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The role of fire as a long-term landscape modifier: Evidence from long-term fire observations (1922–2000) in Greece

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ABSTRACT

The objective of this paper is to document the role of fire in shaping the landscape by identifying links between historical fire records and the current landscape indicating that fire favors certain land use/land cover (LULC) types. We geo-referenced fire records taken from 1922 to 2000 in Aitoloakarnania, the largest prefecture -in terms of surface area- of Greece and compared the past LULC classes where fires burned to the present landscape. The outputs indicated a shift of the historic fire ignition points from natural to agricultural-related LULC classes since a significant proportion of fire incidents that, according to the fire records, burnt natural vegetation units is currently located in agricultural landscape units. Additionally, a significant proportion of the fire-affected land cover classes retain their character thus supporting the argument that these classes, especially fire-prone or fire-resistant, have developed mechanisms to cope with fire. In such ecosystems the role of fire is to maintain rather than transform land cover classes.

The findings of this research lead us to conclude that fire can be perceived as a long-term landscape modifier in the Mediterranean, although its effects may vary from region to region because of differences in regeneration patterns among the main land cover types, topographic constraints and local fire histories. Historical fire records extending back to the early 20th century proved to provide valuable information that can reveal interesting patterns of fire burning history and explain present land cover and use patterns. This knowledge, documented from historical records, can be used to develop fire management and land cover/land use management planning.

1. Introduction

The role of fire in shaping ecosystems is made apparent at various scales through the regulation of ecosystem dynamics and the carbon cycle (Harrison, Marlon, & Bartlein, 2010), supporting the assumption of interaction between pattern and processes. However the long-term fire history and successional dynamics are poorly understood in certain vegetation types (Floyd, Romme, & Hanna, 2000). At global scale, although the availability of resources (water and nutrients) that mainly depend on climatic and edaphic attributes is considered the dominant controller of biomass production and distribution (Polis, 1999), the contribution of fire in restricting forest ecosystems from reaching their resource limited potential distributions cannot be neglected (Bond, Woodward, & Midgley, 2005).

Fire may alter the structure of the landscape, thus affecting ecological processes such as the spread of disturbances (Hargrove, Gardner, Turner, Romme, & Despain, 2000). It has the potential to modify landscape patterns by altering species composition (J. Pausas, 2006) preventing or favoring species invasion (Lloret, Pausas, & Vila, 2003) and controlling a vegetation community's succession through the adaptive mechanisms developed by the plant species, or eventually plant communities, to cope with fire (Arianoutsou, 1998). Some landscapes are able to counterbalance the effect of fire while others tend to increase their proportions of more flammable vegetation or land cover units. Once a critical proportion of the landscape is dominated by flammable vegetation units, a self-induced spiral of fire recurrence can potentially occur (S. Bajocco, Salvati, & Ricotta, 2011; Perry, 1995), supporting the argument that burnt areas have a higher probability of burning again compared to areas that have never burned (Moreira et al., 2011).

Literature often assumes that fires of variable surface and

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location favor vegetation mosaics and pyrodiversity (Gill & Allan, 2008), yet the role of fire in landscape heterogeneity is rather complex as spatial heterogeneity is scale dependent and exists on different scales (Trabaud & Galtié, 1996). Fire has a dual role and can be described either as a homogenizing agent at fine scales, or a diversifying agent at broader scales (Pérez, Cruz, Fernández-González, & Moreno, 2003). At fine scales and short term, the most immediate effect of fire on the landscape is the homogenization. A large, intense fire incident can completely destroy the above-ground vegetation and there are indications suggesting that the proportion of vegetation units that are most frequently affected by fire is increased, resulting in less fragmented landscapes (Viedma, Moreno, & Rieiro, 2006). However, since all vegetation and Land Use/Land Cover (LULC) types do not react to fire incidents in the same way, at mid- to long-terms and at broader scales, fire can contribute to the formation of complex landscapes.

Humans have used fire to control the size of and manage natural and human-induced ecosystems (Harrison et al., 2010). Since the Paleolithic and Mesolithic eras there is clear evidence of the use of fire as a landscaping tool (Bowman et al., 2009; Keeley, Bond, Bradstock, Pausas, & Rundel, 2011; Pausas & Keeley, 2009) and during recent history, fire was extensively used to convert forests into agricultural or pastoral LULC units (Bowman et al., 2009; Pezzatti, Zumbrunnen, Bürgi, Ambrosetti, & Conedera, 2013). Especially in the Mediterranean region, wildland fires have been extensively used as a landscaping tool, not only in historic periods but also during modern history (Guiomar et al., 2015; Naveh, 1975; Salvador & Pons, 1995; Valbuena-Carabaña, de Heredia, Fuentes-Utrilla, González-Doncel, & Gil, 2010) and have long played an important role in defining ecological trajectories. Accidentally or deliberately, humans are responsible for the vast majority of fires worldwide (FAO, 2007) including those recorded in Greece (Tsagari, Karetsos, & Proutsos, 2011).

