

# ADVANCES IN FOREST FIRE RESEARCH

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# Rekindles or one- $\sigma$ quality in forest fire fighting: validating the pressure on firefighters and implications for forest fire management in Portugal

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## Abstract

A long time after many business activities started struggling for six sigma quality in their operations, in Portugal, fire suppression operates at a one sigma quality level with disappointing performance results expressed by too many rekindles – re-work caused by defects in the suppression process. Indeed, they represent a high burden on wildland fire suppression resources, but despite the relevance of this phenomenon in Portugal, related research is still scarce.

Seeking to contribute to address this gap, the purpose of this study was to organize and provide an overview of the problem of rekindles in Portugal, and to verify whether evidence exists that the high proportion of rekindles in Portugal is related to the double duty of Portuguese firefighters to perform initial attack and mop-up operations.

Our study included informal meetings, formal recorded interviews, dispatch centre visits, actual rekindle observation, and an analysis of the National Forest Authority database.

From the study of genealogies of rekindles, we concluded that 17.2% additional forest fires (rekindles in successive generations) had their origin in only 7.4% of primary fires. Through regression analysis, we found that their proportions increase in days with more occurrences, preliminarily supporting the hypothesis of premature abandonment of mop-up operations, as a result from the pressure to immediately attack starting fires by the same crews.

A more detailed analysis of two representative districts highlighted specific organizational and natural challenges to successful mop-up efforts and provided further evidence of the hazardousness of rekindles. Finally, we suggest management practices to mitigate this problem and increase the level of quality of forest fire suppression in Portugal.

**Keywords:** *wildfire, rekindle, mop-up operations, reburn, initial attack, suppression*

## 1. Introduction

A complex and hazardous part of forest fire are rekindles, or reignitions, that reburn an area over which a previous fire has passed, but has left fuel that later ignites due to latent heat, sparks, or embers (NWCG 2011). Throughout the 2010 summer, Portugal had 14,551 primary wildfires, of which 17.2% rekindled into an additional 2,497 fires, leading to a total of 17,048. That summer accounted for 94.7% of the wildland annual burnt area of 132,241 ha. However these figures may be more severe. Several authors suggest that the number of rekindled forest fires is higher than that officially reported (ANIF 2005; Lourenço and Rainha 2006). Expert-judgment elicitation in field interviews performed by the authors points to the double. Even assuming that the available information is correct, the number of rekindles is too high (Beighley and Hyde 2009). This is a concerning situation that has been getting worse over the years (ANIF 2005), and results from ineffective mop-up operations (Murdock *et al.* 1999; ANIF 2005; ISA 2005; Lourenço and Rainha 2006; Lourenço 2007; Beighley and Hyde 2009), despite effective initial attacks (ANIF 2005; Lourenço and Rainha 2006; Lourenço 2007). Although there is a danger of fatalities during the mop-up stage (Alexander *et al.* 2007), this danger is even higher in a rekindle scenario (NWCG 2005). Finally, ineffective mop-ups and lack of surveillance

(Lourenço 2007) result in rekindles that often become large fires (ANIF 2005; Lourenço and Rainha 2006; Lourenço 2007). These are usually bigger than the wrongly judged extinguished primary fire, with larger burnt areas and considerable damage (ANIF 2005), even when the initial perimeter was just tens of meters (Lourenço and Rainha 2006).

After the disastrous fires of 2003 (Fernandes 2008), repeated two years later, the government commissioned a technical strategy (ISA 2005) to address this problem. In 2006, a modified version (shifting the emphasis from prevention to an increase in suppression capability) was approved and published (C.M. 2006) as the national strategy for forest protection against fires (Beighley and Hyde 2009). The plan recognizes the impact of rekindles and establishes mitigation as one of the priorities, with a goal of 1% by 2010 defined as an accepted value for the rekindle rate (Oliveira 2011). However, this goal was never achieved (AFN 2011) and the national figures are still much higher than, for instance, the USA 2004-2008 rekindle annual averages, which vary between 2 and 6% (Ahrens 2010).

## 2. Methods

For this study we use data kindly provided by *Autoridade Florestal Nacional* (AFN). This wildfire dataset, although having undergone several changes throughout the years, has been relatively stable in the last 12 years. The current version gathers information regarding the location of the fire, date and time (i.e., alert, ignition and extinction), burnt area, type of event, and causes. The events could be false alerts, fires in agricultural lands, or wildland fires (forests and shrublands). Information about the nature of the fire (single or reignition) is recorded since 1984 (Pereira *et al.* 2011). We focused our attention on 2010 because this is the first year for which more complete data on rekindles is available. For instance, it is now possible to know, for each rekindle, the specific fire whose bad mop-up originated it.

