticus*. It is suggested that the recurrence of wildfire affected negatively the ecosystem attributes, and contributed to the increased risk of degradation.

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Greece is a Mediterranean country with a big problem regarding fire due to the climatic conditions prevailing in summer, high temperatures and drought. The problem is important in zones with prevailing pyrophitic species of the genera *Pinus, Quercus, Erica* and *Cistus*. Wildfires are an integral part of these environments, which have developed different post-fire regeneration strategies (Naveh 1975, Trabaud et al. 1985, Thanos et al. 1989, Thanos and Marcou 1991, Tsitsoni 1997, Ganatsas et al. 2004).

Post-fire regeneration has been extensively studied throughout the world. In the Mediterranean region the post-fire recovery process of burnt ecosystems has been identified through many studies, and several adaptation mechanisms have been well established (Trabaud 1994, Tsitsoni 1997). However, the recovery process depends on the time interval between fires, and varies depending on the kind of ecosystem (Polakow and Dunne 1999, Eugenio and Lloret 2006, Goudelis et al. 2007). In the case of *Pinus halepensis* forests, it is estimated that full recovery (structurally and functionally) requires over 30 years (Schiller et al. 1997, Arianoutsou and Ne'eman 2000, Trabaud 2000, Tsitsoni and Karagiannakidou 2000, Zagas et al. 2004).

Most approaches to fire effects on Mediterranean plant communities addressed vegetation recovery after a single fire. Few studies considered the effects of subsequent fires

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(Eugenio and Lloret 2004, Kazanis and Arianoutsou 2004, Eugenio and Lloret 2006, Goudelis et al. 2007), and more studies are needed to assess the effects of fire recurrence on vegetation composition.

The aim of this study was to estimate differences, 5 years after the last wildfire, in soil and plant community composition of *P. halepensis* forests that were once (1998) and twice burnt in a short time interval (1995 and 1998), in the area of Penteli, central Greece. We monitored physical and chemical attributes of upper soil layers and plant community composition, density, and height, with the overall goal to estimate differences in the recovery process.

# Material and methods

## Study area

The study was carried out in Penteli, 30 km from the city of Athens. The region consists of part of Mount Penteli (altitude range 100 to 1107 m). The parent rock materials are mainly limestone and schists and a small part is covered by sedimentary formations (Mountrakis 1985). The slope gradient was 15–30%. The vegetation of the area belongs to the lower Mediterranean vegetation zone, *Quercetalia ilicis* and particularly to the association *Oleo-lentiscetum*. The climate is characterized as Mediterranean type (Csa) according to Koeppen classification. The annual amount of rainfall is 413 mm and the dry period has an average duration of 5–6 months, lasting from April to September. The ecosystem studied was pre-fire dominated by *P. halepensis* with a shrub understorey of maquis species. Floristic composition of these stands was as follows: tree layers, *P. halepensis*, shrub layer: *Quercus coccifera, Pistacia lentiscus, Phillyrea latifolia, Arbutus unedo, Nerium oleander, Erica arborea, Cotinus coggygria, Dittrichia viscose, Pistacia terebinthus, Olea europaea, Cistus monspeliensis, Cistus creticus, Phlomis fruticosa, Pinus halepensis,* herb layer: *Brachypodium pinnatum*, *Dactylis glomerata, Cynodon dactylon, Sanguisorba minor, Convolvulus arvensis, Convolvulus elegantissimus, Astragalus monspessulanum, Lotus corniculatus, Medicago* sp., *Avena sterilis, Capsela bursa pastoris, Stelaria media, Alcanna tinctoria, Lagurus ovatus, Teucrium divaricatum, Euphorbia characias, Muscari commosum, Melica ciliata, Lathyrus aphaca, Lathyrus digitatus, Tuberaria guttata, Briza maxima, Medicago minima.* The stands of *P. halepensis* were even-aged coming from natural regeneration after previous wildfires. The age of these stands ranged from 30 to 40 years as shown by tree ring analyses. The studied area was burnt in July 1995, and a large part of the area was burnt again in August 1998. The former fire destroyed 2720 hectares and the latest 8350 hectares, both fires burnt completely the existing vegetation, and only a few patches stayed unburnt in valleys and streams.

