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Effects of fuel reduction treatments on a gorse shrubland soil seed bank in the north of Spain: Comparing mastication and prescribed burning

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ABSTRACT

Fuel reduction treatments are commonly used to decrease the risk of severe wildfire in shrubland areas in the North of Spain. Information about the associated environmental effects is required to help forest managers select the most appropriate treatment. Although the soil seed bank plays an important role in post-disturbance recovery and resilience of frequently disturbed shrubland communities, little is known about how it is affected by fuel reduction treatments. We carried out a combined greenhouse and field study to evaluate the effects of two fuel reduction methods (prescribed burning and mastication) on the size and composition of the soil seed bank in a fire-prone gorse shrubland area in northern Spain. Total seedling density, species richness and similarity index were the variables analyzed. We also determine the effect of the depth of the soil organic cover remaining after mastication on the soil seed bank composition.

In the greenhouse experiment, significantly more seedlings emerged from the samples of the soil seed bank obtained after burning (810.6 seedlings m^{-2}) than in those obtained before burning (608.3 seedlings m^{-2}) and after mastication (610.1 seedlings m^{-2}). This contrasted with the lack of differences observed before and after mastication. Species richness in the soil seed bank was not altered by either prescribed burning or mastication. The observed high degree of similarity between soil seed bank and above-ground vegetation in both pre and post-treated soils was attributed to the dominance of resprouting species.

Post-burning seedling density was not significantly related to any of the soil thermal regime parameters during burning. The depth of the soil organic cover after mastication apparently did not affect the composition of the soil seed bank.

The field study revealed a low rate of seed germination of all species, which along with the rapid recovery of cover by the resprouting woody species in the community, suggests that the soil seed bank makes little contribution to the recovery of shrubland communities after fuel reduction treatments.

There was little opportunity to enhance vegetation recovery through the soil seed bank after prescribed burning and mastication. Mastication seems to be a more conservative technique although low intensity burnings as those conducted in the present study did not stimulate seed germination nor reduce seed bank size. In summary, prescribed burning and mastication can be considered feasible techniques for fuel management in these shubland areas.

1. Introduction

In the past decade, more than 35% of the wildland burned in Spain was shrubland (MMA, 2010) and 56% of these fires occurred in northern Spain. Under climate change scenarios (higher temperatures and lower summer rainfall), wildfire frequency and the extent of the area burned are expected to increase in this region (Vega et al., 2009).

Fuel reduction treatments are commonly used to reduce the risk of severe wildfire (Stone et al., 1999; Vega et al., 2000; Baeza et al., 2002). The Spanish Environmental Ministry (Ministerio de Agricultura, Alimentación y Medio Ambiente) is currently carrying out a Forest Fire Prevention Program in different shrubland communities with the goal of reducing the occurrence of human-caused wildfire and recovering the ancestral use of fire in rural areas (Vélez, 2010). Different fuel reduction treatments are implemented within the Program. Prescribed burning is often used because it can be

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applied to large areas of steep terrain at a relatively low cost. Other fuel reduction technique used is mastication (shrub shredding and residues left on the ground), mainly used for fuel breaks construction and maintenance and in the wildland–urban interface where the use of prescribed burning may be problematic.

Although information on different aspects of the environmental effects of fuel reduction treatments (e.g. increased erosion and vegetation dynamics) has been reported in recent years (Keeley et al., 2005; Vega et al., 2005; Keeley, 2006; Fernández et al., 2008, 2012; Potts and Stephens, 2009; Sikes and Muir, 2009), many questions remain unanswered. More specifically, the possible effects of fuel reduction treatments on the soil seed bank have scarcely been addressed.

Soil seed banks can play a relevant role in vegetation recovery after large scale disturbances (Warr et al., 1993; Thompson et al., 1997; Britton et al., 2000; Maren and Vandvik, 2009), particularly after disturbances that create gaps in the vegetation structure (Thompson, 2000). The soil seed bank is considered to be important for the plant communities recovery through seedling recruitment from germinated soil bank seeds which are produced either by the local vegetation or from other locations, and even seed of former plant communities that may be still present in the soil (Bossuyt and Honnay, 2008). A persistent seed bank may mitigate the consequences of habitat fragmentation and protect species from genetic drift and population genetic differentiation (Honnay et al., 2008). However, the soil seed bank has been also reported make a limited contribution to community recovery in the case of low intensity disturbances (Edwards and Crawley, 1999) and this may also apply to fuel reduction treatments.

