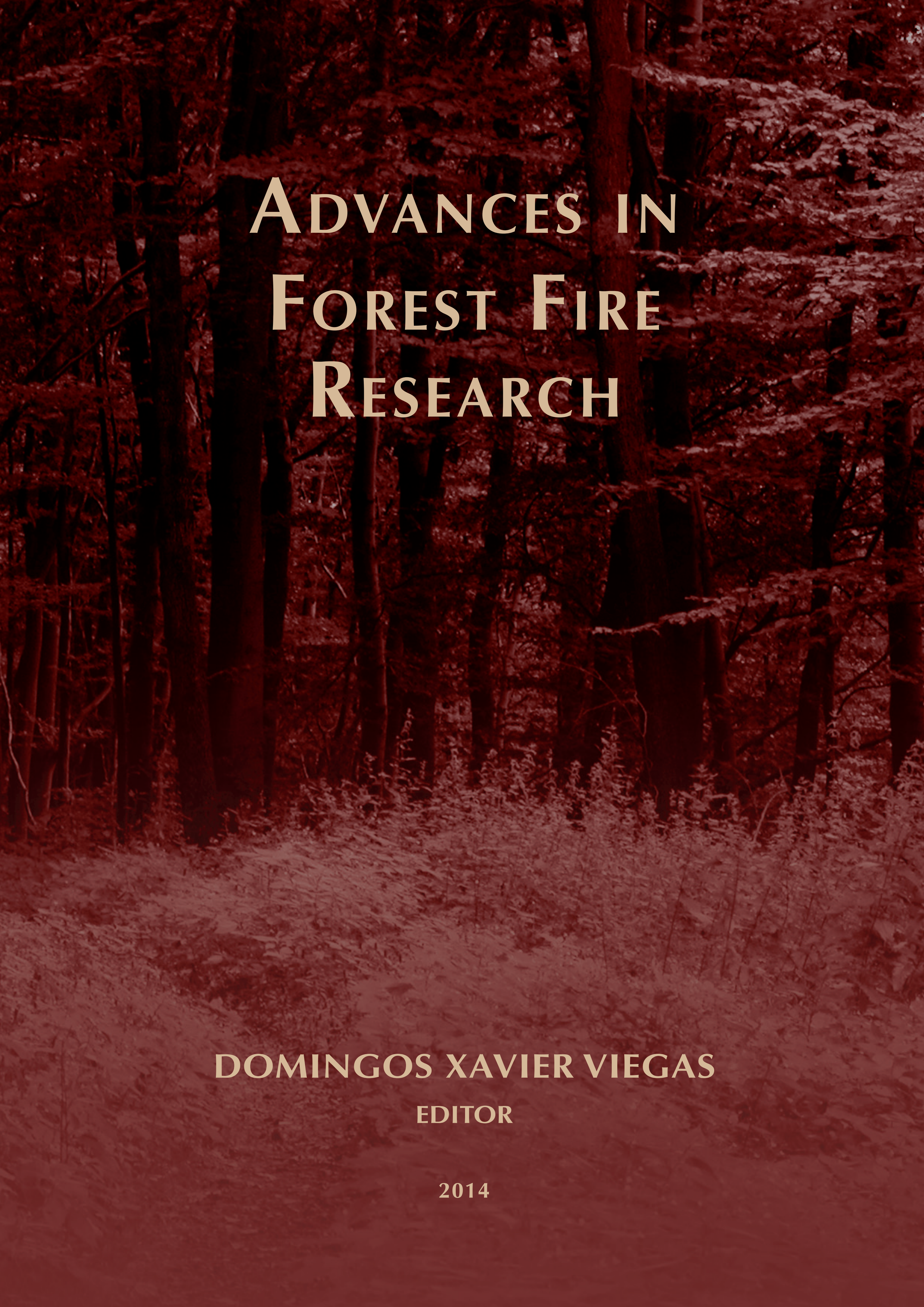

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Waste in non-value-added suppression activities: simulation analysis of the impact of rekindles and false alarms on the forest fire suppression system

