Natural Regeneration Assessment of a Double Burnt Mediterranean Coniferous Forest: A Pilot Study from West Peloponnisos, Greece

Dionisios Panagiotaras, Ioannis P. Kokkoris, Dionysios Koulougliotis, Dimitra Lekka, Alexandra Skalioti

Abstract—In the summer of 2021, Greece was affected by devastating forest fires in various regions of the country, resulting in human losses, destruction or degradation of the natural environment, infrastructure, livestock and cultivations. The present study concerns a pilot assessment of natural vegetation regeneration in the second, in terms of area, fire-affected region for 2021, at Ancient Olympia area, located in West Peloponnisos (Ilia Prefecture), Greece. A standardised, field sampling protocol for assessing natural regeneration was implemented at selected sites where the forest fire had occurred previously (in 2007) and the vegetation (*Pinus halepensis* forest) had regenerated naturally. The results of the study indicate the loss of the established natural regeneration of *Pinus halepensis* forest, as well as of the tree-layer in total. Post-fire succession species are recorded to the shrub and the herb layer, with a varying cover. Present findings correspond to the results of field work and analysis one year after the fire, which will form the basis for further research and conclusions on taking action for restoration schemes in areas that have been affected by fire more than once within a 20-year period.

Keywords—Post-fire regeneration, *Pinus halepensis*, restoration management, policy implications.

I. INTRODUCTION

FIRES are part of the Mediterranean ecosystems, shaping landscapes and culture since antiquity. Additionally, forest fires are considered integral environmental attributes for those ecosystems [1]-[4], affecting and shaping vegetation and landscapes throughout history. However, forest fires are currently occurring even more frequently than in the past, especially in the Mediterranean region, affecting the natural environment, destroying households, cultivations, infrastructure, and economic activities, and in many cases are the cause of human casualties. It is indicative that in summer of 2023 and in just a 12-day period, 135,000 ha have been destroyed in four Mediterranean countries (i.e., Greece, Italy, Tunisia, Algeria), with more than 120,000 affected people [5]. Additionally, wildfires burn in many cases areas that have been also burnt in the recent past (i.e., within a 20-year period), with natural forests, where even species with fire adaptation regeneration mechanisms, such as Aleppo pine (*Pinus halepensis*) [6], struggle to survive. In this study, we assess the natural regeneration potential of an area burnt by megafires twice in the last 20 years (i.e., in 2007 and in 2021) in order to investigate the succession patterns occurring in the area, where natural regeneration of *Pinus halepensis* forest was successfully established in the period between the two fires. The main aim is to assess the landscape transformation of a wider area in Peloponnisos, and in the region of Western Greece, Municipality of Ancient Olympia, where possibly only artificial reforestation will support *Pinus halepensis* forest restoration. Additionally, we want to investigate the possibility of natural restoration via neighbouring unburnt forest stands and correlate the results with erosion potential and soil maintenance.

II. MATERIALS AND METHODOLOGY

A. Study Area

The study area (pilot sampling area for vegetation regeneration) is a burned area (from the 2021 forest fire) of regenerating Aleppo pine (*Pinus halepensis*) forest, approximately 15 years old (assumed to be the regeneration result after the 2007 forest megafire). The general exposure is east, northeast, at elevations ranging from 200 to 290 meters (Fig. 1). The relief consists primarily of two major slopes (one to the south and one to the north) separated by a central ridge and a small stream. The area is fully accessible from the local forest and agricultural road network. Slopes in the area range from mild to very steep (> 100%). In the pilot sampling area, the predominant slopes are 15-30%, with significant surfaces with slopes greater than 45%. The study area is bordered to the west by agricultural land and in all other directions by woodland and/or forest and rural roads.

