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MAPPING THE POST-FIRE RESILIENCE OF MEDITERRANEAN PINE FORESTS: THE CASE OF SOUNION NATIONAL PARK, GREECE

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Abstract

Given the heterogeneity of the Mediterranean landscapes and fhe *restriction* in personnel and resources, the identification of patches requiring the application of specific rehabilitation measures due to low post-fire resilience becomes important. The methodology proposed in this *paper is* acting towards this direction. The research has been carried out in *Sounion* National Park, a site of ecological and aesthetic value, given its proximity to Athens metropolitan area. A large *part* of the *Pinus* halepensis forest of the Park has experienced two overlapping fires in summer 1985 and summer 2000. By definition, all patches burned twice are considered as low resilient to fire. On this biological background, the effect of landscape heterogeneity, by means of soil type and slope inclination, on the most important parameters defining post-fire resilience was studied and mapped. This process is by itself an intriguing objective. In this work, the biological parameters used as bioindicators of the landscape resilience are pine saplings density and woody vegetation cover.

INTRODUCTION

The resilience of an ecological system, i.e. its ability to absorb a perturbation and to recover to its former structure, is a very important property of the system [1]. In most cases, mediterranean ecosystems are considered as being resilient to fire [2, 3, 4]. For mediterranean pine forests and woodlands, in particular, the role of fire towards the maintenance of their structure and biodiversity has been recognized [5]. Studies on the long-term post-fire dynamics of Pinus halepensis forests has shown that in most cases these communities are resilient to fire [6, 7, 8, 9]. Still, these communities are not homogeneous across a forested landscape, since differences in site characteristics are reflected to differences in the composition and the structure of the understorey [10, 11, 12]. Similarly, resilience to fire may differ among the various patches of the forested landscape, since the ability of several key plant species to regenerate after fire maybe different, given the specific biotic and abiotic interactions developed within the various patches [13]. Differences in fire and land use history increase this diverse response to fire [14, 15].

During the last decade, large fire events are a common phenomenon in the European Mediterranean countries. Thousands of hectares of *P.* halepensis forests and woodlands are burned primarily in Spain, France and Greece. As a result, there is an increased public demand for effective post-fire ecosystem management. The above-mentioned heterogeneity in ecosystem resilience across large burned areas and the limitations in personnel and financial support, is essential for the Forestry Department Officials to be able to identify patches with low resilience to fire, so as to apply management practices only to those parts that actually required them. The current methodology adopted aims at proposing a system of supporting these decisions to be made. The research has been realized in the Sounion National Park, Attica, Central Greece.

STUDY AREA

Sounion peninsula is located at the south-eastern most part of Central Greece, less than 80 km far rom the center of Athens (Figure 1). It is a hilly area that was supporting, among others, a dense, old growth Plnus halepensis forest, the ecological and aesthetic value of which forced the authorities to declare the site as a National Park in 1974. The total area of the Park reaches 3500 ha. 750 ha of which are under the status of absolute protection. The long and diverse history of human influence and disturbance together with the variety of geomorphological features explains the diversity of habitats and landscape heterogeneity within the Park. The climate of the Sounion National Park is dry Mediterranean, with an average annual precipitation of 310 mm. The area is question is among the driest areas of continental Greece.

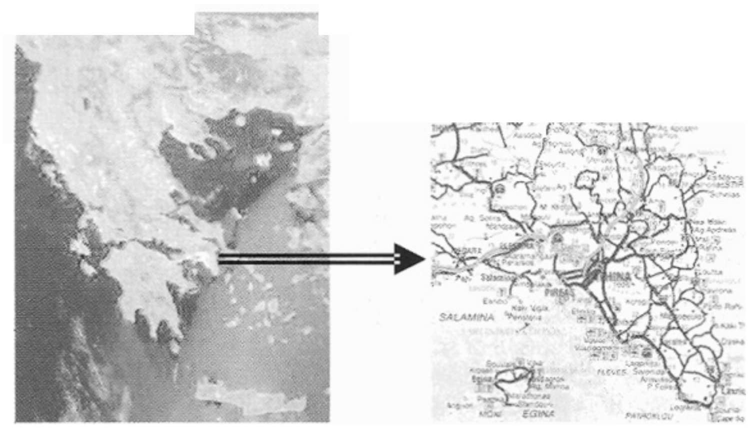

Fig. 1. The geographical position of Sounion Peninsula

The flora of the Park, thought not studied in a systematicway, includes several important species, such as several endemics. Among them there are two narrow endemics of the Sounion Peninsula, Centaurea *laureotica* and C. *attica* ssp. *asperula*, both characterized as vulnerable. Furthermore, due to its geographical position, the area of the Park is importantfor migratory birds.

Urbanization pressures along the peripheral zone and wildfires, usually acting in combination, are the main driving forces for the degradation of the site. The largest case of forest fire took place in the summer of 1985, when almost all the area covered by *Pinus halepensis* forest was burned. Still, the regeneration of the forestwas high almostthroughoutthe burned area (Figure 2).