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Abstract[1]
Rekindles and false alarms are phenomena that have a significant presence in the Portuguese forest fire management system and an important impact on suppression resources in particular and fire management resources in general. As illustration, in 32,357 incidents that the suppression system handled in 2010, 12.3% were false alarms and 13.0% were rekindles, rising to 12.5% and 15% respectively, during the summer, the critical period.
In this work, we propose a discrete-event simulation model of a forest fire suppression system designed to analyze the joint impact of primary fires (ignitions), and non-value-added fire suppression activities such as rekindles (defects, inappropriate processing) and false alarms (motion) on the performance of the system. The work contributes to address a research gap concerning that impact, and features a novel application of simulation to suppression systems, as a screening tool to support more holistic analyses.
The model was implemented in ®ARENA and is applied to a case study of the district of Porto, Portugal, for the critical period of the forest fire season, between July and September 2010.
We study the behavior of the system's point of collapse, comparing the real base scenario with a benchmark scenario built with reference values for rekindles and false alarms, and also as a function of the number of fire incidents, considering historical variations.
The results of the analysis are useful for operational decision-making and provide relevant information on the trade-off between prevention and suppression efforts. In particular, we have found that reducing false alarms and rekindles to benchmark values would significantly reduce pressure on firefighting teams, enabling more effective suppression operations.

Keywords*: wildland fire suppression, rekindles, false alarms, hoax calls, discrete event simulation, wildfire*

1. Introduction

We propose in this work a discrete-event simulation model of a forest fire suppression system, designed to analyse the joint impact of ignitions and non-value-added fire suppression activities such as rekindles (defects, inappropriate processing) and false alarms (motion) on the performance of the system. The application of the model is illustrated with a case study of the district of Porto, in Portugal, for the critical period of the forest fire season, between July and September 2010. Our motivation for this work comes from the perception that rekindles (RK) and false alarms (FA) – malicious or good intent calls – have unusually high values in the Portuguese forest fire management system, and thus

[1] In this work we extend, with additional cost and optimization analysis, the recently published paper: Pacheco, A. P., J. Claro, and T. Oliveira. 2014. "Simulation analysis of the impact of ignitions, rekindles, and false alarms on forest fire suppression." Canadian Journal of Forest Research no. 44 (1):45-55. doi: 10.1139/cjfr-2013-0257.

represent an also unusually high burden on the suppression resources in particular, and fire management resources in general.

Since fire departments cannot presume that a call is an FA and must respond as they would to a fire (Ahrens 2003), the deployment of crews to non-existing fires, cause them to be unavailable for real fires, deprived of time to rest and recover, or hastily redeployed from other incidents, prematurely abandoning mop-up efforts and possibly creating conditions for fires to rekindle. In the little research available about FA performance measures (Flynn 2009), we have found values for the U.S. - 4.4% of all calls in 2009 and 4.1% in 2010 (Karter 2011); New Zealand - between 4.6% and 5.4% (Tu 2002); and the U.K. - 5.0% in Derbyshire (Yang *et al.* 2003) and 6.2% in South Wales (Corcoran *et al.* 2007), accounting for all emergency calls. These numbers suggest that there is still room for improvements regarding FA in Portugal.

The proportion of RK is also extremely high, still very much above the target defined in the “Technical Proposal for a National Plan of Defence of the Forest against Fires”, PTPNDFCI (ISA 2005), or the values of other countries, such as the US, for which, in a report on the factors that contribute to new ignitions, Ahrens (2010) mention rekindles as responsible for 3% to 6% of the local fire department responses, between 2004 and 2008. The figures for FA and RK reveal futile suppression efforts that contribute to an overload of the suppression system.

Fire occurrence rates vary over both time and space (Martell 2001) and an increased response time is considered intrinsically linked to a decreased probability of containment of new fires (Quince 2009) and a larger intensity-weighted burned area (Mercer *et al.* 2008). Hence, it is reasonable to use response time as a performance measure to evaluate an initial attack (IA) and for operational decision-making. Minimizing fire response time is crucial to minimize the number of fires that escape IA (Islam *et al.* 2009). Therefore, the use of response time as a proxy of suppression effort is meaningful because it is related to available suppression resources (Butry 2007) and most strategic fire management planning models use this simple performance measure to reflect suppression cost effectiveness (Martell 2007; Quince 2009). For any fixed quantity of mobile suppression resources, such as IA crews, as the occurrence rate increases, so do response times, and thus, daily IA effectiveness will saturate at some rate, beyond which the proportion of fire escapes will increase (Cumming 2005). This limit where the system starts to fail is what we call “point of collapse”, which we define as an average waiting time above ten minutes, based on conducted field interviews.

