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Fire regime changes and major driving forces in Spain from 1968 to 2010

M. Vanesa Moreno [a,*], Marco Conedera [b], Emilio Chuvieco [a], Gianni Boris Pezzatti [b]

[a] Environmental Remote Sensing Group, Department of Geography and Geology, University of Alcala, Colegios 2, 28801 Alcalá de Henares, Spain
[b] WSL Swiss Federal Institute for Forest, Snow and Landscape Research, Research Group Insubric Ecosystems, via Belsoggiorno 22, CH-6500 Bellinzona, Switzerland

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ABSTRACT

Fire regimes play an important role in ecosystems and climate change, affecting the structure and composition of vegetation and influencing carbon dioxide (CO_2) emissions. Analyses of historical fire regimes have indicated that in many ecosystems, fire regime changes are linked to environmental and climatic changes, but these studies have often been both spatially and temporally limited. To determine whether there have been changes in the fire regime in Spain, we used a statistical change point approach to analyse the number of fires and the burned area since fire statistics were first recorded in 1968 for three pyrologically homogeneous regions over two fire seasons (vegetative season = May–November, non-vegetative season = December–April). Then, to assess the possible driving forces behind these changes, we related the significant change points for the number of fires and burned area to climate, land use and fire management variables. For the vegetative season, we observed upward and downward change points in all three regions. In the non-vegetative season, only upward change points were detected in all three regions, whereas downward changes only occurred in the Mediterranean region. Our analyses suggest that the fire regime changes have been driven by climate and land use and, more recently, have also been influenced by fire suppression policies. Our results may contribute to enhance fire management and future studies of fire ecology and climate change.

1. Introduction

The term ‘fire regime’ refers to the characteristics of fires in a given place over a given period of time (Krebs et al., 2010). Since the early 1960s, there has been a growing interest in understanding fire regimes to enhance fire management measures and maintain the ecological integrity of ecosystems, given the ambiguous role of fire (Conedera et al., 2009; Gill, 1975). Given the current status of global change, it is important to understand the changes in fire regimes and the driving forces behind them (Turner, 2010).

Although it is widely recognised that current fire regimes are changing as a result of environmental and climatic changes (Marlon et al., 2008; Pausas and Keeley, 2009), there is much that remains to be clarified. Some authors have observed climate-linked changes in the frequency of fire, the burned area and the seasonality of fires in several regions, including boreal ecosystems (Kasischke and Turetsky, 2006), the western United States (Swetnam, 1993; Westerling et al.,

* *Corresponding author*. Tel.: +34 918855257.
E-mail address: vanesa.moreno@uah.es (M.V. Moreno).
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2006), human-driven change in Africa (Archibald et al., 2011), fire management changes in Africa (Ramona, 2009) and alpine ecosystems (Pezzatti et al., 2013).

In the Mediterranean ecosystem, several studies have indicated that the changes in fire regimes are mainly driven by fuel accumulation, which is caused by fire suppression policies (Minnich, 1983), climate (Pausas and Fernández-Muñoz, 2012) and human activities (Bal et al., 2011). However, some research suggests that future fire regimes will consist of larger fires (IPCC, 2007), which will reduce the importance of the human role in fire suppression (Loepfe et al., 2012), whereas other studies have highlighted the importance of humans in affecting fire regimes, such as those in Africa (Archibald et al., 2011).

In Spain, the study of historical fire regimes is challenging because the available data are limited (Lloret and Marí, 2001). Nevertheless, several local studies have been conducted using both qualitative and quantitative data (Bal et al., 2011; Kaal et al., 2011; Lloret and Marí, 2001). There are also studies of recent fire regimes, whether using descriptive approaches (Moreno and Chuvieco, 2013) or explicative ones (Vazquez et al., 2002; Vázquez de la Cueva et al., 2006).