Fig. 2. Aview of the 15-yr-old pine community,

In summer of 2000 a second fire event burst over the same area and consumed approximately 1100 ha. Most of the 2000 burned area falls within the limits of the year 1985 burned area (Figure 3), whereas some forest patches that had survived the first fire event were burned. Our study towards the mapping of the post-fire resilience refers to the area burned in the year 2000. The altitude of the studied area varies between 30-320 meters a.s.l.

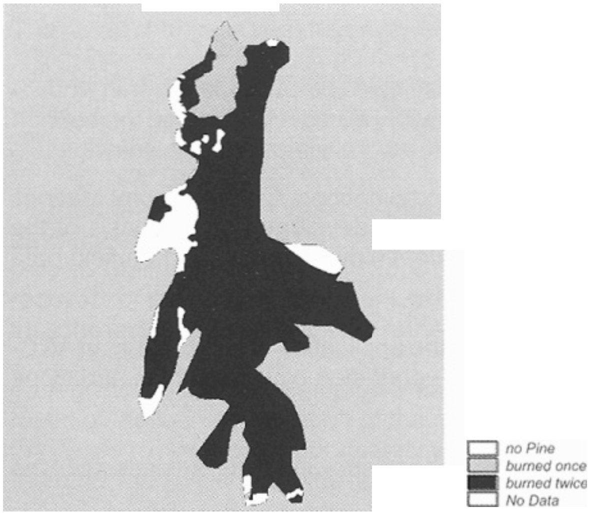

Fig. 3. Fire history of the area burned in summer 2000.

The area in question is one of the most diverse, in terms of geological substrata, in continental Greece, but two types of rock are the most frequent, allowing us to have an adequate number of replicates, that of limestone and schist

METHODOLOGY

The process of mapping ecosystem properties, such as the resilience towards fire is by itself an intriguing objective. For fulfilling this aim, specific components of the ecosystem resilience have been considered to act as indicators. Among others, the components presented in this paper are the *Pinus* halepensis density, which is related to the preservation of forest physiognomy and the woody vegetation cover, the amount of which is related to the potential soil erosion.

The study area has experienced two large overlapping fire events: one in 1985 and a second one in summer of 2000. By definition all patches burned with a time window of 15 years are considered as of low resilience. This is because this period is not enough to allow adequate development of the pine canopy seed bank [3]. On this biological background, landscape heterogeneity is expected to act in a cumulative manner. From this heterogeneity two components were studied, that of soil type and slope inclination.

Consequently, all available combinations of fire interval, soil type and slope inclination were considered for sampling. As a result, five combinations have been identified within the twice burned area (fire interval of 15 yrs): combinations of limestone, with moderate and high slope inclination, and combinations of schist, with low, moderate and high slope inclination. Limestone is always found on the medium and upper altitudinal zones of the hills, while schist is expanding in all altitudinal zones. This explains the unavailability of limestone sites with low slope inclination (plains). Within the once burned area (fire interval >50 yrs), only two combinations were available, those of schist on slopes with moderate inclination and those of schist on slopes with high inclination.

One to three replicates of patches referring to the different available combinations were sampled in spring 2002, i.e. during the second post-fire year. Within each patch, three 50-m-long transects have been randomly established. Among other parameters, the number of pine saplings (linear density) was recorded along the transect and so did vegetation cover, by means of point measurements, i.e. recording species presence at every 50cm point along the transect and calculating the percentage of points that the species or groups of species in question were present along the transect.

Data collected were organized in groups corresponding to the classes of the parameters chosen, taking into consideration the differentiation of the classes defined for the soil types occurring and the classes of the slope inclination defined.

As far as it concerns the *Pinus halepensis* density the classes defined were:
<0.1 individuals/m is characterised as low.
0.1-0.5 individuals/m is characterised as medium and >0.5 individuals/m is characterised as high.

The classes defined for woody vegetation coverwere:
0-20%, corresponding to very low
21-30% corresponding as low
31-60% corresponding as medium and
>60% corresponding as high.

All the classes of the parameters were combined in all logical combinations. On these combinations rules of thumbs of the form: if ....then were applied. These rules were developed on the basis of the general ecological knowledge available related to fire ecology of Aleppo pine forests- and on field data collected. These rulesguided us to the production of a result (output).

These results (outputs) were projected over the landscape after the application of GIS tools in an ARC-MAP environment (ARC GIS 8.3 ESRI), Input maps were those of vegetation cover, soil type and slope inclination organized as raster layers.

The final step of the application was the production of a series of maps showing different aspectsofthe post-fire landscape resilience (resilience maps).

RESULTSAND DISCUSSION

The grouping of recorded data of pine density and woody vegetation cover per available combination of fire interval, soil type and slope inclination in classes is presented in Table 1.

Table 1. Classes of pine density and woody vegetation cover per available combination of fire interval, soil type and slope inclination.

