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# Structural fire risk: The case of Portugal

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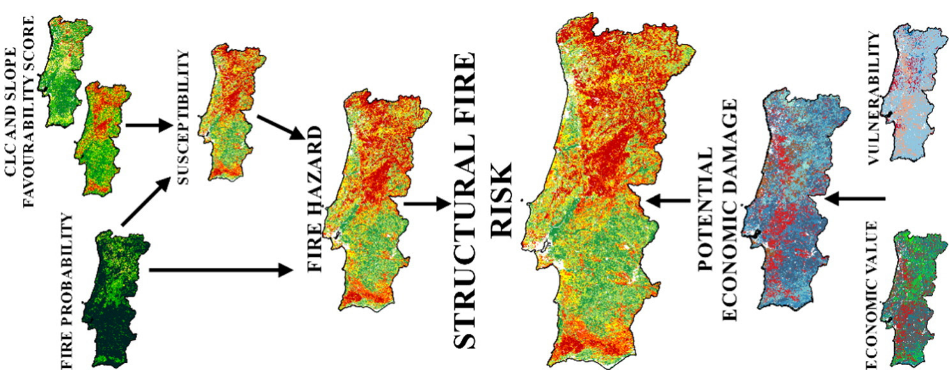
## HIGHLIGHTS

- Verde and Zêzere susceptibility map was updated with longer and high resolution data.
- Susceptibility model's performance and particularities were assessed and discussed.
- Structural fire risk computed for updated potential damage and three hazard scenarios
- Potential damage mapped with recent vulnerability and Horizon 3030 economic values
- Higher fire risk in central, north and extreme south (Algarve) of Portugal

## GRAPHICAL ABSTRACT

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## ABSTRACT

This study is focused in mapping the structural fire risk in the vegetated area of Portugal using a deterministic approach based on the concept of fire risk currently accepted by the scientific community which consists in the combination of the fire hazard and the potential economic damage. The fire susceptibility map of Verde and Zêzere (2010) was adopted and updated by the use of a higher resolution digital terrain model, longer burnt area perimeter dataset (1975–2013) and the entire set of Corine land cover inventories. The susceptibility was mapped with five classes to be in accordance with the Portuguese law and the results confirms the good performance of this model not only in the favourability scores but also in the predictive values. Three different scenarios of (maximum, mean, and minimum annual) burnt area were consider to estimate the fire hazard which allow to estimate the likelihood of a pixel to burn (ranging between 0% and 20%) depending on the class to which it belongs and on the future burnt area scenario. The potential economic damage was estimated with the vulnerability scores and monetary values of species defined in the literature and by law. The obtained fire risk map identifies the areas more prone to be affected by fires in the future and provides an estimate of the economic damage of the fire which will be a valuable tool for forest and fire managers and to minimize the economic and environmental consequences of vegetation fires in Portugal.



## 1. Introduction

Vegetation fires are part of the natural and human systems and, independently of their causes (lightning, accidental, negligent or intentional), may have a highly destructive effect on the ecosystems affecting its ability to recover, causing major environmental problems,

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threaten human lives, activities and infrastructures (Blanchi et al., 2002; Chuvieco, 2009; Jaiswal et al., 2002). Along with the burning/removal of vegetation, fires have very important impacts on soil food web structure and carbon flow (Shaw et al., 2016), microbiological properties and enzymatic activities (Hedo et al., 2015), development of an ash cover (Pereira et al., 2015b), water repellency (Keesstra et al., 2016), terrestrial branch of the hydrological cycle (Pereira et al., 2016a; Van Eck et al., 2016), water quality (Pacheco et al., 2015; Santos et al., 2015a,b) and erosion (Cerdá and Doerr, 2005; Lasanta and Cerdà, 2005). The vegetation fires have a very negative image among the population (Pereira et al., 2014b) but are used as a tool for different objectives (Júnior et al., 2014) namely to increase soil nutrient pools promoting the relatively fast recover of the ecosystems after the fire (Bodí et al., 2014; Pereira et al., 2016b).

Therefore, it's important to understand how the fire is transformed when interacting with its human and biophysical constraints/drivers to an integrated and sustainable risk management approach (Tedim and Carvalho, 2013). The existence of a fire risk map will be a valuable tool to support forest and fire management decisions, focus prevention activities, improve the efficiency of fire detection systems and manage resources and actions of firefighting with greater effectiveness (Catry et al., 2010; Freire et al., 2002). Therefore, many authors have worked to contribute for the development of fire risk maps all over the world and associated with specific hazards such as climate change and the Mediterranean region (Moriondo et al., 2006) and post-wildfire logging in USA (Donato et al., 2006). On this respect, Catry et al. (2010) used logistic regression models to predict the likelihood of ignition occurrence to produce an ignition risk map for the Portuguese mainland. Chuvieco et al. (2010) presented methods to generate the input variables and the risk integration to map wildland fire risk for several regions of Spain, using geographic information system and remote sensing technologies. Finney et al. (2011) conducted a simulation study in order to develop a large fire risk assessment system for the adjoining land area of the United States, by using stochastic and statistical models.