B. Data and Methods

The first step of the study was the historical survey of the area through available aerial and satellite imagery, in order to determine the type of vegetation that existed in the site over time. To this end, a review of relevant background data was conducted for the years 1945, 1996, 2007 (pre-fire), 2012, 2018 and 2023. The layers used were obtained from the Hellenic Cadastre S.A. Viewing Service, as well as from satellite imagery as available for viewing from the Google Earth and Bing Maps applications. In this way, the areas covered by forest historically, as well as the percentage of natural vegetation cover and/or any existing unburned stands, that may under

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certain conditions support the establishment of natural vegetation in the study area, were spatially determined.
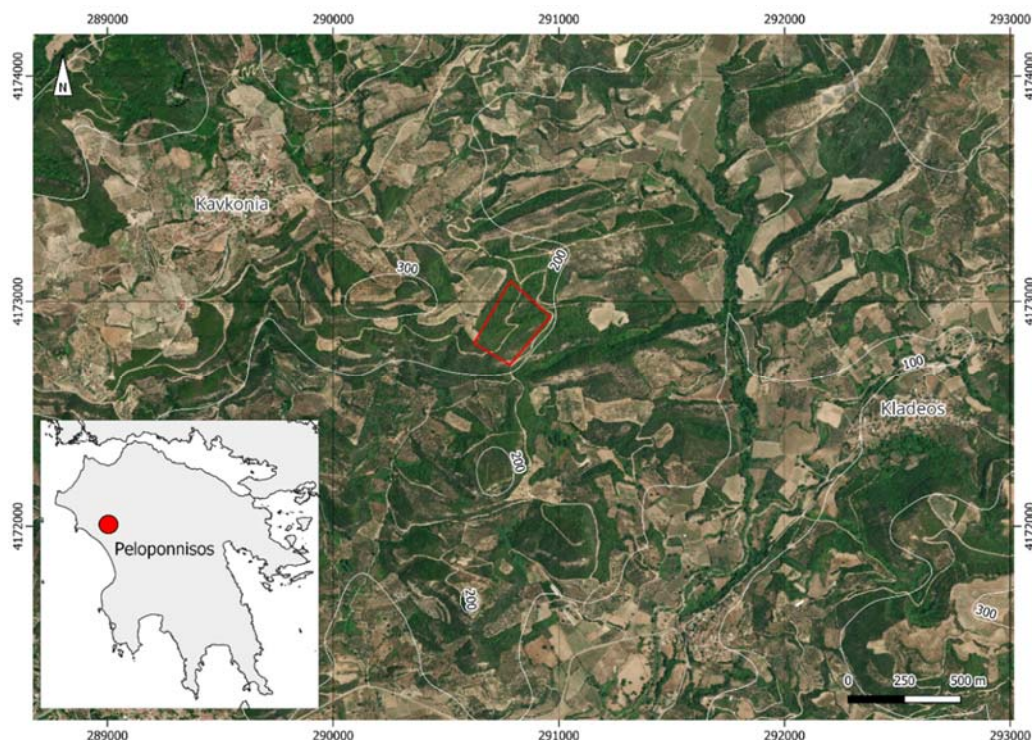

Fig. 1 Study (sampling) area (red outline) at Ancient Olympia Municipality, Western Peloponnisos, Greece

For the primary assessment and mapping of the degree of regeneration in the study area, the guidelines of the project "Predicting the establishment of natural regeneration in burned pine (*Pinus halepensis*) forests in the prefecture of Ilia" [7] and for the field sampling the proposed regeneration sampling protocol was used, which was created by the above project, according to [8], [4], [9]. Regeneration rating was made using a Likert scale, i.e., "Excellent", "Good", "Moderate", "Bad", "Very bad".

The area, as mentioned above, is fully accessible, except for places with very steep slopes and loose, friable soil. Therefore, fieldwork, photography, sampling, and mapping of vegetation boundaries were carried out over most of the area, moving along both sides of the forest road that crosses the area. Fieldwork was conducted on the 10th of April (primary reconnaissance visit of the wider area and extent of the disaster) and on the 2nd of August 2022 (sampling, photography, mapping).

