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Comparing the effectiveness of seeding and mulching + seeding in reducing soil erosion after a high severity fire in Galicia (NW Spain)

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A B S T R A C T

Ecoengineering treatments are increasingly being used as a feasible and efficient alternative for soil stabilization after wildfire and soil erosion mitigation. This study assessed the effectiveness of two of those treatments to reduce soil erosion after a severe wildfire in NW Spain: straw mulch + seeding (2.5 Mg ha^{-1} + 3 gm^{-2}), seeding (3 gm^{-2}) compared to a control (untreated burned area).

During the study period (first two years after fire), only the mulching + seeding treatment significantly reduced soil erosion relative to that in the untreated burned soils (93%). The mean sediment yield after the seeding treatment (27.6 Mg ha^{-1}) was similar to that in the untreated burned plots (27.3 Mg ha^{-1}). Most of the soils losses (81%) occurred in the first year following fire.

Maximum rainfall intensity in 10 min was the only rainfall parameter significantly related to soil erosion during the study period.

Straw mulching significantly favored both recovery of native vegetation and establishment of seeded grass although seeding made a small contribution to total vegetation cover. Vegetation cover was low in the first months after fire when soil losses were highest. Vegetation patchiness significantly and negatively influenced soil loss via erosion in the first year after fire in the seeded and control plots.

The results from this study could help managers to select and apply more appropriate treatments for specific post-fire conditions.

1. Introduction

One of the most serious ecological consequences of forest fires is the increased soil loss via erosion (Benavides-Solorio and MacDonald, 2005; Spigel and Robichaud, 2007; Fernández et al., 2011). The combustion of the vegetation and ground cover exposes the mineral soil to raindrop impact and reduces its infiltration capacity (De Bano et al., 1998; Neary et al., 2005; Shakesby, 2011). Fire can also alter the soil structure, by affecting bulk density, and total porosity; thus, reducing infiltration and promoting overland flow (De Bano et al., 1998; Neary et al., 2005; Mataix-Solera et al., 2011). Changes in water repellency promoted by fire can also greatly contribute to runoff generation and soil erosion (Doerr et al., 2004; Keizer et al., 2008; Rodríguez-Alleres et al., 2012).

Emergency post-fire activities for soil stabilization such as mulching and seeding are considered as a first step in fire affected ecosystems restoration and they are often recommended in severely burned areas to minimize overland flow and erosion risk (Napper, 2006). North-western Spain is recognized as one of the European areas with greatest number of fires (San Miguel and Camia, 2009). This territory is particularly prone to post-fire erosion due to the coincidence of pronounced erodibility of burned soils, steep terrain, and high precipitation. In fact, the highest erosion rates following fire in Spain occur in this area (Cerdá and Mataix-Solera, 2009). Bioengineering treatments for post-fire soil stabilization are currently being used (Vega et al., 2013a).

Grass seeding has been widely used for post-fire erosion control because it is relatively inexpensive and easy to apply. Nonetheless, some recent comprehensive literature reviews (Beyers, 2009; Wohlgemuth et al., 2009; Peppin et al., 2010) have concluded that post-fire grass seeding may be ineffective in increasing ground cover or reducing post-fire erosion rates, particularly in the first year after fire, when the risk of erosion is highest. However, research in NW Spain has evidenced the efficacy of sowing grass in reducing post-fire soil loss (Pinaya et al., 2000; Díaz-Raviña et al., 2012). The underlying rationale is that under a warm and rainy climate, such as prevails throughout most of NW Spain, grass becomes established quite rapidly, thus contributing to a substantial degree of soil cover. Other treatments, such as mulching, yield ground cover instantaneously, and have proved

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suitable for reducing soil loss after fire in Galicia and elsewhere (Bautista et al., 1996; Wagenbrenner et al., 2006; Fernández et al., 2011; Prats et al., 2012; Fernández and Vega, 2014; Vega et al., 2014).

Stabilization treatments may also have other ecological consequences. Seeding can interfere with the natural recovery of vegetation (Conard et al., 1995; Beyers, 2004; Keeley, 2004; Dodson and Peterson, 2009) and mulching can both inhibit plant establishment and introduce exotic species (Kruse et al., 2004; Beyers, 2009). However, positive effects on plant installation have been also observed after mulching in both dry (Wagenbrenner et al., 2006; Bautista et al., 2009; Dodson and Peterson, 2010) and wet climates (Fernández and Vega, 2014). Wildland managers need specific information about the potential effects of soil stabilization treatments on native plant species, to enable them to make appropriate decisions about which treatments to apply to control erosion without hindering natural regeneration in burned areas.

