ADVANCES IN FOREST FIRE RESEARCH

2022

Edited by

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The geography of forest fires in Greece: fire resilience vis-à-vis management crises

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Keywords

Extreme wildfire events; fire regimes; fuels management; climate change; stochastic fire simulations; transboundary wildfire exposure

Abstract

Greece has an ever-increasing appeal for establishment of new and/or expansion of existing human settlements in the wildland-urban interface that in turn cause pressures on the natural environment, increasing the fire risk and decreasing resilience at a landscape level. A multitude of Mediterranean-type of ecosystems exist in the country, ranging from low shrubs and coniferous woodlands on coastal sites to high-elevation conifer and broadleaf forests. Fire plays a critical role on how these ecosystems were formed and function. Due to the topography, land uses, numerous islands, extensive coastlines and local microclimates, we find either broad zones with similar fire-related characteristics or enclaves where unique interactions with landscape fires prevail. We described the fuel and fire schemes in Greece as formed by different combinations of topography, weather, vegetation and human activity. A geographical context for this analysis was provided by examples of recent wildfires occurred in Greece during the 21st century, which re-shaped the landscape and affected in multiple ways the natural environment and human settlements from severe fire effects. In addition, we showed how these wildfires created crises that drove fire management policies; and we illustrated how fuels and wildfires should be managed based on their respective fire regimes and expected fire effects. Finally, we briefly reviewed future implications for wildfire management from the cumulative effects of climate change, urban sprawl and unmanaged forest growth.

1. Fire environment and regimes

The problem of forest fires in Greece is intensified when extreme events occur that cannot be suppressed immediately due to the inherent weaknesses of firefighting, the widespread wildland-urban interface (WUI) and the lack of forest management in the midst of climate change. Apart from the high and increasing risk of forest fires, a large number of deaths from wildfires in residential areas in Greece has shown that the problem cannot be solved by suppression alone. Extreme behavior of the recent catastrophic fires with human losses in Greece can be attributed to many explanatory factors, such as the ever-expanding urban footprint in forested areas, increasing human-caused fires, mountainous topography, fuel accumulations, intensifying drought and stronger winds from unexpected directions due to climate anomalies.

In Greece, the low elevation pine forests of the moderate-sized serotinous-cone species of Aleppo pine (*Pinus halepensis*) west of the 25th meridian, and Calabrian pine (*Pinus brutia*) at the east of the 25th meridian, have frequent crown fire regimes and transmit most of the catastrophic wildfires; trees can reach a height of up to 30 m, if left undisturbed, but usually they are between 10-20 m in frequently burned forests (Keeley *et al.* 2012). Other important conifers that burn less often and under surface fire regimes are the serotinous Mediterranean cypress (*Cupressus sempervirens*) and maritime pine (*Pinus pinaster*), and the non-serotinous stone pine (*Pinus pinea*), Scots pine (*Pinus sylvestris*) and black pine (*Pinus nigra*). Except Scots pine, all these pines have thick bark and large-sized buds to tolerate relatively high fire intensities and heating. The needle drape (suspended live and detached dead needles) of all these conifers is usually mixed with conifer saplings, broadleaf evergreen shrublands (referred as maquis or phrygana) and cured annual plants (Kalabokidis and Palaiologou 2019).

The shrub fuel types consist of non-tree, woody and foliage vegetation biomass (live with hard leaves or dead twigs) from the dominant shrub species. When assorted with conifers, the shrub fuelbed is mixed with conifer needles and branches, and saplings in canopy openings. Maquis form high canopy density shrublands with heights between 2-8 m and foliar cover >30%, when they are dominant in open landscapes (scrub), forming woodlands with tree heights of more than 8 m if left undisturbed for several decades. When found on the understory of conifers, they can be either sparse and suppressed in closed canopy stands (low shrubs, 0-2 m tall) or dense and tall in open canopy or sparsely forested stands. These shrublands regenerate vigorously after fire through resprouting with high success rates or seedling recruitment, forming a densely covered post-fire fuelbed mixed with dead conifer biomass, fallen logs and annuals. The most typical maquis evergreen shrub is Kermes oak (*Quercus coccifera*), forming vast and severely burned shrublands (and sometimes low woodlands on moister sites), which has a strong post-fire resprouting capacity from rhizomes. In phrygana and/or garrigue shrublands, *Sarcopoterium spinosum* is a thorny dwarf shrub colonizer that accumulates high proportions of standing fine and dead fuel in over-burned and overgrazed areas with land degradation and desertification problems (Moreira *et al.* 2012). Oaks (*Quercus* spp.) have important contribution in the formation of fuelbeds forming woodlands on a transitional zone to temperate forests, including winter-deciduous species. Oaks epicormically resprout from dormant buds (buried in bark) after moderate-severity wildfires, but they may fail following high-intensity fires. Fuelbeds in oak-dominated landscapes consist of dead leaves and branches, mixed with annual vegetation (usually geophytes that resprout by means of underground buds) and short shrubs or maquis, and rarely support active crown fires. When mixed with conifers or tall maquis, oaks can be scorched or completely consumed by passive crown fires (Kalabokidis and Palaiologou 2019).