Environmental factor combinations (age, soil, slope)	Pine sapling density	Woody vegetation cover
15 yrs - Schist Low inclination	Medium	Very Low
15 yrs - Schist Medium inclination	Low	Medium
15 yrs -Schist High inclination	Low	Low
15 yrs - Limestone Medium inclination	Low	Low
15 yrs - Limestone High inclination	Low	Very Low
>50 yrs - Schist Medium inclination	High	Medium
>50 yrs - Schist High inclination	Medium	Low

The information included in the above Table was applied towards the production of the resilience maps that we present here. In Figure 4, the *Pinus* halepensissapling density map isshown.

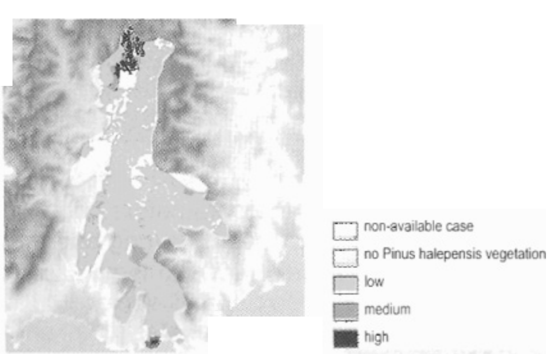

Fig. 4. *Pinus* halepensis density map

The risk of change in vegetation physiognomy is derived from the application of the rules:

- Low pine density results in high risk of having the forest vegetation physiognomy changed
- Medium pine density results in medium risk of having the forest vegetation physiognomy changed
- High pine density results in low risk of having the forest vegetation physiognomy changed

As it is shown in Figure 3, most of the studied area falls in the class of high risk of vegetation physiognomy change. This could be predicted by the given fire regime: two consecutive fire events with only 15 year interval (1985 and 2000). As it was mentioned earlier, the time window is not adequate for full recovery of the canopy seed bank of the dominant tree species, so the availability of seed rain is low and thus the produced seedlings are rather few and quite scarce.

A great portion of the studied area has either low or very low woody vegetation cover (Figure 4), as a result of the low regeneration of the respective species. Apart from the pine, most of the woody species that failed to regenerate adequately were obligate seeders (*Cistus* spp., *Genista* acanthoclada, Satureja thymbra, etc.) which form the functional group that is most affected by fire interval [16].

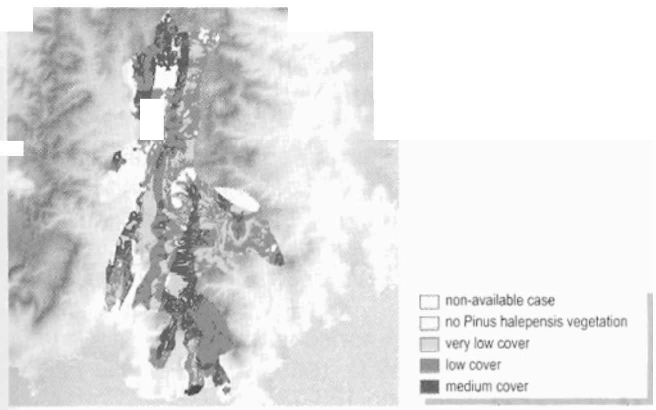

Fig. 4. Woody vegetation cover map.

Sparse and poor woody vegetation cover over a large part of the burned area means that the risk of soil erosion is increased. Risk of erosion is generally regarded as high when woody vegetation offers a permanent plant cover lower than 30% - 60% depending on the conditions [17, 18]. This risk is multiplied by the high slope inclination of several of the patches across the landscape (Figure 5).

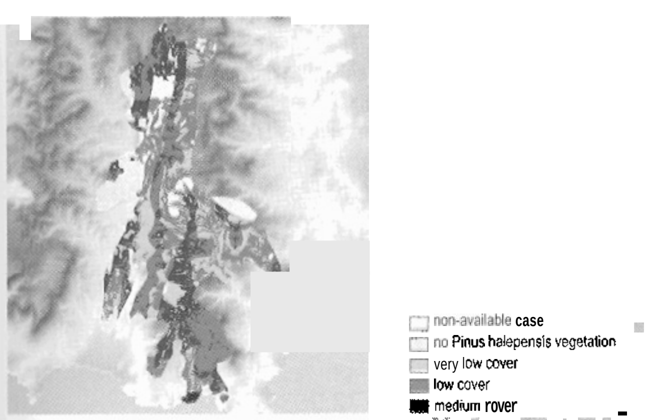

Fig. 5. Soil erosion risk map.

CONCLUSIONS

There is a lot of literature on impacts of fire on the Mediterranean plant species and their communities as well as on their responses towards fire. On the contrary, very few are published on the responses of the Mediterranean landscaoes towards fire.

Recently, an effort of modeling landscape interactions with fire has begun at a European level and some publications have been produced. Most of them concern land use-land cover changes occurring after fire or spatial representation of fire events (perimeter of fire) [19, 20]. The model proposed here seems that works quite satisfactoryfor the cases of the Mediterraneanforests and it is pioneer in its effort of projecting biological properties over the scale of the landscape [21]. It is beyond any discussion that its applicability can be tested in other regions of the Mediterraneanhaving *Pinus* halepensisforests, while it can befurther developed tocoverothervegetation types.

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