## Sampling

Sixteen permanent plots of 100 $m^2$ were established just after the second fire (August 1998) in the burnt areas in different locations; five in areas burnt once (B1) and eleven in areas burnt twice (B2). The choice of burnt areas was based on maps created by the local forest administration office. Within each plot, five subplots of 1 $m^2$ were selected; four plots 2 m from each corner and one in the centre. In each subplot, all woody plant species were recorded, as well as their density and height growth. Each sprout was separately measured. The monitoring took place 5, 10, 15 and 60 months after fire, in January 1999 (before spring, to record the early plant regeneration), June 1999 (after spring and before summer), in October 1999 (after the first post-fire summer) and five years after the fire, in September 2003. Site characteristics were also recorded; altitude, aspect and topography. Soil sampling was carried out five years after the fire and included one soil sample from each plot. The sample was taken from the upper 20 cm.

## Data analysis

Statistical analyses were performed using the SPSS statistical package. The plot differences in total stem density, species density and height between $B_1$ and $B_2$ treatment were assessed using t-tests for each date ($p < 0.05$, Norusis 2002). Soil statistical analysis (pH and total organic matter in %) was tested in a similar way.

# Results

Five years after the wild fire, soil pH did not differ between areas burnt once or twice, while the total organic matter was slightly higher in once-burnt areas, although differences were not significant (Table 1).

Plant community composition was similar in the two areas but, while dominant species were those pre-existing the fire, vegetation density was considerably lower in the twice-burnt areas. However, no statistically significant differences were observed in the relative abundances of regenerative groups (Table 2). Woody vegetation consisted mainly of resprouting species, like *Quercus coccifera, Pistacia lentiscus*, and *Phillyrea latifolia*, and less from seed-regenerated species, *P. halepensis,* and the seasonal dimorphic subshrubs such as *Cistus monspeliensis*, and *C. creticus*. While resprouters appeared immediately after fire, the regeneration of seeders took place in both burnt areas during the first spring and summer after the fire. An analytical list of plant species recorded in post-fire communities for the same region is reported by Kazanis and Arianoutsou (2004).

The pattern of post-fire vegetation density is similar in both cases (Fig. 1). Stem density increased during the first

Table 1. Soil pH and total organic matter (%) 5 years after the wildfire. The values are means and standard error of means (in parenthesis), and where n = 16, ns = non-significant differences ($p < 0.05$, t-test), between the means at the same soil depth.

| Land category | Soil depth (cm) | pH | Total organic matter (%) |
|---|---|---|---|
| Once-burnt | 0 – 5 | 6.78 (0.05)$^{ns}$ | 4.54 (1.34)$^{ns}$ |
| | 5 – 20 | 6.71 (0.05)$^{ns}$ | 3.55 (0.73)$^{ns}$ |
| Twice-burnt | 0 – 5 | 6.71 (0.07)$^{ns}$ | 4.21 (0.84)$^{ns}$ |
| | 5 – 20 | 6.68 (0.81)$^{ns}$ | 3.05 (0.66)$^{ns}$ |

10 months after the fire, and then decreased again during the first post-fire summer (in months 10–15) due to the high summer temperatures. Later between 15–60 months post-fire stem density decreased due to competition. The height of woody species oscillated in the same levels in the two areas.

## Discussion

This study shows that an autosuccession process took place in both once- and twice-burnt areas, and that pre-fire dominant species composed the post-fire communities, as reported in other cases (Trabaud 1994, Arianoutsou 2001, Ganatsas et al. 2004). Even though there were significant differences in stem density of woody species between once- and twice-burnt areas, community recovery took place following a similar pattern, resulting in a similar composition. Likewise, no differences between once- and twice-burnt areas were observed by Eugenio and Lloret (2006) in the northeastern Iberian Peninsula.