Runoff and erosion have been shown to be strongly correlated with plant spatial patterns in several dryland ecosystems (Cerdá, 1997; Cammeraat and Imeson, 1999; Wilcox et al., 2003; Puigdefábregas, 2005; Bautista et al., 2007); however, these relationships have not been demonstrated neither after fire nor in post-fire stabilization treatments in wetter climates. In addition to the above factors, precipitation characteristics play an essential role in temporal patterns of erosion following fire. In a previous study in the same area (Vega et al., 2014), erosion of burnt soils in the first year following fire was not related to the intensity or energy of rainfall, whereas the amount of precipitation over a few consecutive days explained a large portion of the variability in the measured erosion. A question arose as to whether this type of response would also occur in severely burned soils.

In view of the above reflections, the aims of the study were as follows: (i) to compare the effectiveness of two different post-fire soil stabilization treatments (seeding and mulching + seeding) in reducing sediment yields, relative to those in an untreated control, throughout the first two years after a severe wildfire in a shrubland; (ii) to assess the influence of selected rainfall parameters on soil loss, (iii) to determine whether the above treatments have different effects on the recovery of both native and seeded plants cover during the study period, and (iv) to explore how sediment yields during the first year after fire are affected by plant connectivity.

2. Materials and methods

2.1. Study site

The study site comprised a burned area in the municipality of O Irixo (Ourense, NW Spain). The wildfire, which occurred in September 2009, burned 350 ha of shrubland. Prior to the wildfire, the shrubland was dominated by *Pterospartum tridentatum* (L.) Willk., *Ulex gallii* Planch., *Ulex europaeus* L., *Erica umbellata* Loefl. (L)., and *Halimium lasianthum* ssp. *alyssoides* (Lam.) Greuter were also present. This plant community typically forms a continuous thick layer of vegetation that completely covers the soil. The study site was located on a relatively homogeneous slope of 36% and SW orientation (42° 31′25″ N; 8° 4′ 23″W; 815 m a.s.l.).

The climate in the area is oceanic, with a slight continental influence. The average rainfall is 1241 mm year^{-1}, with a dry period of one month in summer, and the mean annual temperature is 11.7 °C (6.0–18.4 °C). The soil, developed on schist, was classified as Alumi-umbric Regosol (FAO, 1998). The soil texture is loam–sandy. The main chemical properties of the unburned soil are as follows: pH 4.7, organic carbon content 17.5%, and total N 1.1%.

2.2. Experimental design

Fifteen experimental plots (22 × 5 m each) were established with the longest dimension parallel to the maximum slope angle across a representative hillslope (Fig. 1). The plots were established

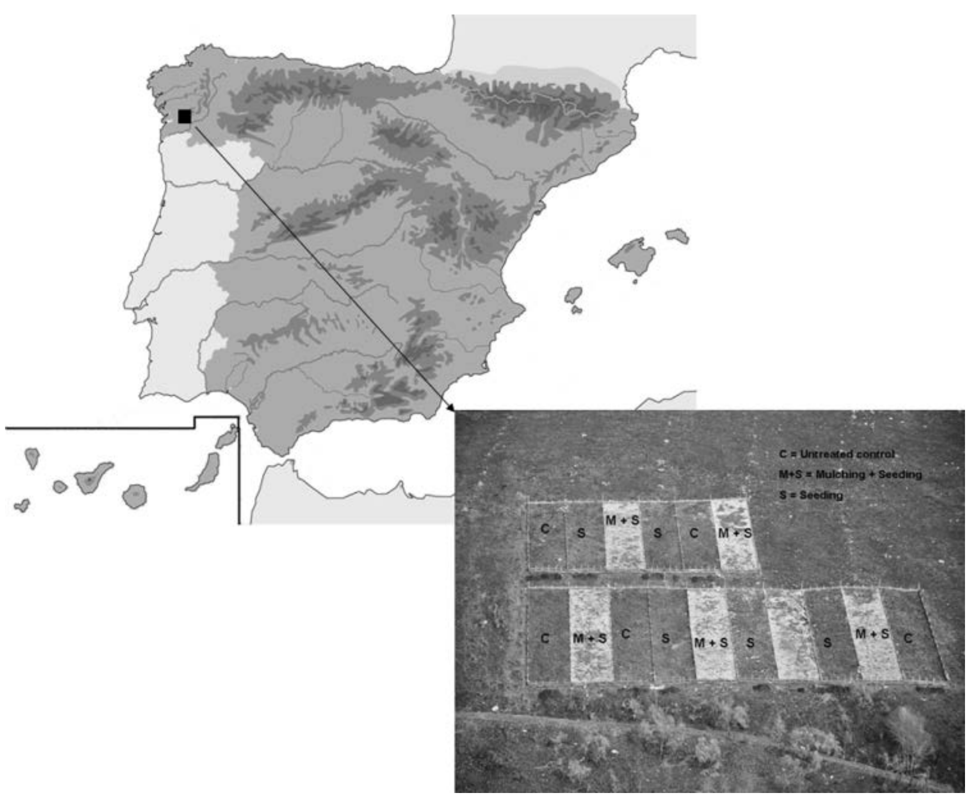

Fig. 1. Location of the study site and plot layout.