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Assessing the benefits of a national fuel break network to reduce wildfire exposure and risk in Portugal

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Abstract

The impact of rural fires in the Mediterranean Basin is rapidly increasing as extreme fire seasons become the new norm. Following the catastrophic 2017 fire season in Portugal, a national-scale fuel break network (FBN) was designed by the Rural Fire Management Agency (AGIF), and the implementation of fuel treatments along the fuel break network was initiated. Despite growing interest in developing extensive fuel treatment programs to prevent catastrophic wildfires and reduce exposure and risk in the Mediterranean region, there is still little information on the effectiveness of such programs. The Portuguese nation-wide FBN is part of the fuel management plan aiming to prevent loss of lives, reduce large fires (> 500 ha) and decrease annual burned area is under implementation. In this study, we used Monte Carlo methods and mechanistic wildfire spread modeling to simulate plausible wildfire events in Portugal. The modeling system was calibrated to local fuels and weather at monthly time steps. We then examined how the proposed fuel break network was intersected by simulated fires and the effectiveness in terms of protecting residential buildings and designated protected areas. The fuel breaks burn over percentage, i.e. the percentage of fires that are not contained by the FBN was modeled as a function of pre-defined flame length thresholds for individual FBN segments. From these outputs, we were able to compare priorities as determined from the simulation system to the FBN implementation plan by AGIF. Our results show that the full implementation of FBN can provide tactical opportunities for rural fire suppression and containment. The FBN has the potential to reduce up to 1) 13% in the annual burned area due to large fires; 2) 8% in the annual number of residential buildings exposed, and 3) 14% in the annual burned area in protected areas. However, the results also reveal that in many cases the FBN intersects fires after they have grown to over 500 ha, hence representing minimal potential in preventing large fires. The expected burn-over percentage was highly variable among the segments. An overall average decrease of 40% of the total benefits was estimated, with the most important fuel breaks typically showing a high percentage of fire burn over. Our results suggest that additional landscape-scale fuel reduction strategies are required to meet short-term national wildfire management objectives.

1. Background

Recent extreme wildfire events marked a turning point for Portuguese society and motivated a coordinated national response aimed at preventing catastrophic wildfires. The 2017 fire season was particularly harsh, with a record-breaking area burned of 557 thousand ha, 119 fatalities, thousands of structures destroyed, and over 1456 million euros in economic losses (Castellnou and et. al., 2018; Guerreiro et al., 2018). After this disaster, the Portuguese authorities were widely criticized for their lack of response and initiatives to reduce the potential for future catastrophic wildfires (Guerreiro et al., 2018). These and other factors led to the development of a new 10-year fuel management plan to reduce national wildfire risk (AGIF, 2020). The plan proposed three strategic targets: 1) the loss of lives in rural fires is reduced to a rare event; 2) the percentage of fires larger than 500 ha is reduced below 0.3 % of the total number of fires; and 3) the cumulative burned area over a period of a decade is less than 660,000 ha. To achieve these, the plan proposes (among other fuel reduction actions) the implementation of a nation-wide fuel break network (FBN).

Fuel breaks are defined as "a strategically located wide block, or strip, on which a cover of dense, heavy, or flammable vegetation has been permanently changed to one of lower fuel volume or reduced flammability" (Green, 1977). Ultimately, fuel breaks are expected to facilitate fire containment and consequently decrease burned area, by providing safe conditions to engage in firefighting (Syphard et al., 2011a, 2011b).

In this study, we used simulation modelling and scenario analyses to evaluate the effectiveness of the Portuguese national 125-meter-wide FBN in terms of potential reduction burned area and in exposure of communities and protected areas to rural fires. We further quantified the probability of failure in containing the fire for each FBN segments based on the estimated flame lengths in the adjacent vegetation areas. We also added a simulation scenario we prioritized the implementation of the FBN over a period of five years according to estimated effectiveness of each FBN segment.

