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Exploring the occurrence of mega-fires in Portugal

Fantina Tedim [a,*], Ruben Remelgado [a], Célia Borges [a], Salete Carvalho [a], João Martins [b]

[a] Universidade do Porto, Faculdade de Letras, Via Panorâmica, s/n, 4150-564 Porto, Portugal
[b] Direção Regional de Florestas do Algarve, Braciais – Patacão, Apartado 282, 8001-904 Faro, Portugal

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ABSTRACT

In the last few years, in several parts of the world, under extreme weather conditions, several catastrophic fires have taken place. These fires are called mega-fires. They are not just large fires but extreme events in their behavior, difficulty to control and impacts. Portugal historically has little experience with mega-fires, but recent fire events exacerbated by climate change and landscape management has changed this situation. In the year 2003, the worst and largest wildfires were ever recorded in the Algarve region and in the central region of Portugal. However, this paper focuses on the Algarve region, using primary (i.e. questionnaires, interviews, satellite images, and fieldwork) and secondary data (i.e. Portuguese wildfire database, central and local governments' fire damages reports). Using wildfire ecological and socio-economic impacts as an important criterion to classify an event as a mega-fire, this paper conclude that two mega-fires occurred in 2003 in the Algarve Region. Taking into account the weakness in Portuguese wildfire impacts reporting process, it is proposed a checklist of categories of damages and losses to support future data acquisition. Considering that mega-fires are a new reality in Portugal, this paper shows that increasing suppression capabilities in terms of means, readiness and effectiveness are important to avoid small fires to become mega-fires in days of critical fire danger. Nevertheless, facing the impossibility of changing the extreme weather conditions, given the complexity and uncertainty surrounding mega-fires occurrence and severity, the main challenge is to improve wildfire risk reduction instead of focusing only on fire suppression.

This paper proposes a framework which conceptualizes fire impacts as a result of interaction between fire behavior, vulnerability and suppression capabilities. It can be used for promoting wildfire prevention and mitigation. It is urgent to enhance prevention measures in order to change fire behavior and reduce vulnerability of ecosystems and societies, as well as to increase the engagement of communities in wildfire risk management.

1. Introduction

In the last few years, in several parts of the world, under extreme weather conditions, several catastrophic fires took place (e.g. Greece 2007, USA–California 2007, Australia–Canberra 2003 and Victoria 2009). These very complex events (e.g. size, intensity, resistance to control, severity) started to be called mega-fires in several parts of the world (Williams et al., 2011; Pyne, 2007a).

According to McRae and Sharples (2011) these fires develop energy transfer processes of the convective plume with the atmosphere, well above the surface which explains their rapid spread and aggressive burning making the surface meteorology and fuel characteristics less influential. These fires behave in a manner that goes beyond the suppression means and fire-fighters are unable to control the fire spread even in the most prepared and equipped regions (Hyde and Williams, 2007; Williams and Hamilton, 2005). Only when the fire burns into different vegetation and/or the weather moderates is it possible to control these fires (Castellnou et al., 2010; Eftichidis, 2007; Maditinos and Vassiliadis, 2011).

The difficulty or impossibility to control explains that these fires can burn larger areas. It is not possible to establish an absolute threshold to define mega-fires that is universal, because landscape characteristics are very different around the world. Mega-fires size can only be considered in reference to each country. Hyde and Williams (2007) defined as mega-fire threshold the "historical measure of the large fire". However, just because a fire is large it does not necessarily mean that it is a disaster (Keane et al., 2008).

The size is important, however the overall short-term or long-term mega-fires impact, in terms of damages and losses involved, it is the most important attribute (Hyde and Williams, 2007; Turner et al., 1999). Nevertheless, a comprehensive framework is still missing for the assessment of all the damages as well as an agreement concerning the terminology to capture fire behavior and fire effects. The descriptors of fire behavior are fire intensity, i.e. energy released from the combustion process and the rate of

* Corresponding author. Tel.: +351 226 077 100; fax: +351 226 091 610.
E-mail address: ftedim@letras.up.pt (F. Tedim).

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spread, even though some authors consider it as a measure of fire intensity (Key and Benson, 2006; Lentile et al., 2006). However, there is not a single metric that could record the fire intensity measurement properly (Keeley, 2009; Lentile et al., 2006).

The need to provide a measure of fire impact on soil and vegetation, a description of how fire intensity affected and changed ecosystems, explains the appearance of fire severity concept (Escuin et al., 2008; Jain et al., 2004; Keeley, 2009; Lentile et al., 2006; Moreira et al., 2011; Ryan and Noste, 1985). The appearance of the terminology *burn severity* introduced some confusion on the measurements of fire effects not only because the proposed definition overlapped with *fire severity* and replaced it in some literature but also the metrics used were similar. The confusion around the usage of the terms, led some authors to propose new categories to encompass fire effects (Jain et al., 2004; Lentile et al., 2006). However, Keeley (2009) considers that *fire intensity*, *fire severity* and *burn severity* are operationally tractable measures and clarified their scope and appropriate and inappropriate usage. Keeley (2009) considers that *fire severity* and *burn severity* can be used interchangeably. However, he strongly disagrees with the inclusion of the ecosystem responses in the definition of *burn severity* by arguing that this conceptualization is "confounding factors with different effects" (Keeley, 2009:120). In the present paper, the authors propose that burn severity be considered only as a post-fire measure of the organic matter loss and soil alteration by a fire, since that ecosystem responses should be seen in the perspective of resilience concept incorporated in ecology by Holling (1973). Resilience is the capacity of an ecosystem to cope and recover from a disturbance (e.g. a fire) which can be measured namely by the amount of time necessary to return to function.

