The choices of the fire — Debating socioeconomic determinants of the fires observed at Portuguese municipalities ☆

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ABSTRACT

Forest fires have been an important source of economic losses in Portuguese municipalities. This work is one of the first studies to test a large range of socioeconomic determinants to explain the differences in the burnt forest areas observed in 278 Portuguese municipalities between 2000 and 2011. Using Classification and Regression Trees, the amount of municipal burnt area per forest fire was observed to depend on the economic dynamism of each locality, the population density of a municipality, the availability of trained teams of forest firefighters, and the presence of relatively high municipal expenditures on environment outlays. We also studied the number of forest fires, concluding that the frequency of forest fires depends on the aging index, the economic dynamism and the average altitude of a municipality.

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1. Introduction

A Finnish proverb claims that "fire is a bad master but a good servant," suggesting that societies do not fully learn from their experiences with fires despite having co-lived with fire for thousands of years.

It is currently recognized that beneficial ecological and economic aspects of fires exist and that modern, integrated fire management shall include investments in fire use (for instance, prescribed burning) along with fire prevention, detection (preparedness), and suppression. However, in this work, we focus on Portuguese forest fires, which are usually associated with significant damages. These damages generate huge economic losses, especially when forest fires destroy agricultural products, obstruct routes and lead to long periods of reforestation that are generally characterized by the absence of inflows for forest investors (Jiang and Zhuang, 2011; Serra et al., 2013).

These facts are generally well recognized and discussed by academics in various universities around the world. However, no Portuguese case study has examined the determinants of the burnt forest area per fire in all 278 of the mainland municipalities. This study seeks to test the socioeconomic causes of burnt areas within Portuguese municipalities. The dimension and incidence of forest fires have

recently increased in European countries (especially in the Mediterranean area) and have produced substantial consequences with indirect effects on several levels, namely, economic consequences. Portugal has experienced an increasing amount of burnt areas, and in 2003 and 2005, the country experienced its most extreme fires (Bastos et al., 2011).

The literature in this field has highlighted a square of confirmed factors. This square has four dimensions: effective public expenditures to prevent forest fires, the availability of forest firefighters to fight different types of forest fires, the dichotomy of rural areas versus urban areas and natural/climatic conditions.

However, our literature review has identified other causes. Most notably, the economic dynamism of localities, housing markets, and the municipal propensity to consider other outlays (such as sports and cultural factors) with significant municipal expenditures were highlighted as alternative and important outlays. Therefore, our study builds upon research recently conducted by Montiel-Molina (2013) and Pezzatti et al. (2013). On the one hand, Montiel-Molina (2013) has highlighted how combinations of different factors, including the variety of quality of national laws and socioeconomic factors, can more thoroughly explain the determinants of Mediterranean forest fires than models focused on single dimensions. On the other hand, Pezzatti et al. (2013) have recognized that forest policies, climate policies, and each country's fire combat strategies significantly impact any forest fire's damage.

Given the nonlinearity among variables, authors such as Dobbertin and Biging (1998), Trombetti et al. (2005), Amatulli et al. (2006), Abendroth (2008) and Kamimura et al. (2008) have not suggested traditional procedures (such as regressions on panel data) to empirically

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test the large number of dimensions in these subjects. These various authors have suggested that CART (Classification and Regression Trees) comprise the most appropriate technique to explore the complexity and nonlinearity among variables.

Therefore, the remaining sections of this paper are organized as follows. Section 2 reviews Portuguese data and the related literature on the heterogeneity of burnt forest areas per reported fire. Section 3 introduces the CART methodology and presents the statistical tests and empirical results produced by the CART methodology. At the end of Section 3, we discuss the implications of our results and the further work to be conducted. Finally, Section 4 concludes the paper.

2. Forest fires and burnt areas — searching for determinants within Portuguese municipalities

Every year, forest fires appear in many locations and greatly impact local, regional, and national economies. It is important to define efficient and adjusted methodologies to prevent forest fires, which are rarely randomly distributed in time and space (Serra et al., 2013).

In many countries, the forestry sector is a source of important economic activity in which timber production and related products greatly contribute to gross domestic product. Additionally, forests make a positive determinant contribution to the climate through carbon sequestering (Wu and Kim, 2013).

Biotic (diseases or pets) and abiotic (fires or climate) factors determine most forest destruction. Natural conditions such as soil coverage (agricultural, rural or forest land), altitude and the dimension of localities are important factors that can determine an area's propensity toward forest fires. Climatic variables, which are extremely related to natural conditions, namely, altitude, are also important factors (Flannigan et al., 2005; Volokitina et al., 2008; Jurjevic et al., 2009; Verde and Zêzere, 2010; Costa et al., 2011; Armenteras and Retana, 2012).