III. RESULTS AND DISCUSSION

A. Assessment of the Degree of Regeneration of Natural Vegetation Units

Ten sampling plots were conducted using the regeneration recording and assessment protocol. The main conclusion reached is that there is no longer any pine regeneration in the area, either in the form of survival of existing trees from previous regeneration, or by recording pine seedlings. The surfaces are mostly covered by standing, burnt individuals and stands of *Pinus halepensis*, some of which have open cones. No living, tree layer of any species is present.

The shrub layer is dominated by *Cistus* sp., evergreen species, with *Phillyrea latifolia* and *Pistacia lentiscus* dominating, while *Quercus coccifera*, *Spartium junceum* and *Olea europaea* participate in places. *Cercis siliquastrum* and *Arbutus unedo* are scattered throughout. *Asparagus acutifolious* is very often recorded, while *Anthyllis hermanniae* and *Hippocrepis emerus* subsp. *emeroides* are also found. Among the herbaceous species, *Arundo plinii*, *Pteridium aquilinum*, *Smilax aspera* (mainly in herbaceous form or slightly climbing on burnt individuals of Aleppo pine and evergreen-shrubs), *Avena barbata*, *Trifolium* sp., *Lotus* sp., *Dorycnium* sp. and others dominate in places and on fine-grained soil.

Shrub species, mainly those of evergreen shrubs, seem to regenerate and grow well, although their cover is considered relatively low. Shrub species such as *Cistus* sp., well adapted to fire and post-fire succession, contribute together with the larger shrubs to soil retention.

Cover of legumes, essential for soil improvement, is present, but is currently not satisfactory, limited to a coverage of between 0% and 15 % per sampling area (per 100 m^2).

In conclusion, the degree of regeneration of the natural vegetation is characterized as "Moderate" to "Bad", without taking into account the restoration of the pine forest in any form. If this is also taken as an assumption of regeneration, then the

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assessment of the degree of regeneration is "Bad" to "Very bad".

It is noted that erosion phenomena were recorded during both visits, and both on dirt roads in the wider area, as well as within the study (sampling) area.
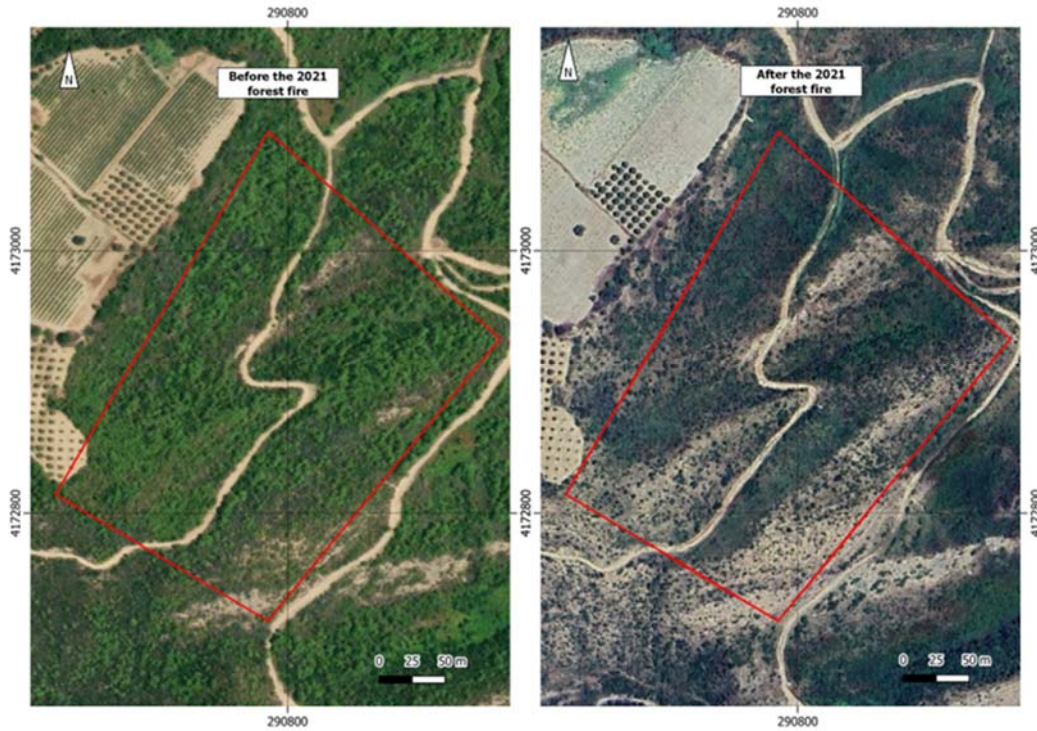

