Prescribed fires

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Background

Fire is a natural disturbance phenomenon. Despite recognition of the importance of fire in ecosystems, fire suppression policies have been favoured, contributing to the accumulation of fuel in wildlands. Political options coupled with land abandonment, livestock reduction, plantation of monospecific species and the increasing number and length of summer droughts, as a consequence of climate change, are responsible for the occurrence of severe wildfires such as occurred in 2017 in Portugal and California. These kinds of fires have tremendous and unwanted impacts on the environment, society and the economy, including ecosystem services degradation and the loss of life (Nadal-Romero et al., 2018; Pereira et al., 2016a, 2018). To tackle this problem, more investments are needed in preventive measures such as forest management techniques to reduce the amount of biomass in wildland environments. The most commonly used are mechanical thinning (e.g. clearcutting, partial cutting) and, if authorized by government bodies, prescribed fires (Fernandes and Botelho, 2003; Knapp et al., 2017).

Prescribed or controlled fires are a tool used by fire-fighters with a specific objective, normally to facilitate the development of a certain type of ecosystem, ecosystem restoration, or reduce the amount of fuel in specific areas to reduce the occurrence, propagation and severity of wildfires. Prescribed fires are carried out during the autumn or spring seasons under specific situations (e.g. meteorological). Overall, prescribed fires aim to increase landscape heterogeneity, promote economic diversification, increase wildfire protection and improve pastures for livestock (Fernandes et al., 2013; Ferreira et al., 2015; Shakesby et al., 2016). It has been argued that the ecosystem impacts of prescribed fires are always lower than wildfires (Wiedinmyer and Hurteau, 2010; Alba et al., 2014; Fultz et al., 2016; Liu et al., 2017; Alcañiz et al., 2018), and in this context the application of this management tool is more sustainable than a non-management scenario or favouring suppression policies. Aggressive suppression policies are responsible for the increasing number of large wildfires, the so called "mega-fires" (Stephens et al., 2014; Barbero et al., 2015; Calkin et al., 2015).

Previous works found that prescribed fires do not have detrimental direct impacts (e.g soil heating) on soil physical and chemical properties because the peak high temperatures and contact time is reduced (e.g. Agustine et al., 2014; Gonzalez-Pelayo et al., 2015; Meira-Castro et al., 2015) and highly variable (Cawson et al., 2016). In the case that prescribed fires reach high temperatures, the impacts are restricted to the first few cm of soil (Armas-Herrera et al., 2016; Girona-Garcia et al., 2018). However, some impacts may be observed in soil microbiological activity, since biological properties are more sensitive to soil heating (Catalanotti et al., 2018), specially the extracellular enzymatic activity (Badía-Villas et al., 2017).

Despite the reduction of surface fuels after a prescribed fire, the charred material and ash layer protect the soil, reducing its vulnerability to overland flow and erosion as compared to severe wildfires that normally consume the majority of the litter layer. The degree of prescribed fire impact on ecosystems depends on the intensity, duration, seasonality and ecosystem management (Muqaddas et al., 2015;

Tulloch et al., 2016; Reilly et al., 2017). The most visible effects are indirect, as a consequence of the incorporation of ash and charred material from plant biomass, duff and/or litter into the soil profile that will affect soil temperature, increase the amount of soil organic matter, aggregation, hydrophobicity, pH, extractable ions, soil respiration, emission of greenhouse gases etc. (Zhao et al., 2015; Alcañiz et al., 2016; Krishnaraj et al., 2016; Plaza-Alvarez et al., 2017). The return of soil properties to pre-fire levels may take place over short (Zhao et al., 2015), or long (Alcañiz et al., 2016) time spans, depending on the temperature reached, topography of the burned area, post-fire rainfall and the degree of vegetation recuperation. Previous works observed that some properties recover more rapidly than others (e.g. Alcañiz et al., 2016; Fonseca et al., 2017). The increase in soil fertility may allow rapid germination and resprouting of plants, and an increase of flora and fauna diversity has frequently been observed after prescribed fires (Pastro et al., 2014; Sitters et al., 2015; Larroulet et al., 2016; Valko et al., 2016; Newman et al., 2018; Ramberg et al., 2018).