The country mainland is divided in 18 main administrative regions (districts), their corresponding municipalities (278 counties) and 4,050 parishes. There are significant geomorphologic, climatic and demographic differences between the northern and southern parts of Portugal (Pereira *et al.* 2011). Fire policies, suppression and prevention efforts are organized at the district level. They are therefore too heterogeneous, and we chose them as units of analysis.

Rekindles represent a high burden on suppression resources. Our goal (and hypothesis) was to find whether there was evidence that in days with more ignitions, the firefighters are compelled to prematurely abandon fire mop-up operations, thus promoting more rekindles. In other words, we wanted to know if the high number of rekindles was associated with the pressure to immediately combat all the new fires, to prevent them from becoming big fires. To accomplish this, we conducted a linear regression study, considering two variables. We consider as explanatory variable the number of fires that were simultaneously fought in each day (active fires). For the first component of the dependent variable, we counted the number of fires with a bad mop-up in that same day, i.e., the fires erroneously declared extinct, and origin of some later rekindle. However, because it is expected that bad mop-ups increase with adverse climatic conditions and the number of fires in each day, we divided this component by the number of active fires in that day. To count the number of fires with a bad mop-up in a particular day, we performed a detailed treatment of the database to uncover the genealogies of rekindles, identifying for each rekindle the bad mop-up that originated it. We used Microsoft Excel<sup>®</sup> and MapPoint Europe 2011<sup>®</sup> for the pivot tables and maps, IBM SPSS Statistics 19<sup>®</sup> for descriptive statistics, and STATA/IC 12<sup>®</sup> for regression analysis.

## 3. Results

Among the districts with a relevant number of rekindles, only one – Viana do Castelo – did not present a statistically significant positive correlation between the proportion of bad mop-ups and the number of active fires. The plot of the relationship between the two variables (Figure 1, left) displays no discernible

trend; however it shows very clearly a persistently very high proportion of bad mop-ups. In our contacts with experts, a key explanation that was put forward for this result was the fact that this is the district in the country with the lowest ability to mobilize volunteer firefighting efforts, which leaves mop-up activities permanently understaffed. Another potential cause is the fact that the district has a very large mountain area, where wildfires are more difficult to control, resulting in higher burnt areas and perimeters, and therefore higher probabilities of rekindling.

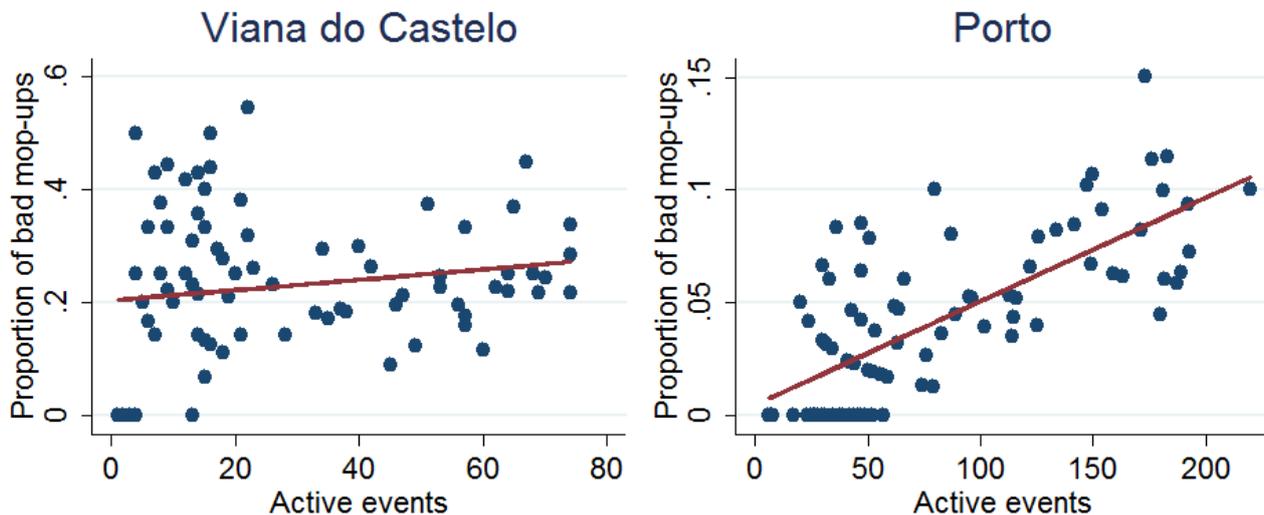


Figure 1. Plots of values and fitted values for Viana do Castelo and Porto.

The district where the effect of suppression pressure on bad mop-ups is clearer is the district of Porto; the correlation is high and the plot (Figure 1, right) shows a distinct trend of increase in the proportion of bad mop-ups with the increase in active events. The district of Porto has a historical trend of a very high number of forest fires, which remained through 2010, with a very high proportion of forest fires with a burnt area below 1 ha – 90.6% of the six thousand incidents (Pacheco 2011). This very high number of incidents puts a huge pressure on the suppression system, which not only works at constantly very high levels of capacity utilization, but also is constantly being requested for initial attack of new fires or rekindles.

