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Scientific support to prescribed underburning in southern Europe: What do we know?

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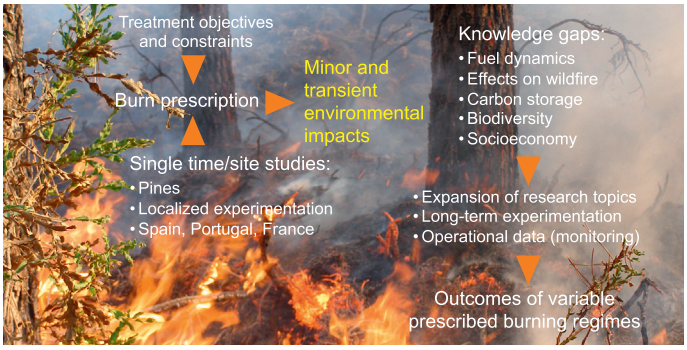
HIGHLIGHTS

- Knowledge gaps may restrain prescribed underburning development in southern Europe.
- Current burn prescriptions guarantee that impacts are minor and fade rapidly.
- Socioeconomy, biodiversity, fire hazard and carbon implications merit further study.
- Research should evolve from the burn event to the burn regime.
- Long-term studies and monitoring of management practices are needed.

GRAPHICAL ABSTRACT



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ABSTRACT

Prescribed burning is a technically demanding and usually highly scrutinized and debated practice. Barriers of various natures have constrained the development of prescribed burning in forests (PUB) in southern Europe, with insufficient research and outreach among the contributing factors. This paper synthesizes PUB knowledge in the region and identifies research needs. PUB research in the western Mediterranean basin was fostered by international cooperative projects that studied the ecological and management ramifications of low-intensity burning for fire hazard mitigation. Effects of PUB on soil and vegetation are minor and short-lived and regulated through forest floor moisture content, fire intensity, tree resistance to fire, and ignition patterns. Generic burn prescriptions are available and specific burn windows targeting site-specific burn objectives can be developed with the existing software tools. However, the need to increase the depth and breadth of PUB research is apparent. Current knowledge is based upon pine forests, particularly *Pinus pinaster*, as past research has overlooked hardwoods; was obtained across a limited number of research teams and study sites; and essentially reflects short-term treatments. Fuel consumption by PUB effectively decreases fire potential, but post-treatment fuel dynamics and effects on wildfire spread and severity warrant further study. Future work should devote more attention to the socioeconomic, biodiversity and carbon storage implications of PUB and should expand to encompass cumulative effects and the whole PUB regime and its variation; long-term experiments and monitored management programs are crucial to this end.

1. Introduction

The deliberate application of fire to wildland vegetation for predefined management goals under suitable environmental conditions

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is defined as prescribed burning (PB) (Wade et al., 1989). PB users define objectives to be accomplished by the treatment and complying with site conditions and restrictions of variable nature (Pyne et al., 1996). PB planning thus implies answering the questions of what (vegetation type), why (goal), and where (spatial considerations) to burn, as well as when and how, such that objectives are met. Planning involves preparing burn prescriptions in terms of weather-related variables, season, and ignition patterns, as these factors determine fire behaviour characteristics and corresponding impacts. Prescribed underburning (PUB) refers to the use of PB in forest stands, whereby the fire treatment is restricted to the under-canopy vegetation strata, which is usually burned with low to moderate intensity to remove flammable fuels and decrease wildfire hazard.

Southern Europe forests and woodlands reflect a long history of anthropogenic disturbance and thrive under various soils and climates, from oceanic to semi-arid, but with the prevalence of hot- or warm-summer Mediterranean conditions. Forest types reflect this variation and comprise either deciduous or sclerophylous evergreen broadleaves, dominated by *Quercus* spp., and conifers, mostly *Pinus* spp. Ignitions are overwhelmingly human-caused and active fire suppression policies are enforced; for a comprehensive synthesis on the Mediterranean fire regime and its drivers see Prichard et al. (2017). Extensive afforestation and natural vegetation dynamics associated with the retreat of agriculture and decreased use of biomass increased the connectivity and flammability of forests and shrublands in the Mediterranean over the last decades, highlighting the need for fuel management programs, and more so in a warming climate (Moreira et al., 2011; Fernandes, 2013).

PUB in southern Europe is mostly for fire hazard reduction, with pastoral or biodiversity management as secondary objectives (Fernandes et al., 2013), but accounts for a minor fraction of the current PB area (Fernandes et al., 2016). The diversity of burn objectives (rangeland and habitat management in addition to hazard reduction) explains in part the prevalence of PB in shrubland, but the existence of stronger obstacles to apply fire in forests should also play a relevant role. And yet PB is expected to be more effective at reducing fire hazard in forest than in shrubland. This is because of the multi-layered nature of fuel structure in forest stands that implies more variable fire behaviour in comparison with shrubland, e.g. surface fire versus crowning, and longer duration of the treatment effect (Fernandes, 2015). Comparatively with other fuel treatment options, PUB has the seldom-recognized effect of decreasing fuel components that increase flame depth, combustion duration, and spotting, all of which contribute to extreme fire behaviour (Finney, 2016).

