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Strategic and tactical planning to improve suppression efforts against large forest fires in the Catalonia region of Spain

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ABSTRACT

The study explores use of the Ecosystem Management Decision Support (EMDS) System to standardize the process of allocating Management Areas for Fire Suppression Support (MASSs) in Catalonia, Spain. MASSs are defined as those areas in the landscape that change fire behavior, reducing the magnitude of the wildfire, and improve significantly fire suppression effectiveness/capacity. Considerations for allocating MASSs include high likelihood of large fires in the vicinity, potential for spread, proximity of the location to valuable resources at risk, proximity to adequate water supply, accessibility by mechanized means, and fuel management opportunities. The combination of accessibility, water supply and fuel management opportunities, when allocating MAASs, provide the minimum requirements to allow fire suppression actions, while improving effectiveness and safety levels. For these purposes, we combine the newest data available, outputs from fire simulators and expert knowledge to define a problem that could be solved using EMDS within a participatory planning framework. To support the fire suppression mission of the firefighting service in Catalonia, this study uses a combination of strategic and tactical solutions, in which the strategic solution identifies high priority locations within the landscape for fire suppression activities, and tactical solutions identify high priority management activities within specific locations.

1. Introduction

Research on methods for preventing the negative impacts of large wildfires continues to be an important area in forest and land-use planning, fire suppression, and civil protection research. The problem is complex as it involves a myriad of aspects that should be taken into account, either from the point of view of predicting the occurrence and behavior of future forest fires, when assessing the value and level of risk of resources at stake, or when identifying the impact that management actions will have on mitigating both the occurrence of large fires and expected losses. Each of these aspects of the problem, individually, and in combination, are affected by several interconnected factors (Millar et al., 2007, Ryan and Opperman, 2013, Herawati et al., 2015).

Fire behavior is influenced by fuel conditions, topography, weather, and fire suppression efforts. Among these factors, fuel conditions and suppression resources can be effectively managed through planning to reduce risks to resources and firefighting personnel. Fuel-management planning traditionally aims to reduce landscape flammability by creating fuel discontinuities in the landscape (Hof et al., 2000; Finney, 2001, Stratton, 2004), or to reduce both the spread of fires and the potential loss of forest resources when combined with forest management (Wei et al., 2008; Gonzalez-Olabarria and Pukkala, 2011). In contrast, planning related to suppression resources aims to allocate those resources to improve their cost-effectiveness (Dimopoulou and Giannikos, 2004, Kirsch and Rideout, 2005, Haight and Fried, 2007). Combined approaches, in which fuel management and fire suppression are integrated into the planning problem, have also been considered (Wei, 2012; Minas et al., 2015), although they are less common. The latter studies rely on the accepted principle that, by modifying fuels across a landscape and therefore controlling the behavior of fire, it will be possible to generate an increased number of opportunities for fire confinement when applying suppression measures.

However, there are various aspects that may limit the effectiveness of planned measures when dealing with large and intense fires, or even the possibility to implement the results of sound research studies in the field. When considering suppression, for example, it is known that under extreme weather conditions, fire behavior often exceeds suppression capabilities (Andrews and Rothermel, 1982), meaning that if a

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fire escapes an initial attack and gathers momentum, suppression efforts have little impact on the occurrence of very large fires, if sufficient fuels are available (San-Miguel-Ayanz et al., 2013, Fernandes et al., 2016a). Furthermore, large fires have several associated factors (either operational, social, psychological, or institutional) that may limit the effectiveness of suppression efforts (Katuwal et al., 2017), as for example the need to protect exposed households in the wildland-urban interface (WUI). Regarding fuel management, even if recognized as the best way to influence fire spread under any condition, it should encompass both a sizeable portion of a landscape under threat and significant reduction of fuel on the treated areas, when dealing with extreme weather conditions (Fernandes et al., 2016b). These requirements often are a limiting factor for implementing effective fuel management in the field. Extensive fuel management requires an economic commitment and negotiation between institutions, landowners, and other social actors. Although the social acceptance of, and even the willingness to pay for, fuel management treatments has been increasing over time (Toman et al., 2014, Varela et al., 2014), especially in areas subject to high fire exposure, this perception does not always translate into the required budgets necessary to cope with much needed fuel reductions. Moreover, in rural landscapes with fragmented ownership, finding the required cooperation between landowners and government agencies to implement large-scale management plans can be a challenging task (Fischer and Charnley, 2012).