Despite the difficulties in comparing different sources of data, there are studies that focus on the detection of fire regime changes (Lloret and Marí, 2001; Pausas, 2004; Pausas and Fernández-Muñoz, 2012), which highlight different aspects of fire regimes (e.g., frequency, seasonality, size and ignition sources) and how they may be triggered by different drivers (e.g., legislation, local agricultural habits, fire management, land use and climate). However, a comprehensive and long term approach for the whole country is still lacking.

Based on the longest statistical data records currently available, i.e., the 42 years from 1968 to 2010, in this paper we investigate changes in the fire frequency and the burned area of three pyrologically homogeneous regions of Spain (the Northwest, Interior, and Mediterranean regions) and we discuss qualitatively the possible driving forces related to changes in climate, land use and fire management measures since 1968.

2. Methods

2.1. Study area

The study area includes all of the Autonomous Communities on the Spanish peninsula, covering a total surface area of 493,716 km^2, and includes mainly Oceanic and Mediterranean climatic conditions. Spain has experienced several environmental and social changes since the 1960s. For example, the human population density increased from 59 to 88 n/km^2 (Population Census 1960–2011).

The economy changed from agricultural to largely industrial and, more recently, to a reliance on the third-sector. The crisis in traditional agriculture has caused a huge exodus from rural areas, and those changes have, in turn, driven land use changes.

Much of the marginal agricultural land has been abandoned, and the natural management of the land through livestock grazing and wood gathering has declined, promoting a large accumulation of fuel in some areas. With these industrial changes, livestock rearing has become more intensive, promoted by EU agricultural policies, while the state's reforestation policy of using fast growing species for the paper industry (Seijo, 2005) has also contributed to an increase in woodlands. As a result, woodlands now cover about 37% of the study area, which represents an increase from 115,871 km^2 (First National Forest Inventory 1966–1975) to 182,582 km^2 (Third National Forest Inventory 1997–2007). Conversely, the livestock density decreased from 45 to 12 n/km^2 (Agricultural Census 1968–2009).

The transformation from a predominantly rural to urban society has promoted the growth of the forest–urban interface, and forest use has changed from providing resources to recreation (Martínez et al., 2009; Pausas, 2004).

Technological developments have greatly improved fire management practices, shifting from a focus on fire suppression to a more environmental approach that promotes prevention activities and the introduction of sylviculture (Vélez, 2000).

In addition to these changes, climatic variability, which has resulted in frequent droughts and warmer temperatures, may also have changed the fire regime.

2.2. *Defining pyrologically homogeneous regions*

Due to its heterogeneous climatic and environmental characteristics, Spain has different fire regimes in different regions. To select pyrologically homogeneous areas, we considered three regions, each consisting of several spatially contiguous provinces. These regions are used by the Spanish Department of Defense Against Forest Fires (ADCIF) in the Ministry of Agriculture, Food and Environment (MAGRAMA) in their forest fire statistical reports (Fig. 1). Furthermore, the study of these regions enabled us to make more extensive use of the dataset by analysing the fire reports without their locational details, which were addressed in previous studies (Moreno and Chuvieco, 2013; Moreno et al., 2011).

The Northwest region includes the Autonomous Communities of Galicia, Asturias, Cantabria and Basque Country, as well as the provinces of Leon and Zamora, covering a total surface area of 78,987 km^2. This region has oceanic climatic conditions, except for the provinces of Leon and Zamora, which have a continental Mediterranean climate. Most northern provinces are affected by the Foehn winds, which originate from southwest of the Iberian Peninsula during the spring season when traditional agricultural burning to maintain pastures occurred historically. This region had the second highest human population density and the lowest population growth rate. Approximately 41% of the region is covered by woodlands, and it had the lowest woodland growth rate. The Northwest region has been most affected by fires that were caused by a conflict of interest between farmers and the previously mentioned reforestation policies (Seijo, 2005). These policies affect early consortium woodlands, which were previously used by farmers. However, the attempt to resolve the previous conflict in the 1980s resulted in a new law that assigned the allocation of communal woodlands and caused new conflicts between landowners over boundaries (Vélez, 1986). The livestock density had a lower reduction in its growth rate than the Interior or Mediterranean regions.