Impediments to PB acceptance and expansion in the Mediterranean Basin are significant and of variable nature (political, cultural, institutional, practical) (Fernandes et al., 2013), with insufficient research and development possibly playing a role as well. Here, I describe the history of PUB research in southern Europe and then review and synthetize the corresponding scientific knowledge, covering (1) PUB effects on soil, vegetation and fire hazard, (2) contributions to PUB planning and operations, and (3) identification and discussion of knowledge gaps and recommendations for future research.

2. History of prescribed burning research in southern Europe

The first Mediterranean Europe fire ecology studies in the 1960–1970s readily acknowledged the potential role of fire. Naveh (1974, 1975) and the European scientists present at the 1973 Tall Timbers Fire Ecology Conference (Komarek, 1974) were pioneers who laid the groundwork for subsequent PB research. The fire adaptation and resilience of shrubland was recognized early on, but historical evidence supportive of PUB had yet to come, i.e. studies showing that Mediterranean conifer forests – *Pinus pinaster* (Vega, 2000; Fernandes et al., 2015), *P. nigra* (Fulé et al., 2008; Touchan et al., 2012; Christopoulou et al., 2013), *P. halepensis* (Fournier et al., 2013), *P. canariensis* (Molina-Terrén et al., 2016), *Cedrus atlantica* (Slimani et al., 2014) – endured frequent (return interval < 15 years) fire of low or mixed severity in the past.

Initial efforts examined whether PB was a legitimate practice from the ecological viewpoint and then defined generic burn prescriptions. Pine stands were the initial target of PB burning research and operations in southern Europe. In fact, precursor practices to PUB are known since the 1800s in *P. pinaster* forests of southern France (Alexandrian, 1988) and Portugal (Varnhagen, 1836). PB experimentation was carried out as early as 1968 in pine (*Pinus brutia*) stands in northern Greece (Liacos, 1974, 1986), being followed by trials in oak (*Quercus coccifera*) shrublands in southern France (Trabaud, 1973), and in shrubland and eucalypt plantations in NW Spain (Vega, 1978). In NW Iberia, PUB research was born out of active cooperation between scientists and state forest managers, and was assisted by researchers from the Tall Timber Station and the USDA Forest Service (Silva, 1997; J.A. Vega, personal communication). The Portuguese forest service started experimenting with PUB in pine stands in the mid-1970s, and by 1982, a hazard-reduction burning program was in place in NW Portugal (Silva, 1997). PUB was adapted to the Portuguese context and its development paralleled that of research. Analysis of the practice recommended better planning and monitoring procedures although the potential for detrimental effects on trees or soils was restricted to just 10% of the burn operations (Fernandes and Botelho, 2004). Dissemination to France occurred through the technical literature (Alexandrian and Silva, 1988) and personnel exchanges (Binggeli, 1997).

The 1980s marked the initiation of European cooperative efforts on PB research and the first doctoral thesis on the subject (Rego, 1986). Between 1988 and 2000, the European Commission funded a sequence of four research projects specifically on PUB that addressed effects on soil, fuel, and vegetation (Vega et al., 1994; Valette, 1996) and then examined management-related issues and produced decision-support tools (Botelho et al., 2002). During this period, scientific meetings (rather than peer-reviewed journals) were the primary outlets for communicating findings, and the small European PB research community regularly gathered in fire ecology and management congresses (Goldammer, 1983; Velez and Vega, 1985; Bourdeau et al., 1987; Trabaud and Prodon, 1993; Trabaud, 1998) and dedicated workshops (INRA, 1989; Rego et al., 1989; Vega and Velez, 2000). Subsequent PB research has been scarce and dispersed, but PB as an hazard reduction tool was one of the structuring axis of the FIRE PARADOX project (2006–2010) focused on integrated fire management (Montiel and Kraus, 2010; Silva et al., 2010; Fernandes et al., 2011). Recent national projects on PUB have included FIREGLOBULUS in Portugal (Pinto et al., 2013) and GEPRIF in Spain (http://geprif.agripa.org).

3. Effects of prescribed underburning

3.1. Soil

PUB conditions of high moisture content in the forest floor constrain soil heating and fire severity (Valette et al., 1994; Vadilonga et al., 2008), thus mitigating its effects, which nevertheless vary depending on the soil attribute under consideration (Alcañiz et al., 2018). Changes in water infiltration rate and production of sediments after PUB are minor (Rego et al., 1990; Vadilonga et al., 2008), and changes in surface soil water content have not been observed (Gillon et al., 1987; Rego and Botelho, 1992; Meira-Castro et al., 2015). Additionally, soil total porosity and bulk density are unaffected (Meira-Castro et al., 2015) as they depend on organic matter and require near-total consumption of the forest floor.

Ash deposition after PUB and the corresponding nutrient flux signifies a fertilization effect reported by a number of studies, with higher concentrations of P, K and Ca in *P. halepensis* (Gillon and Rapp, 1989); increased Ca concentration in *P. pinaster*, without significant changes in P (Rego et al., 1987a); and increased P and Ca in *P. canariensis* stands, with decreased K (Arévalo et al., 2014a). Other studies did not detect