The limitations mentioned above are often present in Southern Europe, and definitely in regions such as Catalonia in northeast Spain. There, an increasing number of days with extreme weather conditions, fuel accumulations due to rural abandonment, and a plethora of other accompanying factors have led to an increased number of large fires in recent times (González and Pukkala, 2007). Limited budget and a forest ownership that is mainly private (77%) and fragmented (more than 200,000 owners), with an average size of 30 ha (though many of the properties are much smaller), hamper the application of large-scale prevention plans required to mitigate the negative impacts caused by large fires. As a tool to facilitate the application of management actions in Catalonia, a set of management priority zones have been designed under the umbrella of forest management. One of the most interesting, regarding the mitigation of large fires, is that for the so called *Puntos Estratégicos de Gestión* (PEGs), which are highly delimited areas, which includes a set of infrastructures associated with a pre-defined fire suppression strategy, based on the study of historic large wildfires and their fire spread patterns. On those areas, the Catalan forest administration will implement management actions regardless of ownership once the area is defined as a PEG and a management plan approved. Nowadays, the allocation and delimitation of PEGs is implemented by experts from the GRAF (Group of Support to Forest Actions), a branch of the Catalonian firefighters oriented toward issues related to wildfire. Although the expertise of the GRAF is widely recognized across the EU, the application of mainly expert knowledge to PEG delimitation has certain shortcomings. In particular, the selection of planning criteria and their relative importance are not always as standardized as a regional program might be (Ryan and Opperman, 2013), because delimitation of the PEGs is designed independently for distinct landscapes across Catalonia and implemented by different fire experts.

At the request of the Catalonian government, a project to explore new methodologies to standardize the process of PEGs allocation and resource allocation to PEGs was initiated in 2016. As explained, PEGs consist of a set of infrastructures associated with a pre-defined fire suppression strategy, based on fire spread patterns of past large wildfires and field work. In this sense, Management Areas for Fire Suppression Support (MASSs) were defined as areas that, once adequate fuel management is implemented, could reduce the intensity of fires and support fire suppression maneuvers, according to the requirements of the firefighting service. Therefore, defining the allocation of MASSs, through an open and systematic use of data and decision support systems could be a first step prior to the allocation of PEGs. The specific objective of the project is to define areas that, when properly managed, will have a significant impact on the on-site fire behavior, ease suppression efforts, and subsequently reduce the magnitude of fires. Considerations in the planning process for allocating MASS to landscape units include high likelihood of large fires in the vicinity, potential for spread, proximity of the location to valuable resources at risk, access to adequate water supply, and fuel management opportunities. The combination of accessibility, water supply and fuel management opportunities, in particular, was considered necessary to the allocation of MASSs to ensure that adequate levels of firefighter safety are achieved during fire suppression efforts. Our overall approach to the project employs a combination of strategic planning for spatially allocating MASSs on the landscape, and tactical planning to select priority management actions within individual MASS, for which we used the Ecosystem Management Decision Support (EMDS) system (Reynolds et al., 2003, 2017).

2. Material and methods

2.1. Study area

Based on an existing fire prevention plan, we selected the area of Tivissa – Vandellos – Llaberia – Pradell. The study area covers 76,980 ha, of which 56,287 ha correspond to a core area included in the existing prevention plan, and 20,703 ha correspond to an additional 2-km buffer around the non-coastal limits of the core area (Fig. 1). The area is located in the province of Tarragona, a region of Catalonia in northeast Spain. The area is considered to be at high risk of fire due to a history of recurrent large fires, abrupt topography that goes from sea level to 921 m.a.s.l, and the presence of towns and individual households embedded within the landscape. Forested lands in the study area occupy 27,187 ha, and are mainly dominated by *Pinus halepensis* forests (81.68%), and *Quercus ilex* (14.43%). An additional 23,481 ha are covered by shrublands, 17,700 ha to fruit and olive trees plantations, 3382 ha to small shape agricultural cultures, while the remaining areas correspond to urban land, roads and paths, rock lands or any other land use without vegetation cover. The study area encompasses 37,392 landcover units (LCUs) as defined by the Land Cover Map of Catalonia (MCSC-4 2009, http://www.creaf.uab.es/mcsc/usa/index.htm), which were used as the GIS input layer for our analysis and results. LCUs have a mean patch size of 20 ha, but patch size is highly variable, ranging from less than 100 m^2 to over 1000 ha.

2.2. Conceptual design of the planning problem

The first objective of the study was to prioritize LCUs within the study area (1) based on conditions that support the spread of large wildfires, (2) that have valuable resources nearby, (3) and that have good access to water points and escape routes (paths at least 3 m wide). In the context of spatial decision support, this phase of the analysis can be viewed as strategic prioritization insofar as we are attempting to spatially allocate MASSs, considering which are the high priority landscape units (Reynolds et al., 2017), given the above three criteria. The second objective, given the identification of MASSs under objective 1, was to identify which fuel treatments would be the most effective within high priority MASSs with respect to limiting potential fire intensity and allowing firefighters to work more efficiently and more safely during suppression activities. In the sense of Reynolds et al. (2017), objective 2 is concerned with tactical prioritization, in which the focus shifts from the question of *where* (objective 1) to the question of *which* management activities (e.g., alternative types of fuel treatment) are the highest priority, given the spatial context of any particular MASS.

In order to meet the above objectives for strategic and tactical planning, our analysis process implements the following general steps (Fig. 2):