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Does fire occurrence modify the probability of being burned again? A null hypothesis test from Mediterranean ecosystems in NE Spain

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Abstract

Two main causes have been proposed as drivers of fire regime in Mediterranean-type ecosystems: fuel build-up and weather conditions. If fuel build-up is the main cause, then areas recently burned will not burn again until some years later. Contrarily, if weather is the main cause, then all areas will burn irrespective of their age. We have devised a statistical test aimed to distinguish between these two hypotheses. To use the test is necessary to know the spatial distribution of fires during a period of time as long as possible. Then, a percolation algorithm procedure is applied to mimic the location, extent, and perimeter/area ratio of the real fires, independently of previous fire occurrence. This model is run many times and each run is considered a realization under the null hypothesis that a pixel burns irrespectively of whether it was burnt in the previous years. The actual number of pixels burned twice is then compared to the histogram of the probability density function of pixels burned twice, which is obtained from the simulations. Actual values falling in the right tail of the distribution point to a clumped pattern (fires tend to be more abundant in some locations), while falling in the left tail will indicate a segregated pattern (burning reduces the probability of further fires in the same site). The method was applied to three different areas of Catalonia (NE Spain) by comparing the actual fires from 1975 to 1998 to the pattern obtained from random fire simulations. An aggregated pattern was obtained in two of the studied areas when the origin of the simulated fires was located randomly, indicating that fires were not uniformly distributed in the territory. When the simulations were started at the centroids of the real fires, the null hypothesis of independence from previous fires was not rejected, and the fuel-driven assumption was not supported. In the third area, results were inconclusive because two large fires, occurred in 1994, totally changed the results obtained until then.

Keywords: Fire regime; Fire spatial pattern; Forest; Null hypothesis; Percolation algorithm

1. Introduction

There is an ongoing debate on the effect of forest fire suppression policies over fire size in areas with Mediterranean climate. One point of view defends that

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the systematic extinction of all reported wildfires allows a build-up of fuel (fuel load and an increased fraction dead materials) that may in the future produce very large fires in periods of adverse weather (Minnich, 1983, 2001; Minnich and Chou, 1997). Moreover, the effect of fire suppression policies on total surface burned and in return periods would be negligible: with no suppression, there would be frequent and small fires, while fire suppression would lead to few larger fires. This view assumes that fire regime is only controlled by fuel, and that ignition probability is uniform throughout the territory. Minnich conclusions were supported from a comparison of wildfires in Southern California (US) and adjacent Baja California (Mexico) based on Landsat imagery. However, these results have been challenged by Keeley et al. (1999). Based on the California Statewide Fire History Database (1910–1998), these authors show that fire size did not increase during that period of time, strongly suggesting that the increased effort in fire suppression in California along the 20th century had no effect in fire size and fire intensity. In short, Minnich view implies that large fires would be fuel-driven, whereas Keeley, among other authors (Keeley et al., 1999; Keeley and Fotheringham, 2001; Moritz, 1997; Moritz et al., 2004) advocate for large fires being mostly wind/weather driven.

In non-Mediterranean ecosystems the role of fuel and climate over the dynamics of vegetation and the subsequent effects of fire suppression on the fire regime are much clearer Thus, for example, the open *Pinus ponderosa* forests of southern Rocky Mountains historically had a fire regime dominated by low-intensity understory fires, and, consequently, fire suppression had an important impact on their dynamics (Allen et al., 2002). On the other hand, many northern and subalpine conifer forests such as those of Yellowstone National Park are naturally characterized by infrequent stand-replacing fires, and is the climate and not fuels the main determinant of the occurrence of large fires (Turner et al., 2003).

In Spain, frequencies of crown fires and total burned area have increased throughout the last decades (Moreno et al., 1998). Several causes have been proposed to explain this increase: (1) increasing fuel build-up as a consequence of agricultural abandonment along the 20th century (Terradas et al., 1998); (2) increasing climatic hazard of fire due to the combination of high temperatures and low air humidity (Piñol et al., 1998); (3) more ignition sources due to extensive human activity across the territory (Terradas et al., 1998). Thus, in this region, fire regime can be driven by fuel, climate, and human activity, providing new insights for the debate.

Previous studies have attempted to characterize fire regime by fitting empirical fire occurrence distributions (for example, time interval between fires, fire probability at time *t*, extreme fire extant) to theoretical models such as Weibull, Poisson, or extreme event distributions (Johnson and Gutsell, 1994; Mandallaz and Ye, 1997; Moritz, 1997). The ultimate goal of this approach is to correlate fire occurrence to potential drivers, such as climate conditions (Moritz, 1997), fire suppression policies (Johnson et al., 1998), forestry practices (Gauthier et al., 1996) or age of fuel (Moritz et al., 2004). Particularly, an effect of fuel accumulation is assumed to produce an increasing probability of fire with the age since the last fire (fire hazard), which is revealed by the *c* parameter of the Weibull distribution (Johnson and Gutsell, 1994; Moritz, 2003; Moritz et al., 2004).

In this paper we propose a novel approach to analyze fire occurrence patterns in relation to previous fire events. This is based on randomly simulating fires with features similar to those that really occurred, and on the subsequent comparison of the randomly generated fire maps with the maps of burned areas derived from satellite images. We use a percolation model that does not intend to reproduce fire behaviour, only observed fires with exactly the same origin, area and shape than in the field. The proposed approach intends to give answers to two different questions: (i) do all locations of an area of interest have the same probability of being burned? And (ii) does the occurrence of fire modify the probability of being burned again? These questions are based on the hypothesis that large fires are fuel-driven (so recent fires prevent fuel accumulation). The methodology developed is applied to a historical series of fires occurred in three regions of NE Spain.

2. Material and methods

2.1. Study area

The study region includes an area of around 32,000 km^2 in north east Spain. The region was divided