Starting from a literature review and the results of our fieldwork to identify, organize, and relate the set of physical, natural, technical and organizational factors that influence the occurrence of rekindles, we used data analysis and descriptive statistics to present evidence of the size and impact of the problem of rekindles in Portugal (Pacheco *et al.* 2012). A key contribution of our work resulted from a simple linear regression analysis of the relationship between active events and the proportion of bad mop-ups to active events. A statistically significant positive relationship was found for six of the seven districts with a relevant number of rekindles. Finally, a more detailed view of rekindle dynamics in the districts of Viana do Castelo (the only district with a non-significant regression) and Porto (the district with the higher significant correlation) highlighted specific organizational and natural challenges to a successful mop-up effort and provided further evidence of the hazardousness of rekindles. As future work, we plan to extend this study to new data that is becoming available for more recent fire seasons, and analyse the performance of alternative organizational architectures for suppression efforts, with specialized teams assigned to the different suppression tasks.

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## 5. References

- AFN, I (2011) Monitorização e Avaliação do Plano Nacional de Defesa da Floresta Contra Incêndios, 2009/2010 - Relatório Final Preliminar. Autoridade Florestal Nacional.
- Ahrens, M (2010) Brush, Grass, and Forest Fires. National Fire Protection Association, Fire Analysis and Research Division No. 0877650357.
- Alexander, ME, Mutch, RW, Davis, KM (2007) Wildland fires: Dangers and survival. In 'Wilderness Medicine.' (Ed. PS Auerbach.) pp. 286-335. (Elsevier:
- ANIF (2005) Relatório Final (Vol I). Autoridade Nacional para os Incêndios Florestais Available at [http://www.bombeiros.pt/Arquivo1/Perdidos\\_e\\_achados/Relat%F3rio%20Inc%EAandios%202005%20-%201.pdf](http://www.bombeiros.pt/Arquivo1/Perdidos_e_achados/Relat%F3rio%20Inc%EAandios%202005%20-%201.pdf). Accessed: 2012-03-07. (Archived by WebCite® at <http://www.webcitation.org/65zfKdsAT>).
- Beighley, M, Hyde, AC (2009) Systemic Risk and Portugal's Forest Fire Defense Strategy. C.M., 2006. Resolução do Conselho de Ministros n.º 65/2006, PNDFCI. Diário da Republica, I SÉRIE-B, nº102 (26 de Maio de 2006).
- Fernandes, PM (2008) Forest fires in Galicia (Spain): The outcome of unbalanced fire management. *Journal of Forest Economics* 14, 155-157.
- ISA (2005) Proposta técnica de Plano Nacional de Defesa da Floresta contra Incêndios. In 'Volume I.' Vol. I Available at <http://www.isa.utl.pt/pndfci/> [Accessed
- Lourenço, L (2007) Incêndios florestais de 2003 e 2005. Tão perto no tempo e já tão longe na memória! *Colectâneas Cindínicas-Riscos Ambientais e Formação de Professores* 7, 19-91.
- Lourenço, L, Rainha, M (2006) As mediáticas 'mãos criminosas dos incendiários' e algumas das 'lições dos fogos florestais de 2005 em álbum fotográfico. Contributo para a desmistificação dos incêndios florestais em Portugal. *Territorium* 71-82.
- Murdock, JI, Borough, MS, Wasilla, A (1999) 'Cross-training Standards for Structural and Forestry Personnel in Urban Interface Wildfires: One Alaskan Solution.' (National Fire Academy:
- NWCG (2005) 'Wildfire Origin & Cause Determination Handbook.' (National Wildfire Coordinating Group, Fire Investigation Working Team:
- NWCG (2011) 'Glossary of wildland fire terminology.' Available at <http://www.nwcg.gov/pms/pubs/glossary/> (Archived by WebCite® at <http://www.webcitation.org/65wjoO4i7>) [Accessed 5 March].
- Oliveira, T, 2011. Relatório da visita ao Chile. grupo Portucel Soporcel,
- Pacheco, AP (2011) Simulation Analysis of a Wildland Fire Suppression System. University of Porto.
- Pacheco, AP, Claro, J, Oliveira, T (2012) Rekindle dynamics: validating the pressure on wildland fire suppression resources and implications for fire management in Portugal. In 'Modelling, Monitoring and Management of Forest Fires III.' Vol. 3 pp. 258. (Wessex Institute of Technology: Ashurst, Southampton, UK)
- Pereira, MG, Malamud, BD, Trigo, RM, Alves, PI (2011) The history and characteristics of the 1980–2005 Portuguese rural fire database. *Nat. Hazards Earth Syst. Sci.* 11, 3343-3358.