Five years after the fire, the ecosystems were dominated by maquis species that existed before the fire, with a small presence of the tree species *P. halepensis* and a relatively high proportion of *Cistus spp.* (both obligate seeders). The plant community was mainly composed of evergreen broad-leaf shrubs: *Q. coccifera*, *P. lentiscus*, *P. latifolia*, *Erica arborea*, *Arbutus unedo* and *A. andrachne* as well as some seasonal dimorphic sub-shrubs like *C. creticus*, *C. monspeliensis* and *Callicotome villosa*.

Post-fire stem density and plant height was low in naturally regenerated, pre-fire dominant tree species *P. halepensis* and did not differ between once- and twice-burnt areas. The low number of naturally regenerated *P. halepensis* compared to other studies (Kazanis and Arianoutsou 1996, 2004, Tsitsoni 1997, Zagas et al. 2004) can be attributed to the high post-fire human pressure at the burnt areas (Goudelis et al. 2007).

Concerning the vegetation density changes during the studied period, a high percentage of stems of several species died back during the first summer after the fire due to drought stress (Eugenio and Lloret 2006, Goudelis et al.

Table 2. Post-fire density and height growth of woody species, in B1 and B2, five years after the wildfire. Values are means and standard error of means (in parenthesis). Values of the same species for the same parameter followed by different letters are significantly different, ns = non-significant differences,$^{*}$ = insufficient data for the test.

| Species | B1 areas Density (stems $m^{-2}$) | B1 areas Mean height (cm) | B2 areas Density (stems $m^{-2}$) | B2 areas Mean height (cm) |
|---|---|---|---|---|
| Resprouters | 10.40$^{a}$ | | 5.40$^{b}$ | |
| *Quercus coccifera* | 6.65 (3.13)a | 47.43 (2.437)$^{ns}$ | 3.56 (1.12)$^{b}$ | 52.74 (3.13)$^{ns}$ |
| *Pistacia lentiscus* | 0.00 | 0.00 | 1.04 (0.60) | 65.77 (3.60)$^{*}$ |
| *Phillyrea latifolia* | 0.16$^{*}$ | 181.25 (11.25)$^{a}$ | 0.07 (0.07)$^{*}$ | 25.83 (2.20)$^{b}$ |
| *Arbutus unedo* | 0.20$^{ns}$ | 31.67 (1.86)$^{a}$ | 0.21 (0.21)$^{ns}$ | 110.71 (12.17)$^{b}$ |
| *Nerium oleander* | 0.00 | 0.00 | 0.16 (0.15) | 136.14 (9.75)$^{*}$ |
| *Erica arborea* | 1.50$^{*}$ | 28.80 (1.33)$^{*}$ | 0.06 (0.06)$^{*}$ | 47.50 (5.00)$^{*}$ |
| *Cotinus coggygria* | 1.45$^{*}$ | 39.17 (2.95)$^{*}$ | 0.00 | 0.00 |
| *Dittrichia viscose* | 0.00 | 0.00 | 0.18 (0.18)$^{*}$ | 59.92 (8.33)$^{*}$ |
| *Pistacia terebinthus* | 0.16$^{ns}$ | 146.50 (8.67)$^{a}$ | 0.12 (0.12)$^{ns}$ | 51.75 (7.40)$^{b}$ |
| *Olea europaea* | 0.28$^{*}$ | 107.14 (12.99)$^{*}$ | 0.00 | 0.00 |
| Seeders | 1.6$^{ns}$ | | 1.77$^{ns}$ | |
| *Pinus halepensis* | 0.33 (0.27)$^{ns}$ | 71.38 (7.87)$^{ns}$ | 0.38 (0.80)$^{ns}$ | 73.64 (6.95)$^{ns}$ |
| *Cistus monspeliensis* | 1.10 (0.62)$^{ns}$ | 38.02 (2.13)$^{ns}$ | 1.39 (0.42)$^{ns}$ | 42.81 (1.68)$^{ns}$ |
| *Cistus creticus* | 0.25$^{*}$ | 34.60 (1.91)$^{*}$ | 0.00 | 0.00 |
| *Phlomis fruticosa* | 0.28$^{*}$ | 112.00 (4.17)$^{*}$ | 0.00 | 0.00 |
| Total | 12.36$^{a}$ | | 7.17$^{b}$ | |