2. Fire activity during the 21st century

While the annually burned area in Greece has been around 40 thousand hectares on the average in the last 40 years from approximately 1,500 fires per year, certain years stand out as exceptionally catastrophic such as indicated from the European Union’s wildfire history statistics (EFFIS 2020). These are the years of 2000 with 145,033 ha and 2007 with 225,734 ha burned in the 21st century. More than 2,500 ignitions occurred during the years 2000 and 2001. The largest fire events of history for the prefectures of Greece took place in the record year of 2007 in the region of Peloponnese, namely in Achaea (30,000 ha), Messenia (11,000 ha), Laconia (22,000 ha) and Ilia with four wildfires (40,000, 32,000, 30,000 and 12,000 ha). In 2000 the fire of Samos Island in the north-eastern Aegean burned 14,500 ha, summing up to a total of 18,000 ha burned during that year in the region. Evia also experienced a large-scale event during 2007 with 18,000 ha burned. During 2012, a large fire on Chios Island burned 15,000 ha including a significant area occupied by the precious and unique mastic producing tree (*Pistacia lentiscus* var. *chia*). Forest fires of 2021 in Greece amounted to 140,000 ha burned, from six large-scale events (more than 5,000 ha each) and one mega-fire in Evia (46,000 ha).

Attica experienced the largest fire event during 2009 with 20,500 ha burned and repeated catastrophic wildfire years in the vicinity of certain highly populated suburbs of Athens. On July 23, 2018, at the eastern foothills of Penteli Mountain in eastern Attica, a lethal forest fire burned through the urban settlements of Neos Voutzas and Mati where houses intermingled with pine stands, killing 102 people, destroying more than 1,500 homes and burning 1,450 ha. These wildfires caused a lot of pain, had a huge impact on society and demonstrated dramatically the urgent need for better fire prevention planning and coordination of fire control resources, including a major reform to obsolete wildfire management policies and tactics in Greece.

3. Fire management implications

Wildfire management of the various forest types needs to take into consideration the fire regime group to which they belong, that as a rule is linked to the adaptation of the particular species to fire effects (damage severity, capacity for post-fire regeneration), and the fuel hazard they represent (characteristics as fuel accumulation rate, fuel loading and arrangement, and ultimately fire behavior). Locally, of course, management needs to also consider non-forest values-at-risk, and the possibility for fire regime alterations due to the increased presence of humans as source of deliberate or accidental ignitions.

In response to the growing scale of fire risk in Greece, it is proposed to implement new forest management principles with landscape-scale fuel management activities and a more representative geography of risk in terms of setting goals and priorities. Effective fire risk management strategies and comprehensive preventive planning are required, rather than investing solely or mainly in forest firefighting and aerial firefighting. Without the management of fuels and forests to mitigate the intensity and spread of fires before they occur, the effectiveness of firefighting is dramatically reduced. Preventing, suppressing and reducing the risk of wildfires follow interconnected paths, and require alternative practices of vegetation management, mitigation of accumulated fuel and clearing of forest areas with timely and valid scientific interventions to reduce fire risks (Palaiologou *et al.* 2020), in relation to the global climate change we are experiencing today.

The management of forest fuels has proven to be an effective method for stopping the continuity and reducing their quantity, reducing the rate of spread and the intensity of fires. Using stochastic forest fire simulations (Kalabokidis *et al.* 2014) and alternative scenario planning and evaluation tools, different fuel management priorities can be located in forest areas to: 1) block the main fire flows to protected areas; 2) decrease the possibility of high-intensity fires, 3) reduce the likelihood of fires spreading within residential areas, 4) protect areas of increased economic value, and 5) optimize the production of commercial forest products. Results show how investing and implementing one management priority can offer trade-offs to other priorities (Palaiologou *et al.* 2021), and where there are opportunities (spatial coincidence) for achieving multiple management objectives at the same time (e.g. Figure 1).

