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Post-fire hillslope log debris dams for runoff and erosion mitigation in the semiarid Ebro Basin

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ABSTRACT

The hydrologic effects of hillslope log debris dams were analyzed in areas of the Castejón Mountains (semiarid Ebro Basin, NE-Spain) affected by a wildfire. Four experimental sites showing differences in the soil composition (calcareous and gypseous) and the aspect of the steep slopes (north and south facing) were selected. All of the experimental sites were located along planar hillslopes, where Aleppo pine forest had burned in 2009, in the four sites per triplicate. Runoff and sediment yields were measured for two consecutive years (2012, 2013) after the construction of log dams on partially re-vegetated sites in 2011.

In 2012, log dam installation significantly decreased soil erosion from 8.51 Mg ha^{-1} year^{-1} to 0.76 Mg ha^{-1} year^{-1}, with a log dam performance of approximately 90% being obtained. Similarly, the log dams caused a significant reduction of runoff, from 6.9 to 3.3 mm year^{-1}, presenting a performance of 52%. Both differences decreased one year later. Approximately 75% of the soil loss from 2012 was collected in only one clean-out period, when rainfall was almost half of annual rainfall. The quality of the eroded sediments and water runoff was related to the composition of the Ah horizon. Log dams reduced soil erosion in three of the four sites tested during the first year. However, in the second year, only one site showed statistically significant differences, which was the site with the greatest amount of bare soil. These findings indicate that in semi-arid areas, post-fire active restoration measures are still active four years after a fire on south-facing slopes with poor soils and slow ground cover recovery.

1. Introduction

Fire is one of the most important disturbances in forest ecosystems, especially in semiarid Mediterranean regions, with long dry, hot summers. In the last several decades (1960–2012), wildfires have affected more than 7 million ha in Spain (Ministerio de Agricultura, 2012). Soil degradation caused by wildfires is particularly accentuated in semiarid Mediterranean regions, where edaphic, geomorphic, and especially climatic factors (such as abundant high-intensity rainfall events in the autumn period just after summer wildfires) tend to increase runoff and soil erosion, both on-site and off-site (Pausas and Fernández-Muñoz, 2012; Shakesby, 2011).

Soil erosion is caused by water through at least two processes: (1) the detachment of particles (splash effect) via the direct impact of raindrops on bare soil and (2) overland flow, which varies according to rainfall (intensity and amount) as well as slope length and roughness (Moody and Martin, 2009; Robichaud et al., 2000). Moreover, fire induces soil surface disturbances such as decreases in soil organic matter and litter (Aznar et al., 2014; Badía et al., 2014). Until soil properties and protective vegetation or litter cover are recovered, soil erosion can continue for months or even years in Mediterranean areas (Shakesby, 2011). During this "window of disturbance" (Prosser and Williams, 1998), some erosion control measures can be applied. Certain slope treatments have been promoted since the 1990s in an attempt to mitigate post-wildfire runoff and soil erosion, including seeding, mulching (with cereal straw or wood shreds) and the construction of erosion barriers (Robichaud et al., 2000; USDA, 1995). On the Iberian Peninsula, pioneering works to control soil erosion in burned areas were developed (Badía and Martí, 2000; Bautista et al., 1996; Vallejo and Alloza, 1998) and in an attempt to improve pastoral value from the new and temporal plant cover (Badía and Martí, 1994a,b; Badía et al., 1994). The effectiveness of these measures varies considerably depending on the climate, relief, vegetation, soil properties, fire severity and the type of treatment and its installation time (Robichaud et al., 2005, 2010, 2013).

Regarding the possible types of post-wildfire hillslope erosion barriers, contour-felled logs, contour trenches, and straw wattle has been used (Robichaud et al., 2008a,b, 2010, 2013; Vega et al., 2013). Despite the increasing use of these barriers in many countries, the results are often contradictory, with no effect being observed in some cases (Chang-Gi et al., 2008; Robichaud et al., 2008a; Wagenbrenner et al., 2006; Wohlgemuth et al., 2001) or a slightly positive effect in others (Robichaud et al., 2008b). Raftoyannis and Spanos (2005) even reported an adverse effect of log erosion barriers (LEBs) on the regeneration of *Quercus coccifera* L., which could delay revegetation. However, some

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studies have indicated that the effectiveness of LEBs varies according to the rainfall distribution, being greater during rain events of short duration (Robichaud et al., 2008a,b; Wagenbrenner et al., 2006) and in areas where rainfall is scarce (Robichaud et al., 2005).

In the semiarid Ebro Basin (NE-Spain), novel hillslope log debris dams have recently been used as a post-fire emergency measure. These erosion barriers consist of overlapping burned logs that are properly cut to build a dam that is then filled with pruning branches or debris. Erosion barriers are installed in staggered tiers to eliminate long uninterrupted flow paths. This study aimed to determine the effects of log debris dams on post-fire hydrologic responses (sheet soil erosion and water runoff, in terms of quantity and quality) generated by natural rainfall over a 2-year period after log dam construction. In addition, the effectiveness of the treatments was compared at four sites with different edaphic properties and slope aspects.

