Science of the Total Environment 610–611 (2018) 720–731

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Short-term effects of spring prescribed burning on the understory vegetation of a *Pinus halepensis* forest in Northeastern Spain

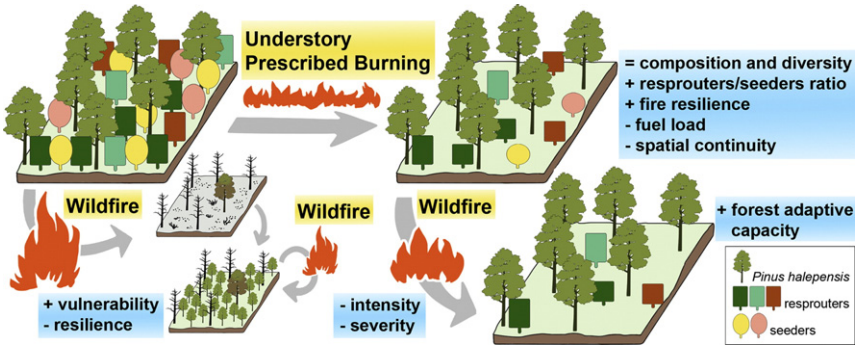
Laura Fuentes, Beatriz Duguy *, Daniel Nadal-Sala

Department of Evolutionary Biology, Ecology and Environmental Sciences, University of Barcelona, Barcelona, Spain

HIGHLIGHTS

- Projected higher fire risk requires promoting forest ecosystems' adaptive capacity.
- Low-to-moderate intensity burning preserved understory composition and diversity.
- Burning may reduce flammable seeder shrubs, thus promoting community's resilience.
- Understory prescribed burning may strongly reduce fuel load and spatial continuity.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 29 June 2017
Received in revised form 4 August 2017
Accepted 5 August 2017
Available online 17 August 2017

Keywords:
Mediterranean Aleppo pine forests
Understory prescribed burning
Species richness
Diversity
Resilience to fire

ABSTRACT

Since the 1970s, fire regimes have been modified in the Northern Mediterranean region due to profound landscape changes mostly driven by socioeconomic factors, such as rural abandonment and large-scale plantations. Both fuel accumulation and the increasing vegetation spatial continuity, combined with the expansion of the wildland-urban interface, have enhanced fire risk and the occurrence of large wildfires. This situation will likely worsen under the projected aridity increase resulting from climate change. Higher fire recurrences, in particular, are expected to cause changes in vegetation composition or structure and affect ecosystems' resilience to fire, which may lead to further land degradation. Prescribed burning is a common fuel reduction technique used for fire prevention, but for conservation and restoration purposes as well. It is still poorly accepted in the Mediterranean region since constrained by critical knowledge gaps about, in particular, its effects on the ecosystems (soil, vegetation). We studied the short-term (10 months) effects on the understory vegetation of a spring prescribed burning conducted in a *Pinus halepensis* forest in Mediterranean climate (Northeastern Spain). Our results show that the understory plant community recovered after the burning without short term significant changes in either species richness, diversity, or floristic composition. Most vegetation structural characteristics were modified though. The burning strongly reduced shrub height, shrub and herbaceous percentage covers, and aerial shrub phytomass; especially its living fine fraction, thus resulting in a less flammable community. The treatment proved to be particularly effective for the short term control of *Ulex parviflorus*, a highly flammable seeder species. Moreover, the strong reduction of seeder shrubs frequency in relation to resprouters' likely promoted the resilience to fire of this plant community. From a fuel-oriented perspective, the burning caused a strong reduction of spatial continuity and surface fuel loads, leading to a less fire-prone fuel complex.

* Corresponding author.
E-mail address: bduguy@ub.edu (B. Duguy).

http://dx.doi.org/10.1016/j.scitotenv.2017.08.050
0048-9697/

1. Introduction

Fire regimes are variable through time and space, resulting from complex interactions between climate, vegetation characteristics (i.e. type, condition and spatial configuration) and probability of ignition (Pausas and Fernández-Muñoz, 2011; Iglesias et al., 2015).

