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Can ash control infiltration rate after burning? An example in burned calcareous and gypseous soils in the Ebro Basin (NE Spain)

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ABSTRACT

Fire is a long-established ecological factor that has shaped the life history, hydrogeomorphological processes, soil formation and landforms of Mediterranean environments. Soil infiltration is one of the properties affected by fire as a consequence of litter and vegetation removal, and heating of and changes to the biological, chemical and physical soil properties. In this context, ash can play an important role in soil infiltration behavior and therefore affect sediment and runoff yield.

The aim of this work is to determine the effect of ash cover on infiltration rates. A single ring infiltrometer was used immediately after a wildfire and before the first storm events to determine the soil infiltration rate. A total of 24 infiltrations were made (2 soil types × 2 treatments × 6 replicates). In each infiltration experiment, the soil wetting front, the bulk density and stoniness were also measured. The results show that the final infiltration rate (f_c) values are higher in calcareous soils than in gypseous soils. The ash cover in calcareous burned soils only temporarily decreases the bulk density of topsoil and enhances infiltration.

1. Introduction

Fire is a long-established ecological factor that has shaped life-history of Mediterranean plant species and plays a decisive role in the dynamics and structure of Mediterranean ecosystems (Shakesby, 2011; Trabaud, 1987). The burned area in the Mediterranean climate zone is 600,000 ha year^{-1} (Martínez-Aznar, 2012). Fire promotes a change in soil erosion and hydrological response (Shakesby and Doerr, 2006), including infiltration, which is the process of water entering the soil. A reduction in infiltration rates leads to an increase in the overall amount of runoff and soil erosion (Cerdà, 1998a).

Mediterranean calcareous soils have been studied after forest fires (Cerdà and Doerr, 2008; Mataix-Solera and Doerr, 2004; Shakesby and Doerr, 2006). However, there is almost no information about the impact of fire on gypseous soils, although there is a need for a better understanding of the specific processes (Herrero et al., 2009). Various works on gypseous soils have focused on its genesis and classification (Herrero et al., 2009), post-fire vegetal recovery (Badía and Martí, 2000; Badía et al., 2008), erosion processes (Desir, 2001; Gutiérrez and Gutiérrez, 1998) or mineralogy (Laya et al., 1998; Porta, 1998), but there are few studies on their post-fire hydrological response (León et al., 2011) and erodibility (León et al., 2013b).

The combustion of vegetation, litter and duff layers creates an ash deposit, which can control the runoff and erosion rates in the period immediately following a wildfire (Bodí et al., 2012; Cerdà, 1998b; León et al., 2013a; Pereira et al., 2010; Woods and Balfour, 2008; Zavala et al., 2009). Because of the high porosity of the ashes, of up to 80%, large amounts of water may be retained (Woods and Balfour, 2008). Moreover, an ash layer often has a high infiltration capacity that prevents ponding and the development of overland flow (Cerdá and Doerr, 2008; León et al., 2013b; Pereira and Bodí, 2013; Woods and Balfour, 2008; Zavala et al., 2009). However, other studies have shown that ash is water repellent (Bodí et al., 2012; Shakesby and Doerr, 2006), which favors an increase in runoff rates and macropore flow (Granged et al., 2011). The amount of ash and its physical and chemical characteristics depend on the degree of combustion, which is correlated with the type and quantity of fuels, the fuel density, the moisture content and the fire severity (Bodí et al., 2011; Keeley, 2009; Neary et al., 2005; Ulery et al., 1993; Woods and Balfour, 2008). Furthermore, the ash cover and its composition are highly dynamic with time. Ash can be exported and disappear within a few days, or it can remain throughout the first year. Usually, there is redistribution by wind or water, and runoff removes most of the ash from the slopes (Cerdà and Doerr, 2008; Pereira et al., 2013).

The ash layer may significantly reduce runoff and erosion from severely burnt areas, during the period immediately after a fire (Cerdà, 1998a,b; Cerdà and Doerr, 2008; León et al., 2013a). The greatest post-fire hydrogeomorphic hazard occurs after the removal of the ash cover by wind and water erosion, usually when the vegetation recovery is taking place (Woods and Balfour, 2008).