Despite the adaptation of ecosystems to fire, the use of prescribed fire is not universally accepted. Some problems have been raised regarding their application such as smoke (Price et al., 2016; Williamson et al., 2016), generation of greenhouse gases (Aurell et al., 2017), air pollution (May et al., 2015), the risk of exposure to fire and the fear of fire escaping containment (Altangerel and Kull, 2013; Twidwell et al., 2015). This can have potential impacts on human health for fire fighters and populations that live near the areas were prescribed fires are applied (Akagi et al., 2015; Haikerwal et al., 2015). In addition, media news coverage about fire is mainly negative (Fabra-Crespo and Rojas Briales, 2015) and has important implications on the public perception about fire impacts on ecosystems (Paveglio et al., 2011). This can result in reduced acceptance of prescribed fires and support for suppression measures (Molina-Terren et al., 2016). Public opinion and stakeholder perceptions about prescribed fire application have not reached consensus. Some studies shown resistance or scepticism towards this approach (Jacobson et al., 2001; Shindler et al., 2009; Harr et al., 2014; Pereira et al., 2016b), that the public does not wish to pay for this type of management (Varela et al., 2014), or they prefer investment in fire suppression measures (Raftoyannis et al., 2014). On the other hand, others agree that it is a good method to decrease wildfire risk and reduce forest fuels (Toman et al., 2004; Rideout et al., 2003), are willing to pay for it (Kaval et al., 2007) and defend the application of prescribed burnings frequently (1-2 years) as a measure to reduce wildfire ignitions (Kobziar et al., 2015). The acceptance of prescribed fire use increases with familiarization/knowledge of this practice, trust in the agencies and officials that implement this activity (McCaffrey, 2004), fire behaviour, local ecology (Nelson et al., 2004), demonstration of positive treatment outcomes (Toman et al., 2014), education, risk perception, skills and access to equipment (Toledo et al., 2014).

Prescribed fires are a cost effective tool for landscape management as observed in several works (Valko et al., 2014; Wonkka et al., 2015), are less expensive than mechanical treatments (Fill et al., 2017) and reduce fire suppression costs. Fitch et al. (2018) observed that prescribed fires decreased wildfire severity, and therefore the suppression costs. The use of prescribed fires can be considered a long-term investment in forest sustainability, restoration, increasing ecological integrity and biodiversity (Ingalsbee and Raja, 2015). This is also true from the human point of view, since areas managed with prescribed fires, increase home protection, fire fighter security, visibility, safe access to the fire, speed of the evacuations, lifesaving and the effectiveness of suppression activities when wildfires do occur (Calkin et al., 2014; Clode and Elgar, 2014; Kalies and Kent 2016).

There are many environmental, social and economic advantages to prescribed fire use, nevertheless, it is a dangerous practice that is risky for properties, natural resources and humans. For this reason, several governments are reluctant to adopt it as a management tool because of the lack of public approval and intolerance that consider fire as bad and destructive (Sun and Tolver, 2012; Ryan et al., 2013; Tedim et al., 2016). In the USA, there is a long-term tradition of using prescribed fires (Ryan et al., 2013). However, in other areas of the world such as southern Mediterranean countries (Fernandes et al., 2013), the United Kingdom (Matt Davies et al., 2016), and Brazil (Durigan and Ratter, 2016) the implementation of this practice has been limited, inconsistent and in some cases forbidden. In the case of Europe fire suppression measures dominate and legislation in the majority of the cases is restrictive or non-existent regarding the use of fire (Montiel-Molina, 2013).

The idea for this special issue was initiated during the **International Congress on Prescribed Fires**, (Barcelona: 1st to the 3rd of February of 2017) that was co-organised by the Catalan Fire and Rescue Service, the University of Barcelona and Pau Costa Foundation. More than 250 people from 18 different countries participated. The objective of the Congress was to bring together fire experts from around the world. Experts and practitioners shared their knowledge and experience about prescribed fires. The topics discussed were:

- What do we know today?;
- Effects of prescribed fire on ecosystems;
- Prescribed fires as a tool for forest management;
- Social perceptions of prescribed fire;
- State-of-the-art practices in different regions;
- Evolution of prescribed burning techniques

This special issue compiles some of the work presented at this conference and aims to bring to light the most recent advances concerning prescribed fires research. The 18 articles published are from different regions of the world (Portugal, Spain, Hungary, United Kingdom, Brazil and Australia), and are focused on the impacts of prescribed fires and heating on soil properties (Alcañiz et al., 2018-in this issue; Badía et al., 2018-in this issue; Girona-Garcia et al., 2018-in this issue; Santin et al., 2018-in this issue), soil erosion (Thomaz, 2018-in this issue), peat bogs and *Calluna* heatlands (Grau-Andres et al., 2018-in this issue), grasslands management (Valko et al., 2018-in this issue), forest carbon and water balance

(Gharun et al., 2018-in this issue), carbon stock (Seijo et al., 2018-in this issue), fuel management (Molina et al., 2018-in this issue; Piqué and Domenech, 2018-in this issue), understory vegetation (Casals and Rios, 2018-in this issue; Fuentes et al., 2018-in this issue), litterfall biomass (Espinosa et al., 2018-in this issue), ecosystem services provision (Harper et al., 2018-in this issue), optimizing prescribed fire allocation (Alcasena et al., 2018-in this issue), fire behaviour and fuel moisture (Pereira Torres et al., 2018-in this issue) and current knowledge about prescribed under_burning in Europe (Fernandes, 2018-in this issue).

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