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Biophysical and lightning characteristics drive lightning-induced fire occurrence in the central plateau of the Iberian Peninsula

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ABSTRACT

Lightning-induced fire occurrence was assessed for the central plateau of the Iberian Peninsula based on topography, vegetation, meteorology and lightning characteristics. Two different methods were used for analysis purposes: logistic regression (a traditional parametric model) and random forest (a non-parametric alternative based on an ensemble of classification and regression trees). Data on the presence/absence of at least one lightning-induced forest fire in a 4 × 4 km grid cell in the period 2000–2010 were used as the dependent variable for model building, whereas data for the same period at a spatial resolution of 10 × 10 km was used for model validation.

Results show that five of the seven independent variables selected as important for each methodology were common to both methods. The probability of a landscape being affected by lightning-induced fire decreased with increasing altitude and the percentage of agricultural crops, whereas it increased with the percentages of coniferous and mixed woodlands and the mean peak current of negative flashes. The percentages of coniferous woodlands and agricultural crops in a landscape were the most influential variables, highlighting vegetation type as the principal factor to consider when rating lightning-induced fire risk.

The area under the receiver operator characteristics curves calculated using the construction and validation datasets indicated similar and acceptable discrimination capacities for both methodologies. The spatial analysis of misclassified predictions indicated slightly better performance of the random forest model, highlighting that this method has potential for the assessment of lightning-induced fire occurrence.

The insights obtained can be useful for spatially explicit assessment of lightning-induced fire risk, planning and coordinating regional efforts to identify areas at greatest risk and designing long-term wildfire management strategies.

1. Introduction

Lightning is a major natural cause of forest fire ignition in Spain and throughout the world (Pyne et al., 1996). In Spain, lightning-induced fires usually produce small-size fires (Vázquez and Moreno, 1998) in contrast to boreal forests, where lightning-induced fires burn over 70% of the total burned area (Flannigan and Wotton, 1991; McGuiney et al., 2005). Nevertheless, despite their small size, their significance for Spanish forests should not be overlooked, as, in the period 2001–2010, such fires were responsible for 7.3% of the total burned area (MAGRAMA, 2012). Moreover, some simulations have illustrated how, under the ongoing climate change scenario, changing weather conditions will result in more frequent lightning-induced fires and will enlarge burned areas (Krawchuk and Cumming, 2009).

Several works have identified biophysical variables and lightning characteristics that potentially influence the probability of occurrence of lightning-induced forest fires. Interactions among these variables in the landscape originate the spatial and temporal distribution of lightning fires. These biophysical variables are usually considered under three broad categories: weather, vegetation type and topography (Krawchuk et al., 2006; Verdú et al., 2012).

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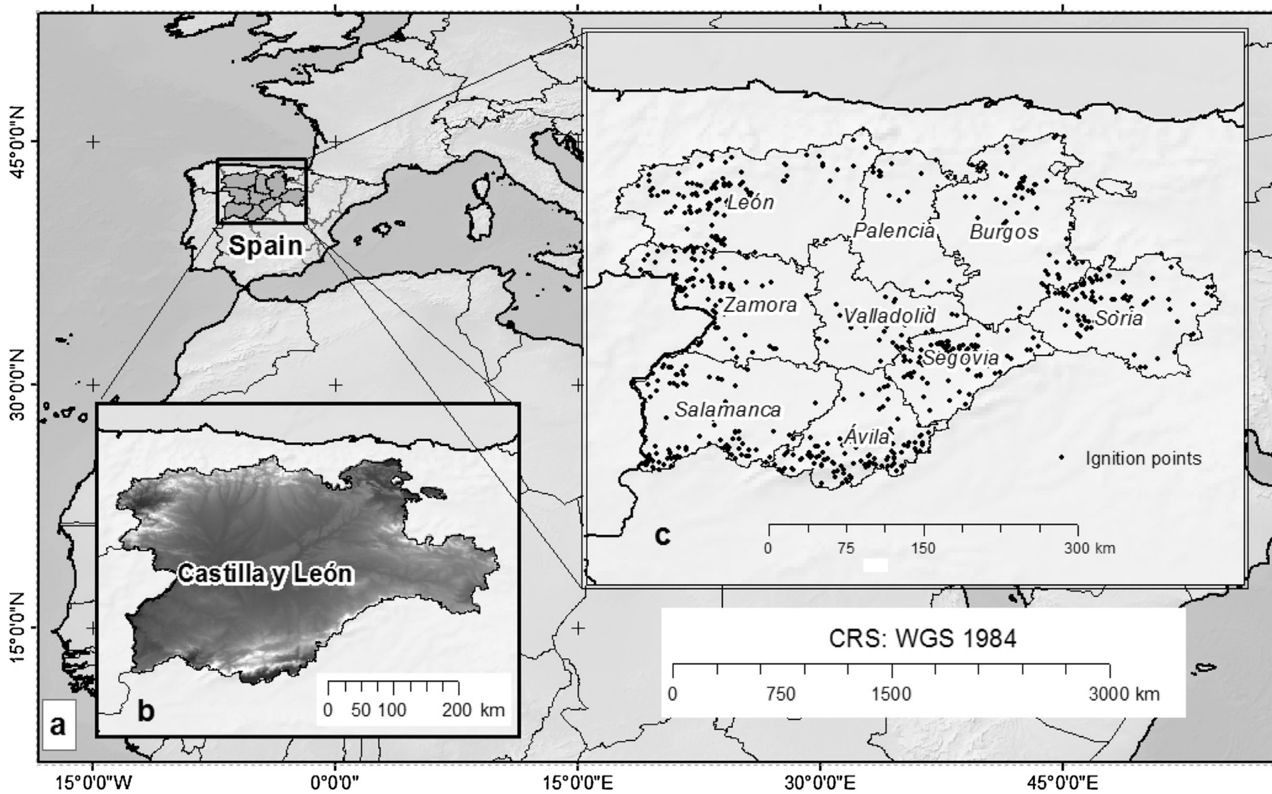