In the Mediterranean region (MR), anthropic activities have strongly determined during millennia the spatial distribution of vegetation types and land uses in the landscapes, therefore affecting fire occurrence and behavior (Pausas and Keeley, 2009; Moreno et al., 2013). Besides, the human use of fire as a tool for agro-pastoral and forestry purposes influenced fire ignitions and their seasonality (Pausas and Keeley, 2009; Bowman et al., 2011; Iglesias et al., 2015).

In recent decades, agricultural land abandonment (Fernández Ales et al., 1992), large-scale afforestation programs (Vallejo and Alloza, 1998), the prohibition of traditional fire uses and some restrictive fire suppression policies (Castellnou et al., 2010) promoted more homogeneous landscapes characterized by increasing fuel loads and more continuous surface fuels (Moreira et al., 2001; Moreno et al., 2013). Besides, fire ignition probability raised in many landscapes due to the growth of the wildland-urban interface (San-Miguel-Ayanz et al., 2012). An increase of large wildfires has been consequently observed in several northern Mediterranean regions since the 1970's (Loepfe et al., 2010; Moreno et al., 2013), although there is some variability depending on the region and the time period observed (San-Miguel-Ayanz et al., 2012; Koutsias et al., 2013). This tendency is particularly concerning under the current global change context, which is expected to enhance fire risk and shifts in spatial and temporal patterns of fire occurrence in the MR (Moriondo et al., 2006; Moreno et al., 2013). Increased fire recurrences, in particular, could cause changes in vegetation composition or structure and affect ecosystems' resilience to fire (Díaz-Delgado et al., 2002; Eugenio and Lloret, 2004; Espelta et al., 2008). Too short fire-free periods might ultimately cause the local extinction of long-lived woody species and favour herb-dominated systems due to the depletion of the seed banks and/or the decline in soil fertility (Zedler et al., 1983; Keeley et al., 1999; Eugenio et al., 2006). Synergistic interactions between these changes and other ongoing degradation processes mediated by human activities or global warming could finally impair ecosystems' functionality and promote land degradation (Cortina et al., 2009).

Prescribed burning (PB) is a vegetation management technique that is used across the world for controlling fuel load and creating spatial discontinuities in the vegetation (Agee and Skinner, 2005; Marino et al., 2011), and for achieving conservation or restoration objectives as well (Stephens et al., 2014). Various studies conducted in the MR support the interest of applying PB as a fuel management tool to reduce fire risk, limit fire intensity and severity, while improving the ecosystems' resilience to fire (Fernandes and Botelho, 2003; Piñol et al., 2005; Cassagne et al., 2011; Marino et al., 2011; Fernandes et al., 2013; Casals et al., 2016). Its use is still limited to few areas in the MR, though, due to a lack of social acceptance and the remaining uncertainties about its ecological effects, its operational feasibility in a wide range of situations (e.g. risks inherent to fire use when wildland-urban interface is overdeveloped) and its advantages in relation to other techniques (Ascoli and Bovio, 2013; Marino et al., 2014).

Studies assessing the vegetation dynamics after PB in ecosystems of the MR, and particularly those addressing burnings conducted under tree canopies, started quite recently (Vega et al., 1987, 2000; Rego et al., 1991; Moreira et al., 2003; Catalanotti, 2009; Esposito et al., 2014; Casals et al., 2016). In the Iberian Peninsula, to our knowledge, all studies dealing with PB effects on the understory vegetation have been carried out in *Pinus pinaster* Ait. or *Pinus nigra* Arn. ssp. salzmannii (Dunal) Franco stands. The present study is innovative, since conducted in a *Pinus halepensis* Mill. monospecific forest. Such type of woodlands experienced a great expansion in Spain throughout the second half of the XXth century driven by afforestation efforts and colonization after land abandonment (Barbero et al., 1990; Pausas et al., 2008). When dense and monospecific, these forests are often very flammable, favour intense crown fires (Pausas et al., 2008) and are very vulnerable to recurrent wildfires that could even constrain their natural regeneration (Eugenio and Lloret, 2004; Espelta et al., 2008).

