Applied Geography 88 (2017) 104–117

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Assessing the social context of wildfire-affected areas. The case of mainland Portugal

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ARTICLE INFO

Article history:
Received 11 May 2017
Received in revised form
9 September 2017
Accepted 10 September 2017

Keywords:
Social context
Wildfire impacts
Coping capacity
Random forest
Cluster analysis
Portugal

ABSTRACT

Wildfires cause different impacts, depending on the conditions and resilience level of the exposed communities. Wildfire occurrence in mainland Portugal was assessed with regard to socioeconomic and demographic parameters, to identify the most distinctive conditions of fire-affected areas, without implying the existence of causal relationships. The latest population and agriculture census data were used to retrieve conditions at the civil parish level, regarding demographic patterns, social and labor conditions, physical structures and agricultural activities. To identify differences between parishes, two groups were created with the communities that showed the highest and lowest 20% of wildfire incidence between 2007 and 2014, separately for density of fire events and for burned area. A stepwise approach based on classification trees and random Forest methods was applied to identify the best discriminant variables between the groups. First, irrelevant variables were removed by an interactive process based on misclassification rates. The second step used random Forest analysis to the remaining variables to evaluate their importance in distinguishing the groups. In the final step, cluster analysis was applied to test the correspondence between the clusters created with the selected variables and the initial groups. Results showed that parishes with higher fire density have higher population density, higher proportion of young and educated people, larger families and more overcrowded buildings. On the contrary, parishes with larger burned area are less populated, less attractive to foreigners, have a higher proportion of elderly people, more degraded housing conditions and agricultural activities, visible in the density of sheep and goat and pastures, are still relevant. The cluster analysis demonstrated a better performance of the model for wildfire density, revealing a strong association with socioeconomic dynamics with an agreement above 0.85, much higher than for burned areas which is 0.29. Overall, the spatial distribution of wildfire impacts is framed by societal settings and particular conditions must be further understood to improve the coping capacity of affected communities.

1. Introduction

Wildfire impact mitigation is a major concern in fire management strategies and has been the focus of a growing body of research in recent years (Calkin, Cohen, Finney, & Thompson, 2014; Finney, 2005; Moreira, Vaz, Catry, & Silva, 2009; Oliveira, Lourenço, Vieira, Nunes, & Bento-Gonçalves, 2013; San-Miguel-Ayanz, Moreno, & Camia, 2013; Tedim, Remelgado, Borges, Carvalho, & Martins, 2013; Tedim, Remelgado, Martins, & Carvalho, 2015a). The high incidence of fire and the magnitude of losses they cause in many areas of the globe (Archibald, Lehmann, Gómez-Dans, & Bradstock, 2013; Bowman et al., 2009; Moritz et al., 2014; Pausas & Keeley, 2009) have encouraged the development of research focusing on exposure and vulnerability assessment, the facet of risk analysis that deals with the potential damages of fire occurrence (Ager, Preisler, Arca, Spano, & Salis, 2014; Alcasena et al., 2015; Aretano et al., 2015; Chuvieco, Martínez, Román, Hantson, & Pettinari, 2014; Duguy et al., 2012; Gaither et al., 2011; Lavorel, Flannigan, Lambin, & Scholes, 2007; Ortega, Saura, González-Avila, Gómez-Sanz, & Elena-Rosselló, 2012; Román, Azqueta, & Rodrígues, 2013; Salis et al., 2013; Soto, Molina-Martínez, Rodríguez y Silva, & Alvear, 2013). Multiple approaches have been suggested to assess exposure, vulnerability and mitigation of wildfires impacts. They vary depending on objectives, data

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https://doi.org/10.1016/j.apgeog.2017.09.004
0143-6228/

availability, scale of analysis and methods, such as comprehensive frameworks that integrate several components and different dimensions of potentially affected assets (Birkmann et al., 2013; Chuvieco et al., 2014; Román et al., 2013; Salis et al., 2013; Soto et al., 2013; Tedim et al., 2013). Other approaches focused instead on a particular dimension, such as ecological effects (Aretano et al., 2015; Duguy et al., 2012; Ibarra et al., 2007) or social impacts (Gaither et al., 2011; Paveglio, Abrams, & Ellison, 2016; Paveglio et al., 2015; Poudyal, Johnson-Gaither, Goodrick, Bowker, & Gan, 2012).

Despite these efforts, the underlying factors driving wildfire impacts, particularly the relation with the demographic and socioeconomic conditions of fire-affected populations and territories, here generally called social context, are still difficult to grasp. These conditions, which vary within different spatial units and depending on scale, help shaping the adaptive capacity of the residents and the type of self-defense mechanisms they can implement to mitigate damages caused by wildfires (Carroll & Paveglio, 2016; Paveglio, Jakes, Carroll, & Williams, 2009; Paveglio et al., 2015; Smith et al., 2016). During the last decade, studies from North America (Bihari & Ryan, 2012; Brenkert–Smith, Champ, & Flores, 2006; McCaffrey, Stidham, Toman, & Shindler, 2011; Mccaffrey, Toman, Stidham, & Shindler, 2013; McGee, 2011; Paveglio, Abrams, et al., 2016) and Australia (Cottrell, 2005; Eriksen & Prior, 2013; Prior & Eriksen, 2013) indicate a close relationship between social factors and wildfire management activities, suggesting that people's preparedness is a crucial element of the adaptive capacity of a territory.