Jain et al. (2004) considered *fire severity* as a broad concept which can be applied to a variety of fire effects and the definition proposed by the NWCG (2011) and Key and Benson (2006) goes in the same direction.

This paper presents a conceptual framework considering that *fire severity* encompass all categories of fire effects. The diagram puts in evidence that fire severity is a result of the interaction between fire behavior; the vulnerability of exposed elements; and the suppression activities.

The fire impacts have been categorized in different ways (Ashe et al., 2008; Bočkarjova, 2007; Dale, 2009; Handmer and Proudley, 2008; Morton et al., 2003; Zybach et al. 2009). Nowadays, an agreement is emerging distinguishing two main categories: direct damages and indirect losses. For Handmer and Proudley (2008) direct damages represent the physical impact of the wildfire that occurred inside the area affected and indirect losses are a consequence of the physical impacts of the fire in the economy and environment that can also occur outside the burned area. Fire impacts can also be tangibles, expressed in monetary terms, and intangibles not completely measurable, difficult to include in the analysis but recognized as having real value (Gonzalez-Caban, 2009; Handmer and Proudley, 2008). In this paper is proposed a checklist to report wildfire damages and losses categories, taking into consideration the weakness of the damages reported in Portugal. A better reporting of fire impacts can be useful to orientating the recovery phase as well as improving prevention.

The concept of mega-fire is unknown in Portugal either in the scientific community or fire agencies, however several authors (Kearney and Warren, 2006; Pyne, 2007a; San-Miguel Ayans, 2011; Williams et al., 2011) suggested that this country was affected by mega-fires in 2003 and 2005.

The main purpose of this paper is the identification of the mega-fires in Portugal during 2003 which was the worst wildfire season ever recorded. In that year the wildland burned area (425,839 ha) (AFN-SGIF, 2011) was 401% larger than the previous annual average (94,128 ha) and the number of fires was 76.4% higher than the previous annual average (17,203 occurrences). Three research questions drive the analysis: (i) Are the larger fires that occurred in 2003 a new reality in Portugal because of climate change, land cover changes and management practices? (ii) Can some of these large fires be considered mega-fires? (iii) Can mega-fires be prevented?

After an overall view on the trend and spatial pattern of large fires occurrence in Portugal, this paper focus on the research done in Algarve Region. It was one of the regions affected by unusual large wildfires in 2003. The paper presents evidences that two mega-fires occurred in 2003 in the Algarve Region, which is the most important tourist area of the country. This research provides Portuguese fire agencies with an assessment on the mega-fires and the challenges they present for wildfire risk management. The threat they represent can be in some extent preventable as already suggested by Hyde and Williams (2007).

2. Material and methods

The Portuguese wildfire database, available on line (http://www.afn.min-agricultura.pt) is managed by the National Forest Authority and has two components: (i) a statistical dataset with records dating back to 1980; (ii) a cartographic component starting in 1990. Concerning the former, until 1995 the statistical dataset was organized by administrative unit (i.e. national level, district and municipality) and by forestry regions. Since 1996 each fire event has been recorded individually and is characterized by several attributes (e.g. location, date and time of ignition, size of the burned forested and non-forested area, the geographical coordinates of the ignition point, cause).

The Portuguese wildfire database in addition with the vectorial information for the period 1975–1989 regarding burned area polygons, provided by the Instituto Superior de Agronomia, were the starting point used in this research for the approach to temporal trends and spatial patterns of large wildfires. The collected data was analyzed using several methods mainly developed in ArcGis 9.3.

The evaluation of fire intensity is not known for Portuguese wildfires. Burn severity field data obtained immediately after the event were non-existent for the fires considered in the present research. In this research only Landsat TM images were used since they have been recognized as a valuable tool (Escuin et al., 2008: van Wagtendonk et al., 2004). The Normalized Burn Ratio was calculated with two bands (i.e. band 4 Near-Infrared (0.76–0.90 μm–30 m) and band 7 Mid-Infrared (2.08–2.35 μm-30 m)). Several studies, some of them in Mediterranean Region, concluded that post-fire NBR followed by the dNBR (difference between the pre and post-fire NBR) present the best correlation with vegetation damage (Escuin et al., 2008).

Although, the calibration with field data should have been done (French et al., 2008; Lentile et al., 2006), it was impossible as this analyses focus on fires that occurred 9 years ago and no field work was done at the time. To minimize the errors, well identified by the literature, derived namely from the use of bi-temporal images (Escuin et al., 2008) a process of image correction was done. Two Landsat 5 TM scenes were used: the first one (4th of July 2003) dated 1 month before the first fire preceding the heat wave and the other was the first available image after the occurrence of the three fires (24th of October 2003). The geospatial analysis of the scenes was done using ILWIS open 3.7, IDRISI and ENVI 4. After the pre-processing of the images the pixels located inside the burned perimeter were extracted. The NBR was calculated for the two scenes ($NBR = (R4 - R7)/(R4 + R7)$) and then was calculated the dNBR ($dNBR = NBR_{pre\text{-}fire} - NBR_{post\text{-}fire}$). The data distribution presented an average of 42.87 for the dNBR and a standard deviation of 64.89. Each pixel value was classified in seven categories (unburned area and level 1 to level 6) and the thresholds of each rank