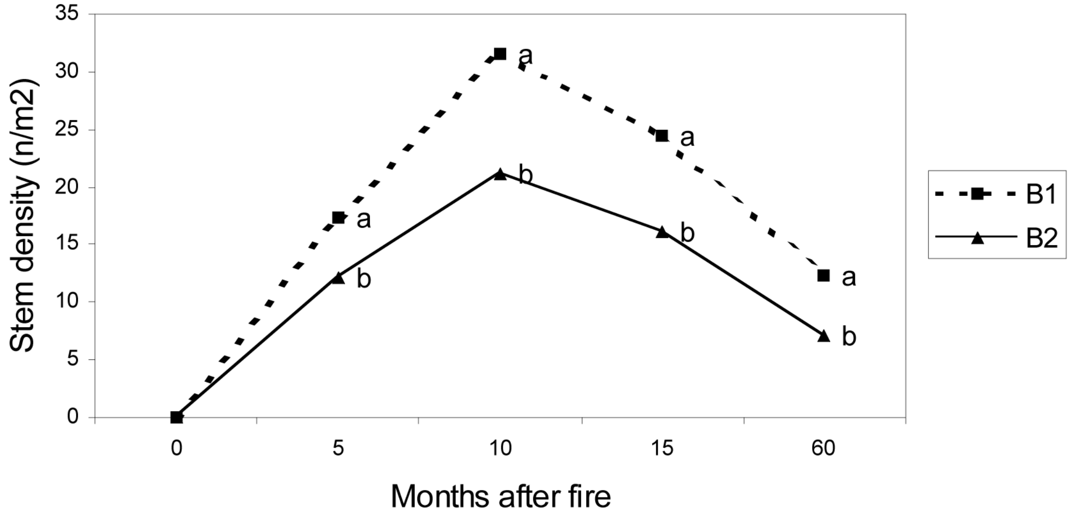


Fig. 1. Post-fire vegetation density changes in 5 years after the fire. B1 = once-burnt areas, B2 = twice-burnt areas.

2007). Vegetation density was further reduced during the next years mainly due to competition between the individuals and less to drought stress. Resprouter species appeared more abundant in twice-burnt areas, while the opposite occurred for seeder species. However, Eugenio and Lloret (2006) found that in most once-burnt areas in northeastern Iberian Peninsula dominant species were shrub species such as *Q. coccifera, Rosmarinus officinalis* and *Ulex parviflorus*, while in most twice-burnt areas dominant species were subshrubs *Dorycnium pentaphyllum* or *Thymus vulgaris*.

All woody species preserved their regeneration ability after the fire on both areas, regardless of the short fire interval in B2. Resprouter species maintained their resprouting ability while seeder species ensured their regeneration through soil or aerial seed banks, but also by the seeds produced by younger plants (3 years old in the case of *Cistus* species). The aerial seed bank was enhanced by seeds from unburnt stands that existed in the surrounding area. There was a floristic similarity between once- and twice-burnt areas despite their scarce appearance in B1 and their local appearance in B2. Overall regeneration appeared higher in B1 plots, due to the regeneration of both resprouter and seeder species, while in B2 resprouter species had lower resprouting ability and seeder species lacked maturity. It is known that *P. halepensis* needs at least 7 years before producing mature seeds (Thanos 2000). However, *Cistus* species were able to flower and produce mature seeds early during the third year after fire (Trabaud 1987).

Based on these data, we conclude that wildfire recurrence has a strongly negative effect on the ecosystem, putting it to the risk of degradation.

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