2. Methods

We used wildfire simulation data from Alcasena et al. (2021), representing 10,000 simulated fire seasons comprising a total of 1,654,448 simulated fires for mainland Portugal. The corresponding fire perimeters were intersected with the FBN to quantify the avoided burned area, reduced exposure of communities and avoided burned area in protected areas under the assumption of fire containment. Given the effectiveness of each FBN segment, we created a 5-year plan of FBN implementation for each objective, where the scheduling of the implementation of FBN segments follows their importance. We created two scenarios of FBN effectiveness: i) we assumed that fire spread stops at the FBN due to the full readiness of fire brigades; ii) we complemented this analysis by estimating the burn over percentage of each FBN segment, i.e., the percentage of times that each FBN segment may not allow for safe firefighting, failing to stop the fire spread. The burn over percentage was estimated using the simulated Flame Length Probability (FLP). We considered flame lengths longer than 2.5 m to represent surface fires likely to generate torching and crown fires, which are extremely difficult to suppress, and that have high spotting activity and spotting distances may be longer than 100 m (FBN is 125 meter wide). Hence, high intensity fires can decrease opportunities for fire control and originate embers that cross the FBN segment, reducing the effectiveness of the FBN.

3. Results and discussion

Our results showed that assuming maximum effectiveness of the FBN (i.e., fire containment) the full implementation of the Portuguese FBN could make a significant contribution to all fire management objectives of the country, with 13 % reduction in annual burned area due to large fires, 8 % reduction in the annual number of residential building exposure, and a reduction of 14 % in annual burned area in the protected areas. Nevertheless, the effect of the FBN in reducing large fires (> 500 ha) was minimal.

When the implementation of the FBN is scheduled following the prioritization given one of the three objectives cited above, its effectiveness showed an inverse exponential curve for all objectives with a sharp increase in the early years of implementation. The objectives of avoiding burned area due to large fires and avoiding exposure of residential buildings were more dependent on the complete implementation of the FBN. This reflects the known widespread risk of large fires and fire exposure of residential buildings across the country. Our analysis also revealed that the effect of the FBN segments already implemented is not different from a scenario of random scheduling (Figure 1).

In this study, we also identified the FBN segments with high burn over percentage caused by extreme fire behavior. Extreme fire behavior (as indicated by the burn over percentage) can jeopardize the safety of firefighters and ignite new fires over the FBN through intense crowning and long-distance spotting events (Alexander and Cruz, 2018; Alexander and Lanoville, 1989; Tedim et al., 2018). When assessing the effectiveness of FBN while acknowledging the possibility of burn over, the benefits of the FBN were dropped by almost 40 % on average for the three objectives studied, even assuming full readiness of fire suppression operations (Figure 1, dashed line).