Within this concept, we attempt to identify the role of fire as a tool in shaping the landscape within LULC classes related to agricultural activities. We searched for possible links between documented historical fire records and the current landscape that would signify the use of fire in favoring certain LULC types, and then draw conclusions on the extent with which fire has been used as a landscaping agent. A basic assumption for our hypothesis is the consideration that a clear pattern of mismatch between the LULC class that was historically burnt and the current LULC class occurring on the same site would signify that fire was, deliberately of accidentally, used as landscape modifier. We geo-referenced fire records taken from 1922 to 2000 in Aitoloakarnania, the largest prefecture —in terms of surface area- of Greece, and compared the LULC classes on their ignition location against the present landscape classification, taking into consideration the spatial uncertainty of historical fire records.

2. Materials and methods

2.1. Study area

The study area is the prefecture of Aitoloakarnania (NUTS-3 level) in western Greece (Fig. 1). It is the country's largest prefecture and has a surface area of 5448 km^2. Large mountain ranges with summits of 2318 m a.s.l. (Mt. Velouchi) are present and the dominant vegetation formations include deciduous oak and fir forests at higher altitudes and evergreen shrublands at lower altitudes. On the basis of data from Hellenic Statistical Authority, the agricultural land of the prefecture is dominated by annual cultivations (47,800 ha). Permanent crops cover an area of 35,600 ha with olives groves being the vast majority of them (30,600 ha). Inland waters over a significant portion f the surface of the prefecture, namely

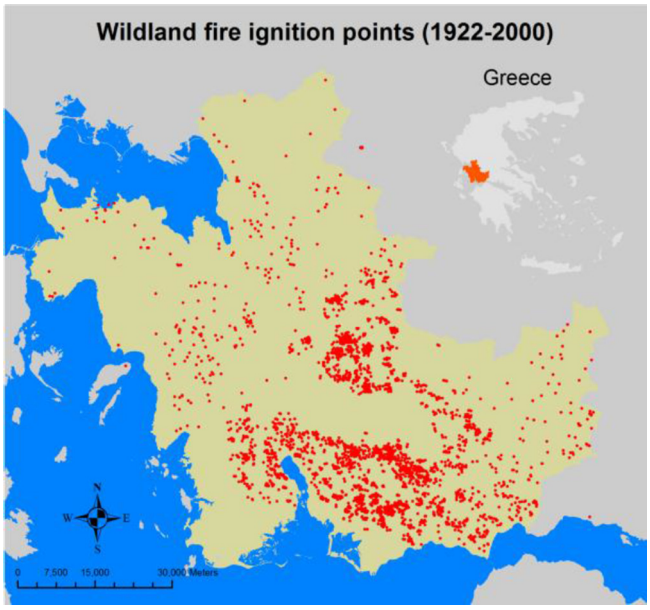

Fig. 1. The study area and the geo-referenced wildland fire ignition observations (1922–2000).

3.87%. Based on data obtained from the closest meteorological station (Agrinio, elevation: 24 m, period: 1931–2010), the prefecture's average mean annual air temperature is 16.7 °C and the mean total annual precipitation is 931 mm with a distinct, Mediterranean-type, dry period from May to September. Shifts of these climate patterns are expected with elevation changes. Aitoloakarnania Prefecture has 210,000 inhabitants, the majority of which is situated in the lowlands. The main economic activity in the area is agriculture.

2.2. Historical wildland fire observations

Data at regional scale (prefecture of Aitoloakarnania) were catalogued from hardcopies of fire events held at the regional Forest Service office and in the prefecture's four Forest Directorates. Fire incidents were recorded from 1922 (with a gap during 1942–1943) including data of the location (community name, forest name and toponym where fire occurred), the date and time of ignition, the total burnt area, the forest species burned, probable cause or even the names of probable offenders.

One major challenge was the use of toponyms to geo-reference each ignition point. During 1922 and 1945 many appellations changed and thus we had to use maps and reference books of previous eras to geo-reference the ignition points. In total, 3444 hand-written fire-incident records from 1922 to 2010 with their respective metadata were catalogued and used. All records of the 3444 entries in the database were plotted onto 1:50,000 scaled maps provided by the Hellenic Military Geographical Service and assigned geographic coordinates with a spatial uncertainty depending on the description of the area where the fire ignited. Actually, we used three spatial indications, found in the historical documented fire records, to locate the ignition point on the map, the name of the community, the name of the forest and the local toponym of the specific area where the fire ignited. However, for the further analysis we kept only the fire ignition points within the period 1922–2000 since Corine land cover was available for the year of 2000 and thus 3173 registered points were further used (Fig. 1).