Fig. 1. Study area: the central plateau of the Iberian Peninsula. Location of Spain (a) and Castilla y León (b). Spatial distribution of lightning-induced forest fires for which the coordinates of the ignition points were known ($n = 662$) (c).

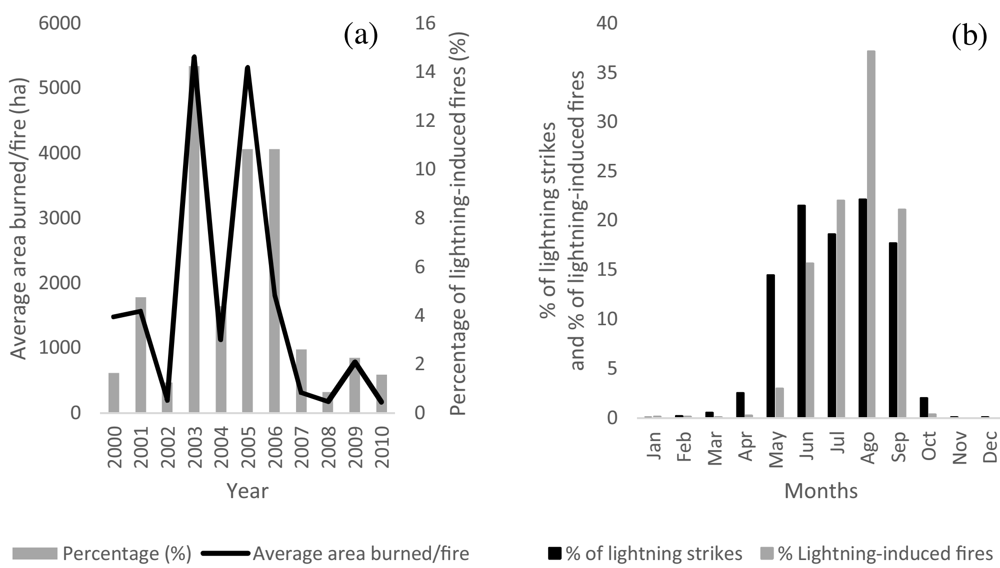

Fig. 2. Yearly distribution of the average area burned per lightning-induced fire and of the total number of lightning-induced fires (a). Monthly distribution of the percentage of lightning strikes and lightning-induced fires for 2000–2010 (b).

Recent precipitation, temperature and relative humidity values determine dead fuel moisture, found to be useful in explaining the occurrence of lightning-induced fires (e.g., Flannigan and Wotton, 1991). According to some authors (e.g., Krawchuk et al., 2006; Mundo et al., 2013), vegetation type and structure are also key elements in determining spatial patterns of lightning fires because they affect fuel load, moisture, flammability and rates of combustion (Rothermel, 1983). Topographic variables, including altitude, exposure and slope, may affect weather and fuel characteristics and also lightning activity (e.g., Díaz-Ávalos et al., 2001).

Regarding lightning activity, three variables of a strike are theorized to play a role in wildfire ignition probability (Fuquay et al., 1972; Pineda et al., 2014), namely, polarity, multiplicity and the characteristics of the electrical current. However, their role is not yet clearly understood for many regions.

In summary, several theories and some debate exist regarding the main factors affecting lightning-induced wildfires. In addition, since the relevance of these factors varies with the magnitude of the studied area (e.g., Krawchuk et al., 2006; Littell et al., 2009), implementing models at local or regional scales is advisable (e.g.,