In the perspective of more extreme fire weather conditions projected for the MR, there is an urgent need for setting ecologically sound forest management strategies aiming to (i) minimize fire risk (reducing ecosystems' fire-proneness, in particular), and (ii) enhance the capacity of forests to cope with new fire regimes increasing their resistance and resilience to fire (Duguy et al., 2013). Such strategies will have to integrate a wide array of stand structure adaptation and fuel control techniques.

In this context, our study intends to gain further insights into short-term effects on the understory vegetation of a spring prescribed burning conducted under a *P. halepensis* canopy. The goal is to contribute to a more comprehensive assessment of this technique's suitability in relation to the promotion of more sustainable and adaptive management practices for Aleppo pine forests in Eastern Spain.

2. Materials and methods

2.1. Study area

The study was conducted in a *Pinus halepensis* forest planted in 1970 over abandoned crops (Vega-García et al., 2014) in the Colladetes area (UTM Zone 31N: 304762, 4530927), which is located in the municipality of El Perelló (Southern Catalonia, Northeastern Spain) (Fig. 1). The altitude range is 238–250 m·a.s.l. The climate is Mediterranean (Sánchez de Dios et al., 2009; Casals et al., 2016), with a mean annual temperature of 16.5 °C and a mean annual precipitation of 504 mm, after data registered by the nearest weather station (El Perelló) for the (1973–2013) period (http://www.aemet.es/). The annual water deficit is 300–400 mm, which is aggravated by frequent dry NW winds reaching a mean annual speed of 9.5 $m \cdot s^{-1}$ and maximum speeds sometimes overpassing 30 $m \cdot s^{-1}$ (POUM El Perelló, 2010). These are some major factors contributing to the high fire-proneness that characterizes the studied forest most part of the year.

The dominant soils, generally shallow (<50 cm), are *Lithic xerorthents* and *Lithic haploxerepts* (Soil Survey Staff, 2010), developed over limestones and dolomites (Duguy et al., 2015).The current landscape mosaic, resulting from centuries of human activity, is dominated by rainfed crops (olive trees, cereals), shrublands (mostly dominated by *Quercus coccifera* L., *Pistacia lentiscus* L. and *Rosmarinus officinalis* L.) and *Pinus halepensis* forests. The latter are generally occupying former agricultural lands that were abandoned throughout the XXth century (Vega-García et al., 2014). The pine forests' understory is composed by *Querco-Lentiscetum* Br.-Bl. et al., 1935 *em.* A. *et* O. Bolòs 1950 macchia, dominated by *P. lentiscus* and *Q. coccifera*, and *Rosmarino-Ericion* Br.-Bl. 1931 shrublands, dominated by *R. officinalis* and *Erica multiflora* L., with the presence of *Ulex parviflorus* Pourr. (Duguy et al., 2015). The herbaceous layer is dominated by *Brachypodium retusum* (Pers.) P. Beauv.

Throughout the second half of the XXth century, land abandonment led to an increase in fuel amount and continuity in this landscape, promoting its fire-proneness. Although in the last decade in the Baix Ebre subregion, in which El Perelló is located, there was only one fire larger than 500 ha (i.e. the Rasquera fire that reached 2800 ha in May 2012; https://www.idescat.cat/), nine of its fourteen municipalities (El Perelló, in particular) are qualified as high fire risk municipalities by the fire prevention administration (http://agricultura.gencat.cat/ca/ambits/medi-natural/). This assessment is based on field-collected fuel moisture measures, meteorological forest fire risk indices, historical fire occurrence, fuel model maps and vegetation flammability maps.

2.2. Vegetation sampling and characterization

Three 10 × 10 m permanent plots were randomly located in a flat pine stand where the Forest Actions Support Group (GRAF) of the Autonomous Catalan Government (Casals et al., 2016) had planned to