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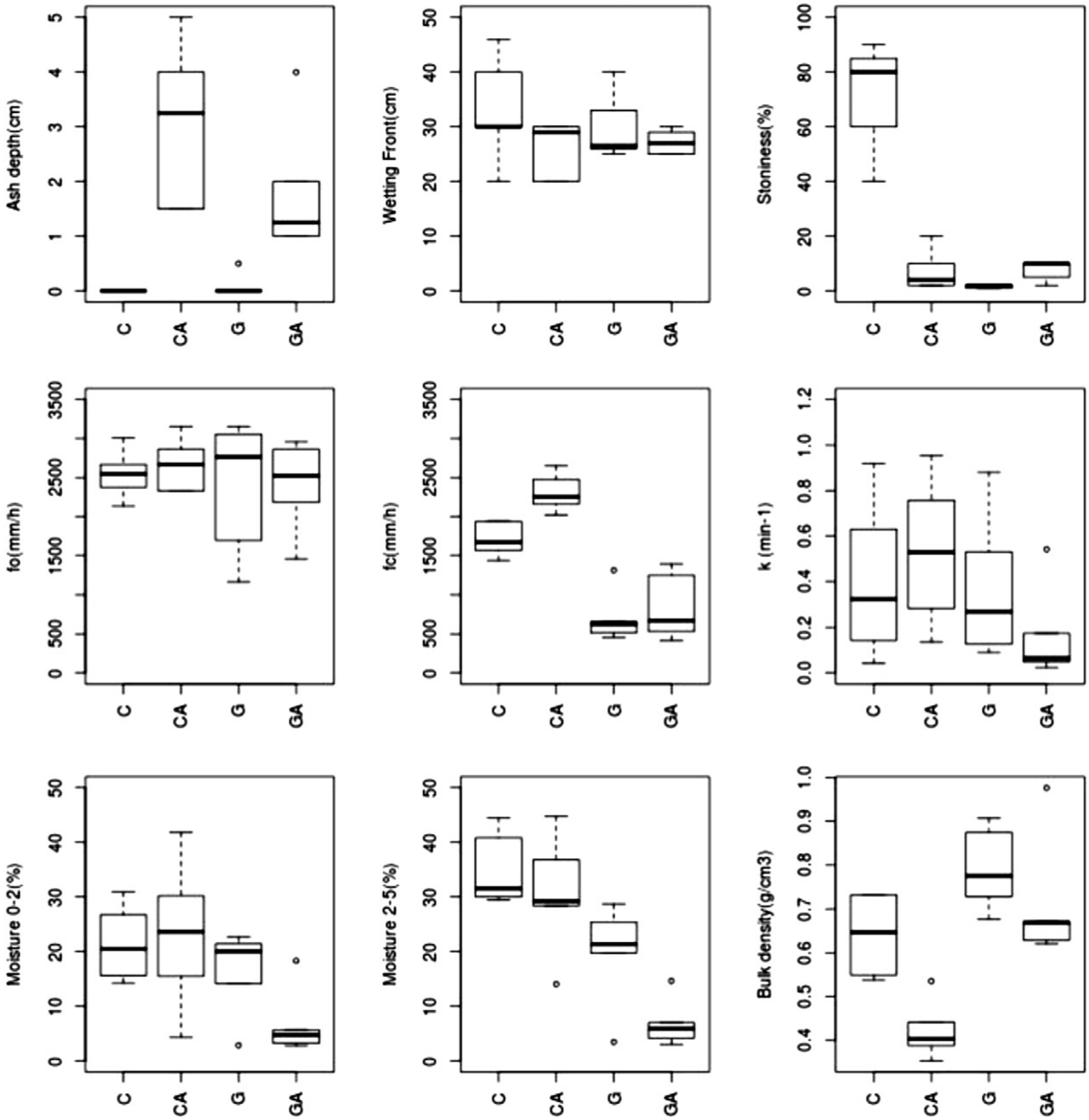

Fig. 1. Effect of ash on infiltration in calcareous and gypseous soils. (C) Calcareous soils without ash; (CA) calcareous soils with ash; (G) gypseous soils without ash; (GA) gypseous soils with ash.

When the ash deposit disappears, the raindrops directly hit the soil. They break down the aggregates, and particles can be rearranged between the pores, thus sealing the soil surface and changing the soil porosity and infiltration capacity (Badía and Úbeda, 2013; Giovannini and Lucchesi, 1997; Mataix-Solera et al., 2011; Wittenberg and Inbar, 2009).

The objective of this study was to determine the effect of ash cover on the infiltration rates of two types of soils (calcareous and gypseous), in burned woodlands of the mountains of Zuera, (NE Spain) using a single-ring infiltrometer. Furthermore, the effect of ash cover on the hydrological response of the gypseous soils was evaluated.

2. Material and methods

2.1. Study area

The Zuera Mountains, located north of the city of Zaragoza (NE Spain), have suffered more than 40 fires during the period from 1920–2006 (Villar, 2006). The mountain vegetation has a good natural recovery, especially in north-facing slopes. However, the long anthropogenic influence, the semiarid climate and shallow soils have been very harmful with respect to the effects and recurrence of fire, particularly those burning in degraded areas. The last large fires were in 2008 (2000 ha) and 2009 (more than 6000 ha). This study was carried out in Castejón (UTM 30T, X671106, Y4644584) under an Aleppo pine forest that burned in 2008 and in Remolinos (UTM 30T, X656794, Y4639884) under a shrubland that burned in 2009.

The vegetation at Castejón is characterized by a mixed forest (*Pinus halepensis* Mill and *Quercus coccifera* L.) and scrubs (*Brachypodium phoenicoides* L., *Brachypodium retusum* Pers., *Juniperus oxycedrus* L., *Lonicera etrusca* G., *Genista scorpius* L., *Helianthemum marifolium* Mill, *Osyris alba* L., *Pistacia lentiscus* L., *Rhamnus lycioides* L. subsp. *lycioides*, *Rosmarinus officinalis* L), whereas in the Remolinos area, the scrub formation is dominant (*G. scorpius* L., *Retama sphaerocarpa* L., *R. officinalis* L., *Gypsophila struthium* Willk subsp. *hispanica*, *Ononis tridentata* L., and *Q. coccifera* L.) and *P. halepensis* Mill. The climate is Mediterranean continental, with a mean annual rainfall of up to 450 mm and a temperature variation from −7.1 °C to 36.5 °C. The mean annual reference