Fig. 2 The study area (red outline) before and after the 2021 forest fire

Fig. 3 Map showing the degree of regeneration of natural vegetation units in the study area (red outline)

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TABLE I
A CHARACTERISTIC SAMPLING PLOT AND THE RECORDED INFORMATION FROM THE FIELD SURVEYS

Plot number and field photo: 1	
X: 290809	Y: 4173018
Elevation (m)	235
Slope (%)	10%
Aspect	SE
% branches/trunks	15
% rocks/stones	10
Pine individuals	0
Total vegetation cover (%)	100%
Arbutus unedo (% cover)	15
Pistacia lentiscus (% cover)	0
Erica sp. (% cover)	0
Quercus coccifera (% cover)	0
Olea europaea (% cover)	0
Phillyrea latifolia (% cover)	2
Cercis siliquastrum (% cover)	1
Cistus sp. (% cover)	0
Arundo plinii (% cover)	85
Asphodelus sp. (number of individuals)	0
Herb layer (% cover)	90
Legumes (% cover)	5
Poaceae (% cover)	85

B. Mapping the Degree of Regeneration of Natural Vegetation Units

The assessment and mapping of regeneration degree pints out that the study area has (as expected) an inadequate regeneration of the *Pinus halepensis* forest and moreover a "Bad" to "Very bad" natural vegetation regeneration in general. Fig. 2 shows the regeneration of the pine forest area after the 2007 fire compared to the current situation after the 2021 fire. The degree of regeneration of natural vegetation mapping refers to the thematic representation of the natural regeneration of vegetation in general in the pilot study area and as presented in Fig. 3. An indicative and characteristic sampling plot, with all recorded parameters, is presented in Table I, highlighting current conditions.

IV. CONCLUSIONS

The study area was historically covered by forests of Aleppo pine (*Pinus halepensis*), like the wider area, with an understory of evergreen species, but has been affected by forest fires in various periods in the past, with the most severe (before the fire of 2021), that of the mega-fire of Ilia and the Peloponnese, in 2007. After the mega-fire of 2007, the pine forest managed to recover naturally in a satisfactorily degree and has formed healthy stands of relatively high pine forest, which covered almost the entire area of the forest in the past. All these changed dramatically after the 2021 forest fire in the region. From the results of the field surveys and the overall picture of the study area and the wider area, it is concluded that the site is very unlikely to recover to the pine forest it was in the past. Possible regeneration from the older cone-bearing individuals should be investigated in a next stage of sampling, after the two-year, post-fire, period. The proposed methodology includes visits and sampling in the following year, so that at least two years have elapsed since the date of the fire, in order to determine the extent to which natural vegetation has grown and the state of the soils in terms of erosion. It should be noted that, for the study area and for the areas that have been affected by fire more than once within the last 20 years, a relevant study proposes the artificial reforestation - restoration of the burnt areas affected by fire in 2021 (see [10], Chapter of the Ilia - Arcadia fire areas). By this, the impact of consecutive forest fires, occurring more frequently than in the past, possibly due to climate change and

human induced reasons, should be a priority for conservation management in terms of nature restoration, natural capital maintenance and amelioration and ecosystem services sustainable provision.

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