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Understanding wildfires in mainland Spain. A comprehensive analysis of fire regime features in a climate-human context

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ABSTRACT

Understanding fire regime is a crucial step towards better knowledge of the wildfire phenomenon. However, the concept itself, in spite of its widespread use, still lacks a clear, widely accepted definition and there is no general agreement on which features define it best. In this paper we provide an in-depth characterization and description of fire regimes in three regions – Northwest, Hinterland and Mediterranean – comprising the whole of mainland Spain, to identify their key features. Data on number of fires, burned area, fire season and cause are retrieved from historical fire records for the period 1974–2010. Specifically, fire frequency, burned area, number of natural/human-caused fires, burned area from natural/human-caused fires, number of large fires (≥500 ha), and burned area from large fires were examined for each region and fire season. We used a multi-group Principal Components Analysis approach to determine the importance of each fire regime feature. Next, climate and socioeconomic variables were explored using Multidimensional Scatterplots and Generalized Additive Models to find the extent to which fire regimes are controlled by either environmental, human, or both factors. Results revealed differences among regions and seasons in terms of the characteristics of their respective fire regimes. However, several common features have been identified as key components of fire regimes, regardless of region or fire season: fire frequency, number of large fires, and burned area from natural fires. In addition, results confirm that fire regime in the Northwest area mainly depends on human activity, especially during winter, in contrast to the Mediterranean region.

1. Introduction

Wildfires are one of the major environmental disturbances worldwide, playing an important role in determining the structure and functioning of many ecosystems (Archibald, Lehmann, Gómez-Dans, & Bradstock, 2013; E. Chuvieco, 2009b; Ganteaume et al., 2013; Pausas & Fernández-Muñoz, 2012). Understanding the complex interactions of factors involved in wildfire activity still remains an unbeaten challenge, which usually involves dealing with complex interactions among numerous variables (Krawchuk, Moritz, Parisien, Van Dorn, & Hayhoe, 2009). In this regard, the analysis of fire regime is a crucial step towards a better comprehension of wildfires. This is especially relevant in the case of Spain, one of the most fire-affected areas within the European Mediterranean region in terms of annual cumulative burned forests (Darques, 2016).

Fire regime is usually defined as the average conditions of fire that are persistent and consistent within a particular area and over a given period (Chuvieco, 2009a, 2009b; Krebs, Pezzatti, Mazzoleni, Talbot, & Conedera, 2010). However, there is no agreement on how fire regime should be characterized, hence the term itself still lacks a clear and well-known definition (Krebs et al., 2010), although there is a list of potential variables describing fire regime commonly accepted (Pyne, Andrews, & Laven, 1996). Among the great variety of fire regime characteristics that are generally described, we found those such as frequency, seasonality, size, type, severity or intensity (Whitman et al., 2015). It is widely thought that fire regime components have been – and still are – highly variable across time and space (M. V. Moreno, Conedera, Chuvieco, & Pezzatti, 2014). Several studies have demonstrated that global fire regime has moved from being essentially controlled by climate factors to become more dependent on human activity (Chuvieco, 2009a, 2009b; Pechony & Shindell, 2010), thus evolving from natural to human fire regime. On a regional scale, and particularly in the case of Spain, climate still influences fire regimes. However, human impact has steadily gained importance over time (M. V. Moreno et al., 2014). In this respect, human influence on wildfire usually has a double-edge (Syphard et al., 2007). Fire suppression helps reduce the impact of fire activity (Chuvieco, 2009a, 2009b), but simultaneously, human pressure on wildlands is nowadays a major source of ignition

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(Wang & Anderson, 2010).

There are many factors involved when a fire regime characterization is approached (Murphy, Williamson, & Bowman, 2011). Despite considerable research being applied to distinguishing attributes belonging to different fire regimes or fire regions, it remains unclear which features should be included, and further research is still needed (Archibald et al., 2013). In this regard, an approach based on inter-regional and/or inter-seasonal comparison, such as the one we propose, might be particularly suitable. Due to the huge variability of fire activity, the best features to characterize fire regimes should be those that best differentiate regions and/or seasons. A first step toward capturing the main contrasts between fire metrics is to divide the whole period of study into two seasons. Even though fire seasonality has been little studied until now, it has proven useful in analysing the influence of human activities on fire regime (Le Page, Oom, Silva, Jönsson, & Pereira, 2010). Several authors have used different seasonal metrics as the median day of the fire season (Whitman et al., 2015), or the length of the fire season (Chuvieco, Giglio, & Justice, 2008) or to distinguish between two seasons inside a year (vegetative and non-vegetative) (M. V. Moreno et al., 2014).

In this paper we characterize and describe in detail fire regimes in three regions – Northwest (NW), Hinterland (HL) and Mediterranean (MED) – comprising the whole of mainland Spain, to identify their key features. We explore several fire regime features under the premise that there are different fire regimes across the Spanish territory, paying special attention to seasonality, cause and the impact of large fires (> 500 ha; San-Miguel-Ayanz, Moreno, & Camia, 2013). The assessment is developed from historical fire records for the period 1974–2010 from the General Statistics Forest Fires database (EGIF). Our first goal is to improve understanding of the spatial-seasonal patterns of fire regime features and analyse their influence on the fire regime itself. A second objective is to determine the extent to which fire regimes are linked to human and/or climate factors. To achieve these goals, we examined fire regimes from a quantitative and qualitative approach. The quantitative approach is based in a multi-group Principal Components Analysis which allows the most representative fire regime features to be identified and selected. In the latter, we combined the selected fire metrics with climate and human variables, and plotted their relationships using multidimensional scatterplots (MDS), then looked for patterns and relationships among these. MDS's outputs are complemented with Generalized Additive Models in order to better describe the potential relationships.