In the European context, Portugal is the country most affected by wildfires, which cause substantial damages and human losses (Nunes, Lourenço, & Castro Meira, 2016; Oliveira, Pereira, San-Miguel-Ayanz, & Lourenço, 2014; San-Miguel-Ayanz et al., 2013; Tedim, Xanthopoulos, & Leone, 2015; Turco et al., 2016). The large majority of ignitions in Portugal (over 97%) are caused by human activity (ICNF, 2014) and part of them result from the use of fire in local land management strategies. Fire occurrence in the country has also been associated with socioeconomic changes (Moreira et al., 2011; Nunes et al., 2016), similar to what has been observed in other southern European countries (Ganteaume et al., 2013; Vilar, Camia, San-Miguel Ayanz, & Martín, 2016), where a shift from fuel-limited to drought-driven fire regime, resulting in larger burned areas, has occurred (Chergui, Fahd, Santos, & Pausas, 2017).

In view of these circumstances, we investigated the social context related to the spatial distribution of wildfires in mainland Portugal. Previous efforts have been developed to examine wildfires in view of socioeconomic parameters at local level in Portugal (Almeida & Moura, 1992; Mourão & Martinho, 2014), indicating potential links, nurturing a debate around the topic and suggesting methodological improvements, which are embedded in this research (Fernandes, 2016).

This study evaluated the characteristics of the population and their living conditions at local scale, represented by demographic and socioeconomic factors, in relation to differences in fire incidence levels regarding both number of fires and burned area. The analysis was steered by the following hypotheses: i) fire incidence levels (for number of fires and burned area) vary as a function of the demographic and socioeconomic characteristics of civil parishes; and ii) the social context of civil parishes has different associations with number of fires and burned area. To test these hypotheses, social variables were analyzed with machine-learning algorithms based on random Forest methods, to obtain a first quantification of the thresholds that frame social interactions with wildfires at local level. By identifying differences in the demographic and socioeconomic conditions associated with wildfire density patterns and burned area distribution, we discuss the implications of the underlying social context for the adoption of specific management strategies and mitigation activities tailored to particular groups and contexts.

2. Materials and methods

2.1. Study area

2.1.1. Physical setting

The study area is mainland Portugal, covering about 89,000 km^2. Located in the extreme southwest of continental Europe, the country has a Mediterranean-type climate, with warm and dry weather conditions extending between May and September, and wet and cool winters. Annual rainfall ranges from 400 to 2800 mm and mean annual temperatures from 8 to 22 °C (IPMA, 2016). Altitude ranges from sea level to circa 2000 m, with evident physical contrasts found within the territory; weather conditions follow a gradient of increasing temperature and decreasing rainfall from northwest to southeast, as a result of the irregular topography, more rugged in the north, and proximity to the Atlantic Ocean (Moreira et al., 2011; Nunes et al., 2016). Forests and woodlands cover over a third of the country with pine stands, mostly maritime pine (*Pinus pinaster*), more common in the north, whereas oak species, such as cork oak (*Quercus suber*) and holm oak (*Quercus rotundifolia*), spread over southern Portugal. Eucalypt (*Eucalyptus globulus*) plantations are found mostly in the western half of the country, while shrublands, which cover approximately a quarter of the territory, are found predominantly in the northern region (ICNF, 2013; Marques et al., 2011; Moreira et al., 2011).

2.1.2. Socioeconomic and demographic conditions

Mainland Portugal is composed of 278 municipalities and 2882 civil parishes (Fig. 1). The latest statistics (INE, 2015a) indicate a total of 10.341.330 inhabitants, most densely concentrated in the northwest of the country and in the Metropolitan Lisbon region. In the north, contrary to the southern areas, the spatial distribution of population is dispersed and the land ownership is heavily fragmented, creating an intricate mosaic of built-up and vegetated areas (Nunes et al., 2016; Oliveira et al., 2014).

Recent demographic changes in Portugal are evident in increased ageing, and decrease of resident population in rural inland areas, contrary to what has occurred in coastal areas (INE, 2012). These trends, mainly felt in inland municipalities of the northern and central regions, resulted in the abandonment of agricultural activities and in expansion of uncultivated land. As a consequence, this land becomes largely occupied by fire-prone vegetation, such as shrubs and grasses, leading to high levels of fuel accumulation (Moreira, Rego, & Ferreira, 2001; Moreira et al., 2011; Nunes, 2012; Nunes et al., 2016; San-Miguel-Ayanz et al., 2012). The activities of the primary sector, namely farming, livestock production, hunting and forestry, currently employ 2.8% of the working population, with higher values in southern regions, despite a decrease of 44% since 2001 (INE, 2015b).

2.1.3. Wildfire incidence

Wildfire distribution is not uniform within the country, for both number of fires and burned area. Previous studies of fire occurrence in Portugal indicate that fire density is highest in the northwest, followed by the Lisbon metropolitan region. On the other hand, burned area is more extensive in inland areas of central Portugal (Marques et al., 2011; Nunes et al., 2016; Oliveira, Oehler, San-Miguel-Ayanz, Camia, & Pereira, 2012; Oliveira et al., 2014; Parente, Pereira, & Tonini, 2016; Verde & Zêzere, 2010).