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The contrasted response of ash to wetting
The effects of ash type, thickness and rainfall events

Javier León[a,*], Merche B. Bodí[b,1], Artemi Cerdà[b,1], David Badía[c,2]

[a] Dept. of Geography and Spatial Management, University of Zaragoza, Pedro Cerbuna 12, Zaragoza 50009, Spain
[b] SEDER (Soil Erosion and Degradation Research Group), Dept. of Geography, University of València, Blasco Ibáñez, 28, Valencia 46010, Spain
[c] Technic School of Agricultural Engineering and Environmental Sciences, University of Zaragoza, Ctra. de Cuarte, s/n, Huesca 22071, Spain

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A B S T R A C T

After a wildfire the soil is covered by ash. Ash properties depend on vegetation type, amount of fuel and fire intensity. The ash layer controls the post-fire soil hydrologic response, but little is known about the effect of ash thickness and ash type on infiltration, which is relevant for post-fire runoff and soil losses and for ecosystems rehabilitation and restoration. This paper analyses the role of i) ash type (black or white), ii) thickness (5, 15 and 30 mm-thick) and iii) temporal variation (0, 15 and 40 days) under three simulated rain events (55 mm for 1 h) on soil surface hydrology. The rainfall was simulated on 0.25 m^2 plots, and time to ponding, runoff and runoff discharge were measured. The infiltration rates, the initial infiltration rate (f_0), the steady-state infiltration rate (f_c), and the infiltration decay factor (k), were calculated and the Horton infiltration equation applied. The results show that soils covered with white ash doubled the runoff rates of soils covered with black ash. In general, runoff decreases as the ash thickness increases and the runoff decreases with the number of rainfall events after the fire in plots covered with white ash. Ponding time and k are positively correlated by the ash thickness and f_0 and f_c are correlated by the rainfall events (in three runs). Ash type and ash depth are key factors on the soil hydrology after a wildfire.

Contents

1. Introduction

Soil hydrology changes within the first days or weeks following wildfires, as a result of the sudden changes in vegetation – modification of vegetation cover, loss of surface litter, duff and other organic ground cover – (Cerdà, 1998a; Woods and Balfour, 2008), soil surface cover and soil properties, from heating on the soil structure (Mataix-Solera and Doerr, 2004) and, in some cases, changes in soil water repellency

* Corresponding author. Tel.: +34 976761000.
E-mail address: fcojleon@unizar.es (J. León).
[1] Tel.: +34 963864882.
[2] Tel.: +34 974239318.

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(DeBano, 2000; Doerr et al., 2000; Shakesby et al., 2000). During the last decade it has been discovered that a definitive factor that affects post-fire soil erosion and the hydrological response of hillslopes is the presence of an ash layer (Bodí et al., 2013; Cerdà and Doerr, 2008; Dlapa et al., 2013; Ebel et al., 2012). The ash layer controls the hydrological response on the soil surface (Cerdà, 1998a, 1998b) due to its high water infiltration capacity in one hand, also due to crust development and water repellency in another hand, as has been analyzed in previous laboratory experiments by Bodí et al. (2013), in relation of the ash type.

Ash is a mixture of organic and mineral materials that covers the soil after fire. However, ash properties are very different in terms of chemical and physical characteristics depending on the fire severity (Keeley, 2009; Neary et al., 2005; Ulery et al., 1993). Fire severity is a tracer of the degree of combustion (Keeley, 2009), which is determined by the fuel density and moisture, fire duration (Hartford and Frandsen, 1992; Miyanishi, 2001; Ryan and Frandsen, 1991; Valette et al., 1994), and vegetation type (Bodí et al., 2011).

Ash color has been used as an indicator of fire severity (Keeley, 2009; Pereira et al., 2010). High-severity fires produce white ash as a result of the complete combustion of the vegetation. The white ash consists mainly of carbonates (Pereira et al., 2013) and oxides of metal and silica (Demeyer et al., 2001; Ulery et al., 1993). The black ash is produced when combustion is not complete and char particles are present (Balfour, 2007; Woods and Balfour, 2008). Black ash is used as an indicator of low severity fire (Pereira et al., 2013). In addition, post-fire responses can vary greatly depending on rainfall (Kinner and Moody, 2007) and especially on the thickness of the layer of ashes (Woods and Balfour, 2008), the combustion temperature and species affected, which determine the physicochemical properties of soil and ashes (Pereira et al., 2010).