2. Materials

2.1. Study area

The study area encompasses the whole of mainland Spain (excluding Balearic and Canary archipelagos and also the autonomous cities of Ceuta and Melilla) and covers a total surface area of 498,000 km^2. From a biogeographic point of view, mainland Spain is dominated by two different bioregions, Eurosiberian and Mediterranean. On the one hand, the Eurosiberian region covers the northern side of the country, including Galicia, the Cantabrian cornice and the Pyrenees and is characterized by an Oceanic climate, dominated by deciduous forest; while the Mediterranean region extends all over the remaining territory. This region is characterized by a Mediterranean climate, and is thus significantly drier and warmer than the Eurosiberian region. These conditions favour complex mosaics of plant communities of evergreen, deciduous and/or mixed forests, scrublands or natural grasslands.

Temperatures (Fig. A2, Appendix 1) vary from annual milder values in the NW provinces of the Eurosiberian region, dominated by an Oceanic climate; to warmer temperatures in the MED region, characterized by high annual thermal amplitude in the inner region and milder conditions towards the coast. The rainiest areas (Fig. A2, Appendix 1) are the Cantabrian cornice, and the highest mountain ranges as Pyrenees (Eurosiberian region) and the western Central System (inner Mediterranean region), with average values over 1000 mm per year and maximum during winter. On the other hand, the driest areas are located in the southeast and the Ebro Valley (inner Mediterranean region) and the province of Almeria (Mediterranean coast). Precipitation in the Mediterranean region is irregularly distributed both in time and space, with autumn-spring maximums. Human activity also changes its footprint across the territory. According to Corine Land Cover 2006, in the NW area approximately 68% of the region is covered by forests, shrubs or grassland. This land cover has been traditionally shaped by seasonal grazing at the end of the winter. In the HL region, there has been a progressive abandonment of agricultural activity (crops and pastures) which translates to around 54% of its territory being covered by wildland. Meanwhile, the Mediterranean region, the most populated area, is characterized by an extended wildland-urban interface, due to widespread urban development during the last few decades (M. V. Moreno et al., 2014).

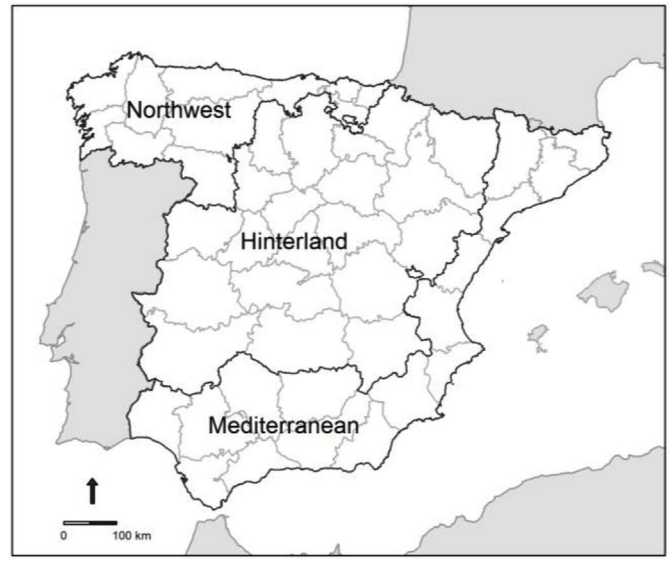

Fig. 1. Spatial distribution of the three regions and provincial division in mainland Spain.

Due to this variety of landscapes, climate and socioeconomic conditions, three different regions – NW, HL and MED – were used (Fig. 1), following the criteria from the Spanish Department of Defense Against Forest Fires (ADCIF). These regions outline homogeneous areas in terms of fire activity and seasonal averages, so that they are expected to have self-defining fire regimes (M. V. Moreno et al., 2014). The NW region includes the Autonomous Communities of Galicia, Asturias, Cantabria and the Basque Country, also the provinces of León and Zamora. This region is located within the Eurosiberian region, excluding the Pyrenees areas. Woodlands cover around 41% of this region which is characterized by long history of agricultural burning to maintain pastures and grasslands (M. V. Moreno et al., 2014). The HL region includes all of the Autonomous Communities without coastline, except for the provinces of León and Zamora (included in the NW region). This region, located in the Mediterranean biogeographical region, has the greatest woodland surface proportion of the whole country (approximately 61%) mostly due to abandonment of agricultural activities and lands (M. V. Moreno et al., 2014). Finally, the MED region (also in the Mediterranean biogeographical region) includes all the Autonomous Communities along the Mediterranean coast. It has the lower woodland proportion (roughly 22%) because of the high degree of urbanisation and tourism development.