2. Materials and Methods

The model that we present was designed based on a literature review, field trips, informal meetings, formal recorded interviews, and data analysis of a database of fire suppression interventions. It was implemented in ®Arena, and used for a case study of the district of Porto in the critical period, between July and September 2010 (Pacheco *et al.* 2012b, 2012a).

There are four key motives for the choice of the district of Porto as a case study: the district is particularly interesting as it has a high number of fire occurrences and available data about deployed resources; the proportion of rekindles and false alarms is slightly below, but still in line with national figures; 84% of the ignitions, corresponding to 96% of the burnt area, occur in the three-month period considered; and 2010 is the first year to have appropriate data on false alarms available. The database was used, jointly with non-parametric statistical analysis, to parameterize and validate the model, which was subsequently used with sensitivity and optimization analyses to understand the impact of ignitions, rekindles and false alarms on the performance of the suppression system, particularly on the “point of collapse”, the system dimension below which the mean time between the alarm and the IA starts to grow exponentially (Pacheco *et al.* 2014).

3. **Results**

Our data analysis of forest fire incidents in the district of Porto, between July and September 2010, highlights the importance of addressing the phenomena of rekindles and false alarms. Jointly, rekindles and false alarms represent almost 20% of the incidents, with daily peaks that are exactly coincident with the peaks of requests of suppression resources for real new forest fires. Although on average false alarms use resources for a time interval lower than an IA, there is a very high opportunity cost to that time. In the case of rekindles, this is worsened by the fact that rekindle suppression operations are much harder, as made clear from the fact that initial and extended attack durations are higher for rekindles.

The extra pressure that these additional classes of incidents put on the suppression system raises difficult challenges to its management. We believe that deviations from operational standards found in our analysis, such as the number of crews dispatched to an IA, or its duration, are evidence of this pressure. In a fire prone country with an extensive wildland urban interface (WUI), where the average number of fires in the last decade corresponds to over 50% of the whole EU Mediterranean region (San-Miguel-Ayanz *et al.* 2013), increasing suppression effectiveness is particularly important to avoid that small fires become mega-fires in days of critical fire danger (Tedim *et al.* 2013).

Using our simulation analysis, we found that bringing RK and FA down to benchmark levels, would lead to a reduction in the point of collapse of approximately 9.8%. This means that managing FAs, for instance, will lead to a lower number of events in the system, which reduces pressure and releases resources that become available for real fires and to invest more time in mop-up, thus reducing the number of rekindles, contributing again to reduce the number of events, and so on, in a positive feedback loop. This highlights as well the risk of not managing FAs (Pacheco 2011).

Another very important challenge for the suppression system is the huge inter-annual variability of the number of ignitions. We sought to characterize the impact of overall ignitions on the point of collapse and, for the range of values observed between 2001 and 2010, we found a linear relationship between the number of ignitions and the point of collapse, with a decrease of 1.00% in the daily rates of ignitions leading to between 0.85% and 0.96% reduction in the number of required suppression teams, in the range that we studied. Since 98% of ignitions are of human origin (arson, negligence or accidental) this indicator provides a relevant threshold for the investment in prevention: a reduction of 1% in ignitions allows for a reduction of the point of collapse of one firefighting team, inverting the vicious circle more fire, more teams.

A final analysis that we performed aimed at comparing the point of collapse criterion with a cost criterion. Two simulation optimization analyses, with each of the criteria, led to the same result in the minimum number of crews, supporting the relevance of the point of collapse as a useful indicator in capacity decisions for a suppression system. Arriving early increases the probability of containing the fire in its initial stage and, additionally, if the resources are insufficient, the pressure to attack starting fires increases the premature abandonment of mop-up operations of already controlled fires, leading later to more rekindles and thus even more fires.

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