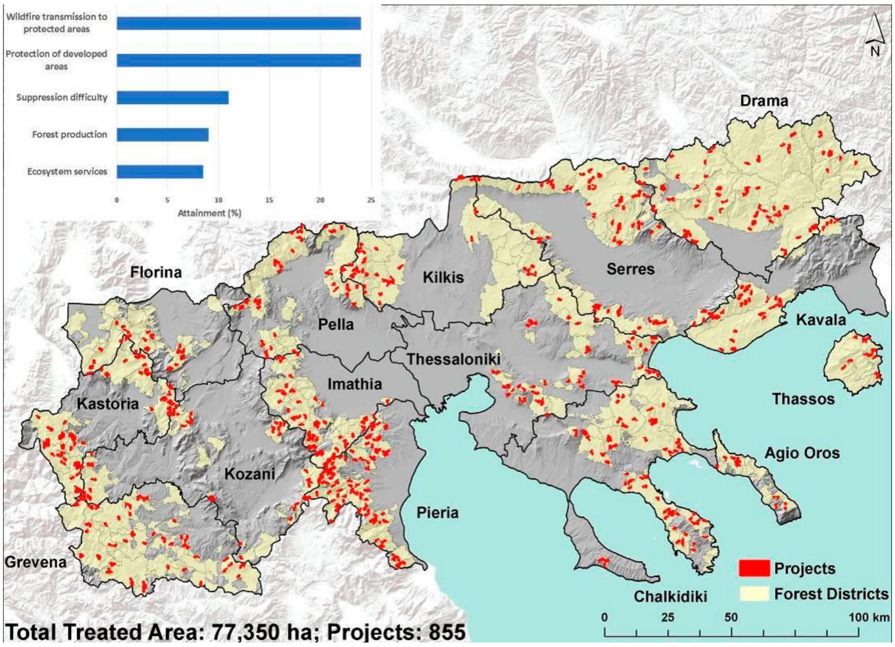

Figure 1: The best 100-ha projects in Macedonia, northern Greece, for each priority with a four-year fuel treatment plan. Attainment for each priority, if all stands that appear on the map are treated, is shown at the upper left corner (Palaiologou et al. 2021).

Post-management changes in forest structure and fuel loads can change the spread and intensity of wildfires and increase the resilience of forest ecosystems. Recent studies have examined the performance of appropriate spatial (composition and density) and temporal (seasonality, efficiency over time) strategies, as well as the effects of different institutional constraints (e.g. protected area management legislation, permitted land uses per property) in reducing the fire risk. In addition, the role and importance of forest management in the protection of settlements is highlighted, with emphasis on the strategic planning of projects and the consideration of the future fire occurrence and behavior (Palaiologou *et al.* 2018). Emphasis should be placed on a combination of thinning, mechanical treatments for managing or arranging the fuel and understory burning to reduce surface and canopy fuels (Omi 2015), while the appropriate planning of fire protection and other socio-economic values that are endangered will be needed, in combination with the fire size and fire regimes (Keane 2015).

4. Concluding remarks

Regions with Mediterranean-type of ecosystems have an ever-increasing appeal for establishment of new and/or expansion of existing human settlements in WUI, which in turn cause pressure on the natural environment (e.g. introduction of alien species, deforestation, human activities in formerly natural areas) that increase the fire risk. This complicated intermix of natural and human systems (Liu *et al.* 2007), aided by the catalyst role of wildfires, leads to new risk governance systems and policies that aim to manage these ecosystems to reduce the loads, change the arrangement and alter the composition of forest fuels on the landscape. Communities can neither eliminate forest fuels (only manage them at a high economic cost on a limited extent), nor totally control the increasing frequency and intensity of wildfires that are influenced by the climate change (Kalabokidis *et al.* 2015), fire suppression policies, land abandonment and reforestation. Human adaptation requires a deep understanding of the role of forest fuels and their effective management, at scales that will prevent future wildfire loses and re-introduce the fire ecosystem resilience (Moritz *et al.* 2014).

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