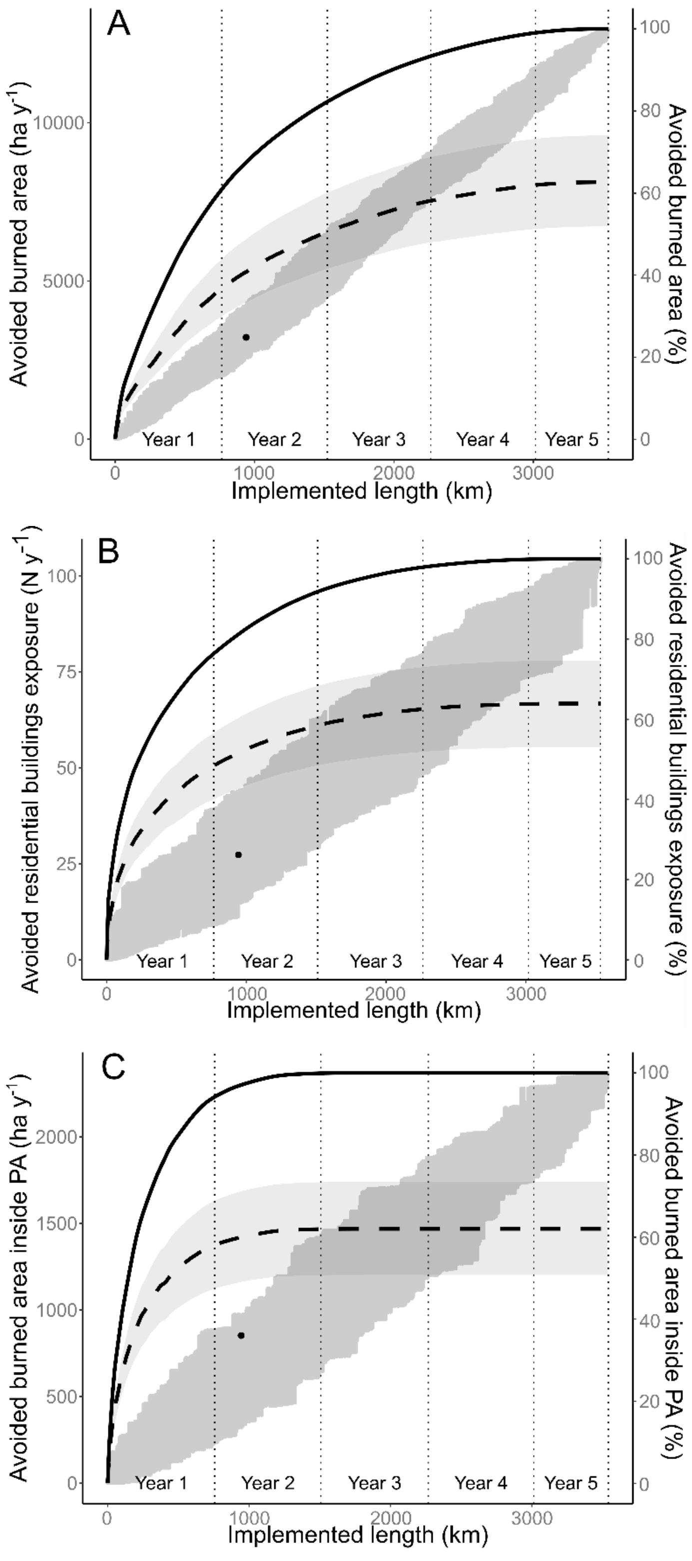

Figure 1. Cumulative annual effect of FBN implementation for avoided burned area due to large fires (A), avoided exposure of residential buildings (B) and avoided burned area inside protected areas (PA) (C). The solid line represents the optimal implementation scenario for each criterion; the dark grey area represents 100 random scenarios of implementation; and the solid dot represents the current stage of FBN implementation (identified in Figure 1). The dashed line represents the optimal scenario of implementation after adjusting the effectiveness of each FBN segment given the fire behavior and spotting distance in its surroundings (i.e. burn over percentage); the light grey area following the dashed line represents the 95% confidence envelope.

Finally, we show that a small portion of the FBN is responsible for great contributions to reduce the wildfire risk and exposure. This highlights the importance of strategically prioritize the FBN segments. These highly importance segments should also be monitored regularly to avoid fuel build-up, as they often have high values of burn over percentage. The widespread high burn over percentages indicates that the FBN itself may not be sufficient to substantially reduce large fires and wildfire risk. This, there is a clear need to integrate ecological restoration treatments in key areas close and adjacent to the FBN. We suggest that prescribed burning and preventive silviculture should be implemented in a synchronized way with the FBN to decrease fire spread and intensity, enhancing the safety of fire suppression operations (Alcasena et al., 2018). We further advocate that the afforestation of the areas surrounding the FBN with fire prone tree species that are either ignited by embers must be avoided (Viegas et al., 2014). We demonstrate how this framework can be used to design, evaluate, and implement future national fuel break programs in any fire-prone region.

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