Theoretically, burning and mastication may lead to different vegetation dynamics. The effect of fire on the soil seed bank depends on the species germination cues (Paula and Pausas, 2008) and the seed location in the soil profile. Furthermore, high temperatures during fires may either stimulate seed germination or may have lethal effects, depending on the species (Rivas et al., 2006; Luna et al., 2007; Moreira et al., 2010). Moreover, burning may affect thermal and moisture soil regimes and light conditions and the heat may destroy allelopathic compounds, all of which will affect seed germination (Keeley and Keeley, 1987). Some studies have examined the role of the seed bank in the recovery of communities after fire (Zammit and Zedler, 1988; Valbuena et al., 2000; Valbuena and Trabaud, 2001; Auld and Denham, 2006), finding from decreases to increases in the soil bank size, depending on the plant species and temperatures reached in the soil. However, the effects of mastication have received less attention and no studies have addressed the role of the soil seed bank in shrubland recovery after prescribed burning and mastication simultaneously applied in the same site.

Mastication can increase soil compaction and the depth of the soil organic layer, thereby altering the soil moisture regime and light availability, which will have negative implications for seedling emergence. Forest floor litter has been found to have a negative effect on germination and seedling emergence (Facelli and Pickett, 1991; Peterson and Facelli, 1992; Bueno and Baruch, 2011). The litter may decrease the amount of sunlight reaching the soil, acting as a physical barrier to seedling emergence, and also promoting allelopathic effects that can inhibit seed germination (van Andel, 2006). Most of the above studies were carried out in forest communities and no information is available for shrublands, particularly after fuel reduction treatments.

The above mentioned information is critical for predicting community responses to disturbances and understanding the resilience of these ecosystems (Hopfensperger, 2007) in the face of different types of perturbation. Such information is also essential for deciding how best to combine natural shrubland ecology and fuel management in order to help achieve more sustainable management methods.

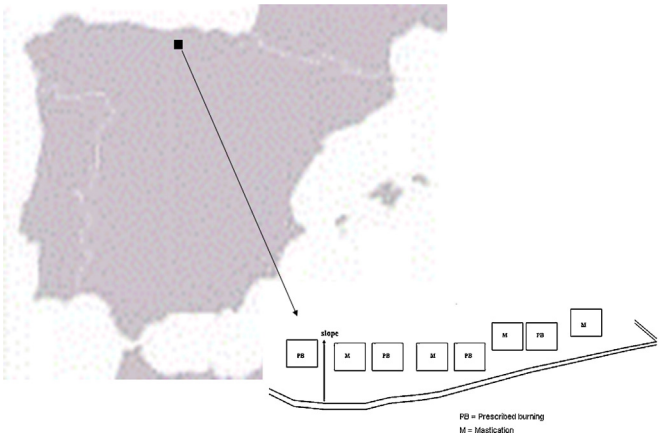

Fig. 1. Location of the study-site and sites layout.

In the present study, we monitored the size and composition of the soil seed bank and its similarity to the above ground vegetation after prescribed burning and mastication in a typical gorse shrubland in northern Spain, an area particularly affected by wildfires and where those treatments are being applied. We aimed to address the following questions: Do the fuel reduction treatments (prescribed burning & mastication) have different effects on the soil seed bank size and species richness?, Does the thermal regime during burning affect seedling emergence?, Does the depth of the soil organic layer remaining after mastication exert any effect on soil seed bank composition?, Does the soil seed bank in these shrublands contribute significantly to the community recovery after disturbance?

2. Materials and methods

2.1. Study site

The study is carried out in the Saja-Besaya Natural Park (43°13′14″N–4°12′57″W; 500 m a.s.l.) in the province of Santander (Fig. 1). The mean slope is 40%. The shrub community is dominated by *Ulex gallii* Planch., with some Ericaceae also present (mainly *Erica ciliaris* Loefl. ex L. and *Erica cinerea* L.). The climate in the area is Oceanic (Rivas-Martínez, 1987), characterized by warm summers, cool winters and precipitation evenly dispersed throughout the year. The average rainfall is about 1400 mm year^{-1}. The mean annual temperature is 12.0 °C. The soils are Humic Cambisols (FAO, 1998) and the soil texture is sandy-loam. The chemical properties of the soil are as follows: pH 4.3, organic carbon content 15.5% and total N 1.0%. In the past, the experimental site was burned repeatedly by man-caused wildfires with high frequency (every 5–10 years), which is common in many shrubland areas in the region.

2.2. Experimental design

Eight sites (each 50 m × 50 m) were installed with one dimension of each site parallel to the maximum slope (Fig. 1). The sites were separated by firebreaks. The experimental design was completely randomized and included two different treatments, prescribed burning and shrub mastication, with four replicates for each treatment. Ten plots (2 m × 2 m) were located in a grid within each site. As cattle grazing and roe deer browsing are frequent in the area, the sites were surrounded by electric fencing to prevent