2. Materials and methods

2.1. Description of the study area

The Castejón Mountains are located in the semiarid Ebro Basin, between the cities of Castejón, Tauste and Zaragoza, NE-Spain (Fig. 1). These mountains were affected by a wildfire that started on 18th August 2009 and was deemed extinct on 21st August, after the burning of 7000 ha, including pine forests, scrublands and farmlands. Based on the type of ashes and the vegetation remains observed, it can be assumed that the fire severity was moderate or high in sites where the orientation of the slope and soil fertility were more favorable to the development of plant growth and was low in other areas (León, 2014). Two years later (summer 2011), hillslope log debris dams were built using the trunks and branches of burned Aleppo pines as a treatment to control runoff and soil erosion in partially vegetated sites (Fig. 2).

The Castejón Mountains consist of steep slopes (approximately 50%) with a planar profile composed of carbonate lithofacies (limestones and marls) in the upper parts (750–500 m elevation) and evaporite lithofacies (gypsum) in the lower parts. According to the WRB system (IUSS, 2014), soils developed on calcareous parent material are classified as Calcaric Regosols and Rendzic Phaeozems, whereas those on gypsum are classified mainly as Haplic Gypsisols (Hypergypsic). According to the slope aspect (N and S) and the soil parent material (calcareous, C and gypseous, G), four study sites were designated (Table 1). More information about other soil properties and the study area was published by Badía et al. (2013).

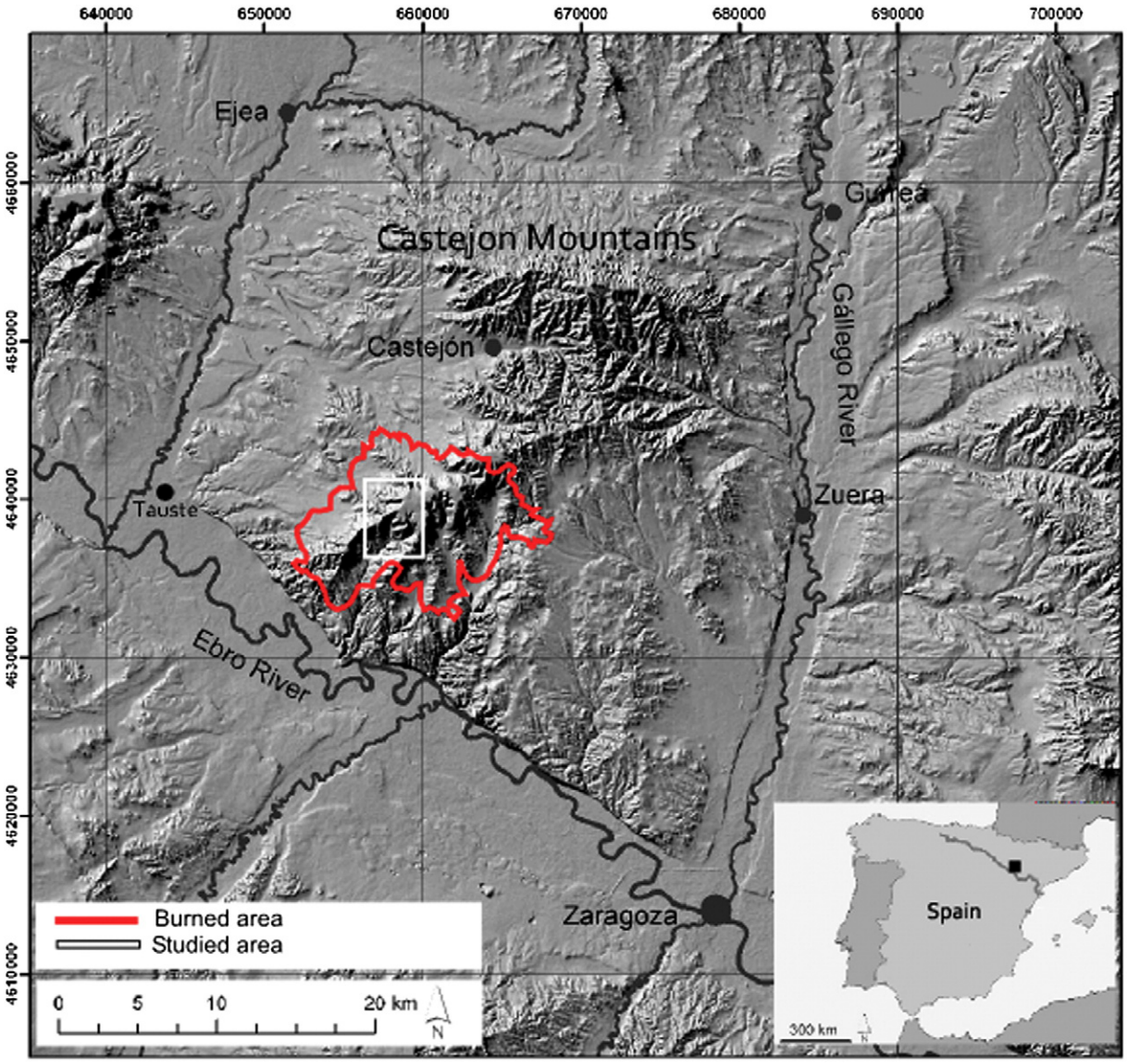

Fig. 1. Location of the studied and burned areas in the semiarid Ebro Basin (NE-Spain).