Ash has been found to be an important factor in the production of runoff immediately after fire (Ebel et al., 2012; Larsen et al., 2009; León et al., 2011; Shakesby, 2011). Some authors found that ash favors the infiltration rates (Cerdà, 1998a,b; Cerdà and Doerr, 2008; Kinner and Moody, 2010; León et al., 2011; Martin and Moody, 2001; Woods and Balfour, 2008), although the fine grain size and easy crusting (Gabet and Sternberg, 2008) are considered by other authors to clog pores (Etiegni and Campbell, 1991) and lead to the high runoff rates, by sealing the mineral soil surface and decreasing infiltration rates (Mallik et al., 1984; Neary et al., 2005; Onda et al., 2008; Wells et al., 1979). Moreover, it was recently discovered that ash generated at low temperature can be water-repellent (Bodí et al., 2013) due to the large content of charcoal and partially combusted organic material. Water repellency favors an increase in runoff rates and macropore flow (Granged et al., 2011). The characteristic of the ash during the post-fire period is a key research priority to understand the effects of ash on soil hydrology (Pereira et al., 2013).

The objective of this paper is to determine, under field conditions, the post-fire soil hydrologic response to torrential rain events: (i) under two different types of ash, (ii) on ash thicknesses, and (iii) on rainfall events (three runs).

2. Materials and Methods

2.1. Description of the Site and Ashes

The experimental area is located in El Teularet Soil Erosion Experimental Station (38º50′N; 0°42′W), in the Sierra de Enguera, Valencia province (Eastern Spain), in a rainfed orchard abandoned in the 70"´s (Figure 1). This study site is representative of the mountainous rangelands of Eastern Spain that are being affected by recurrent fires promoted by the growth of pyrophitic vegetation dominated by *Ulex parviflorus*. The research station is devoted to study the environmental impact of humankind in the Mediterranean Ecosystems from a soil erosion and degradation point of view.

The soil is a *Typic Xerorthent* (Soil Survey Staff (SSS), 2010) and the main properties of the soil and the ash layers (Table 1) are defined by Bodí et al. (2013) and García-Orenes et al. (2009). The soils are developed on Cretaceous marls and placed on slopes stabilized by hand-made terraces, with current slope angles of 5 to 8%. The terraces, built to crop almonds and wheat, frequently ploughed, are nowadays abandoned. The climate is typical Mediterranean with 3 to 5 months of summer drought. Mean annual rainfall at the study area is 479 mm and the mean annual days of rainfall is 37.9. As in other Mediterranean areas, the rainfall intensity can be very high during extreme rainfall

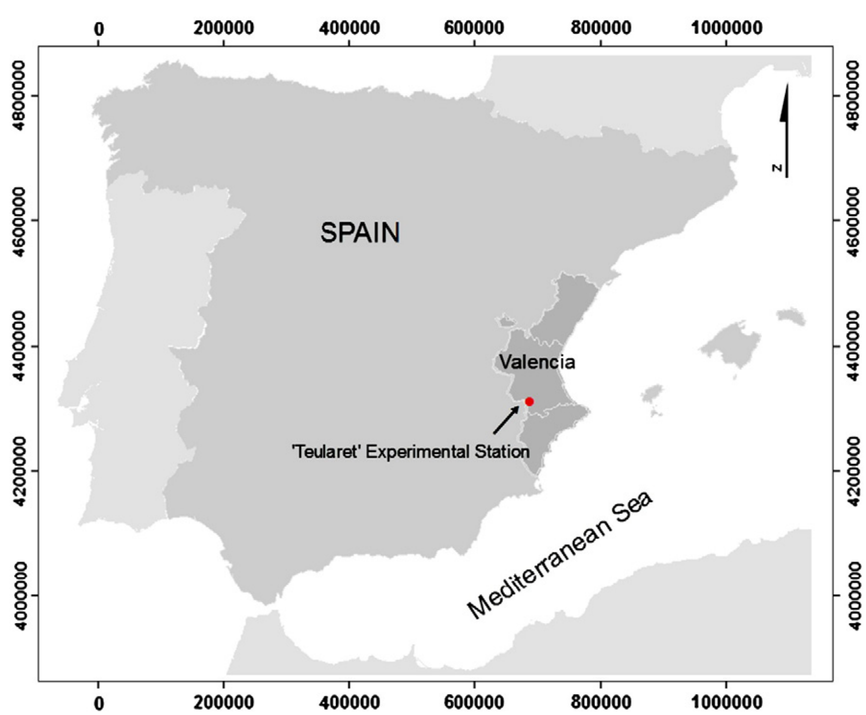

Fig. 1. Location of the Teularet (Sierra de Enguera) experimental station.