Landscape and biodiversity preservation is additionally considered to be highly correlated with sustainable forest management. For this purpose, there is a need for public expenditures to be used toward efficient programs to preserve the sustainability of the landscape and biodiversity conservation. As identified by the Instituto Nacional de Estatística INE (2012), these expenditures were primarily used to support costs associated with forest firefighting teams, equipment, machinery and sponsorships.

As previously observed, these natural/climatic conditions have been widely analyzed. However, there also exist socioeconomic dimensions that simultaneously affect a region's probability of exposure to a given level of wildfires. These socioeconomic dimensions are characterized by three main qualities. The first quality constitutes the dynamics of these dimensions. Socioeconomic dimensions are not as 'stable' as natural conditions; in reality, we can claim that a given region tends to experience more changes because of the action of its societies than because of its natural/climatic characteristics. Second, as previously argued, forest fires have costs and benefits for the economic agents that react to their own experiences with fires. Therefore, these socioeconomic determinants can be identified as relevant restrictions influencing the process by which economic agents prevent and manage the subjection of their spaces to wildfires. Finally, a deep analysis of the ultimate socioeconomic determinants of forest fires constitutes an important step toward effective regional planning that includes not only forest planning but also socioeconomic planning.

Therefore, socioeconomic factors, in addition to natural/climatic conditions, must be considered in wildfire analysis (Serra et al., 2013). Most literature relates to a triangle of socioeconomic dimensions that interfere with forest fires: the economic dynamism of the evolving region, the population density of the region, and the attention of the local government to environmental issues.

Previous research claims that human land use and climate explain the frequency of forest fires over space and time. Human activity is often seen as a factor that prevents forest fires because economic dynamics create the conditions for a population center and the development of a sustainable social context (Huber et al., 2004).

In some regions, such as Italy, forest fires are primarily caused by humans and are dependent upon social activity. Lovreglio et al. (2010) used the Delphi technique to identify the human behaviors that cause forest fires. The improper use of fire in agriculture activities (13.99% of responses) is the principal cause of negligent forest fires. With regard to intentional forest fires, the majority of answers stated that fires are ignited by seasonal workers seeking to create or maintain jobs (8.41% of responses). This cause is influenced by economic dynamics; the occasional lack of economic opportunities creates degrees of unemployment with consequences on several levels. These problems appear to be more relevant in rural zones.

Chuvieco et al. (2008) and other authors have found a relationship between population distribution and the incidence of forest fires. From an economic point of view, these authors observed that a low spatial concentration of economic activity is associated with more random forest fire behavior throughout the year. The duration of fires in these localities is usually low.

Natural conditions were not the primary cause of forest fires in Northwestern Amazonia. Additional socioeconomic factors are principally related to deforestation, and a local socioeconomic pattern is closely linked with agriculture (Armenteras and Retana, 2012).

Different authors have recognized other dimensions related to a region's lowered probability of suffering fire damages, such as bank activity, housing markets (loans and mortgages) and telephone access lines (Lekakis, 1995; Huber et al., 2004; Stephens and Ruth, 2005; Calcerrada et al., 2008; Chuvieco et al., 2008; Lovreglio et al., 2010; Bowman et al., 2011; Carmenta et al., 2011; Costa et al., 2011; Hoyo et al., 2011; Kraaij et al., 2011).

Various challenges throughout recent decades have encouraged population movement from rural to urban areas and contributed to particular incidents of forest fires. Farms have been abandoned, and communities have a lower capability to alert others and extinguish nascent fires (Serra et al., 2013).

Reineking et al. (2010) applied logistic regression models to data collected in the Canton Ticino in Switzerland from 1969 to 2005 and found that human activities related to land use, infrastructure and legislation are determinants of forest fire ignition.

Calcerrada et al. (2008) and other authors stated that two groups of similar variables predict the occurrence of forest fires: socioeconomic variables and spatial variables. For the socioeconomic predictors, the following variables were taken into account: population density, secondary housing density, and livestock density. For the spatial factors, other variables were considered: distance to urban areas, distance to industrial areas, distance to roads, distance to tracks, distance to camping areas and distance to recreational areas.

Considering some Portuguese observations, Barros et al. (2012) indicated that firefighting was preferentially undertaken near infrastructures (houses, firms, etc.). Portugal has been subjected to diverse causes of wildfires, but the media have linked the most prominent fires with socioeconomic dynamics and the countryside. Population density explained only approximately 42% of inter-annual and inter-district fire incidents (Costa et al., 2011). Other studies, such as those by Marques et al. (2011) and Nunes (2012), revealed that population density has been a significant determinant explaining the distribution of forest fires in Portugal.

The work of forest firefighters with firefighters and other forest workers has been highlighted as relevant to help in the aftermath of forest fires and to prevent re-ignition. Municipalities use forest firefighting teams to clean peri-urban spaces and educate the population (AFN, 2011).

Collaboration between forest firefighters and firefighters can improve the activities related to fire elimination and prevention, especially at night. Collaboration uses the collective experience of forest