Portugal is on the top of the European countries most affected by vegetation fires (Caetano et al., 2004; Pereira et al., 2014a) and the Portuguese authorities used two different methods to calculate the wildfire hazard based on the definition of Bachmann and Allgöwer (1999). The Portuguese Geographic Institute (IGP, 2016) uses a physical model and the variables that help to explain the spatial pattern of vegetation fires (namely, land cover, slope, roads, aspect and population density) to estimate the fire hazard (Tedim et al., 2014). On the other hand, the Institute for the Conservation of Nature and Forests (ICNF), (ICNF, 2016a) estimates the fire hazard using the deterministic approach of Verde and Zêzere (2010), which is based on the slope, land cover and fire probability as well as the quintiles to define the 5 hazard classes to map the fire hazard in accordance with Portuguese Law – Decree-Law No. 124/2006 of 28 June – (DL, 2006). Finally, the Portuguese Institute for the Sea and the Atmosphere (IPMA, 2016) computes and provides a daily vegetation fire risk index, combining the structural risk index provided by the ICNF and the Canadian fire weather index which is, in essence, a meteorological index of vegetation fire danger. However, to the best of our knowledge, there is no map of structural fire risk for entire Portugal using this deterministic approach and high resolution updated data which, therefore, is the main objective of this study.

To ensure a consistent quantitative analysis of the risk of fire and the comparability of the results is necessary to use the concepts and terminology recognized, accepted and adopted by the community studying this kind of phenomenon (Bachmann and Allgöwer, 1999; Hardy, 2005). The definition of fire risk is very complex and have evolved and improved over the years, and currently the definition of fire risk accepted by the fire research community is the following: quantitative or qualitative indicator of the probability of an area being the source of ignition by natural or artificial means in a certain period of time, giving even information of the expected positive and negative impacts in that area (Chuvieco, 2009; Finney, 2005; Freire et al., 2002; Hardy, 2005; Jappiot et al., 2009).

This definition includes two components (Fig. 1): (*i*) fire hazard, which is the probability of an area be affected by a fire during a certain period of time, i.e., it comprises the susceptibility of an area and the respective event probability to happen; (*ii*) potential damage, which is the damage caused by a fire as soon as such occurs, i.e., takes into account the vulnerability of an area to a fire and the economic value that entails (Jappiot et al., 2009).

As there is no official method to combine the two main components of the structural risk, the approach adopted in this study is based on the combined use of the methods proposed by Antunes et al. (2011) to assess the potential economic damage of each parcel and of Verde and Zêzere (2010) to map the susceptibility. As from the publication of these studies, there were updated versions of the databases, more complete and with higher quality it is possible to evaluate the effects of new and better data and check the progress and performance of the assessment previously made. Therefore, the objectives of this study are: (*i*) to update the susceptibility mapping performed by Verde and Zêzere (2010) by using a Digital Terrain Model (DTM) with higher resolution, a longer fire history and the complete land use land cover inventories; (*ii*) to assess the fire risk in mainland Portugal; and, (*iii*) to discuss some of the characteristics of the adopted methodology namely their nature, the number and type of input variables/drivers, the effect of

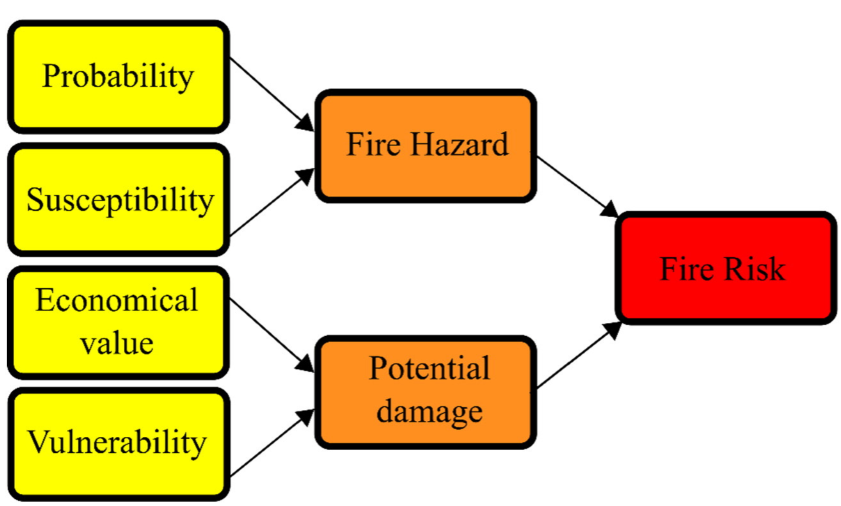


**Fig. 1.** Framework to compute and map the structural fire risk in mainland Portugal in this study.