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Temporal effects of post-fire check dam construction on soil functionality in SE Spain

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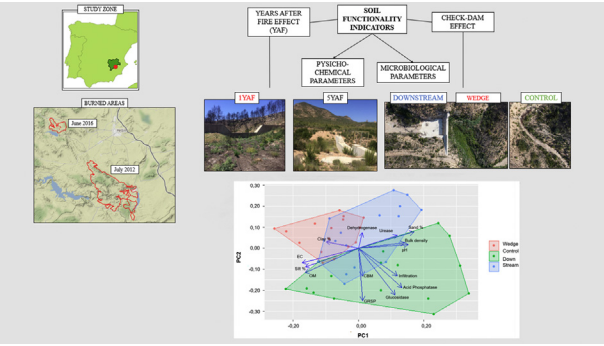
HIGHLIGHTS

- Check dam construction in semiarid environments locally affects to soil functionality.
- Physico-chemical and biochemical variables correlations are key in soil quality assessment.
- Years after fire clearly enhance the local check dam effect.

GRAPHICAL ABSTRACT



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ABSTRACT

Wildfire has historically been an alteration factor in Mediterranean basins. Despite Mediterranean ecosystems' high resilience, wildfire accelerates erosion and degradation processes, and also affects soil functionality by affecting nutrient cycles and soil structure. In semi-arid Mediterranean basins, check dams are usually built in gullies and channels after fire as a measure against soil erosion. Although check dams have proven efficient action to reduce erosion rates, studies about how they affect soil functionality are lacking. Our approach focuses on how soil functionality, defined as a combination of physico-chemical and biological indicators, is locally affected by check dam construction and the evolution of this effect over time. Soils were sampled in eight check dams in two semi-arid areas at SE Spain, which were affected by wildfire in 2012 and 2016.

The study findings reveal that by altering sediments cycle and transport, check dams influence soil's main physico-chemical and biochemical characteristics. Significant differences were found between check dam-affected zones and the control ones for many indicators such as organic matter content, electrical conductivity or enzymatic activity. According to the ANOVA results, interaction between check dams influence and time after fire, was a crucial factor.

PCA results clearly showed check-dams influence on soil functionality.

1. Introduction

Wildfires are a major phenomenon in Mediterranean biomes that play a key role in the distribution and composition of terrestrial ecosystems (Bond and Keeley, 2005). This natural disturbance has modelled and altered the structure of semi-arid ecosystems; (i.e. soil and

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vegetation) (Andreu et al., 2001; Cerdà, 1998; Jordan and Cerdá, 2014; Muñoz-Rojas et al., 2016b).

The affection of wildfire to semi-arid ecosystems, has proven to be a soil erosion and degradation accelerator, due to the removal of vegetation and the resultant runoff and erosion (Cerda, 2009; Cerdà, 1998), although is also recognised as a soil-forming factor (Certini, 2014). Fire disturbs soil functionality by affecting organic carbon and nutrient cycles, soil texture and structure, pH, infiltration and the biological processes that involve the microbial community structure (Cerdá and Doerr, 2005; Certini, 2005; Mataix-Solera et al., 2009; Muñoz-Rojas et al., 2016b).

After a wildfire event in Mediterranean basins, the taken measures can be classified as slope or channel measures (Vallejo and Alloza, 2012). Reforestation or fascines, barriers made from the finest burnt wood remains following the contour lines (Rodríguez and Suárez, 2014) are usually carried out on slopes to avoid soil loss, while check dams are built in channels to retain eroded sediment in order to avoid damaging downstream infrastructures (Boix-Fayos et al., 2008; Castillo et al., 2007; Díaz et al., 2004) and water pollution by reducing sediment/ash loads (Nichols et al., 2012). Several studies refer to the influence of check dams on the geomorphology and hydrological dynamics of watersheds (Boix-Fayos et al., 2007; Nadeu et al., 2015), their capacity to retain sediments (Hassanli et al., 2009; Mekonnen et al., 2014, 2015; Ramos-Diez et al., 2016), and their effect on the carbon cycle (Boix-Fayos et al., 2009, 2015) or vegetation (Bombino et al., 2014). Although check dam construction has proven to be an effective short-term measure (Nadeu et al., 2014), few studies were focused the long-term efficiency and how they affect soil functionality.

To successfully undertake the restoration of ecosystems after a major disturbance, the assessment of soil functionality, is a key issue (Muñoz-Rojas et al., 2016a). Soil functionality is an extremely important factor for ecosystems functioning, such as the capacity of soils to provide ecosystem services (Muñoz-Rojas et al., 2016a). Soil functionality is related to nutrient cycling, biological productivity or physical stability, which are crucial for healthy plant growth and for improving water and air quality (Doran, 1996; Fitter et al., 2005).

Several physicochemical properties can be used as indicators to assess soil functionality, such as electrical conductivity (EC), which is related with plant growth, soil texture and structure or pH (Laishram et al., 2012). However organic matter (OM) content has been considered one of the most important quality indicators (Toledo et al., 2013). Soil microbial biomass carbon or hydrolytic enzyme activities can provide important information about element cycling and microbial activity (Garcia et al., 1994), and have been widely used to assess soil functionality (Hedo et al., 2015; Lucas-Borja et al., 2010, 2012). Glomalin, a glycoprotein produced by arbuscular mycorrhizal fungi, has been widely studied and is considered to be an important soil functionality parameter, due to its influence on aggregates stability or water repellency, this protein when extracted from soils is called "Glomalin-Related Soil Protein" (Bonfim et al., 2013; Lozano et al., 2016).

The main objectives of this study were:

i. To evaluate the local effect of check dam construction on soil functionality.
ii. To evaluate how these effects evolve over time.

For this purpose, physical, chemical and biochemical indicators were measured at eight check dams in two nearby areas burned in different years. Three distinct zones were established for each check dam, i.e. the sediment wedge of the dam, immediately downstream and outside the dam's influence (control). We hypothesized that check dam construction would enhance soil functionality in the wedge due to the greater storage of nutrients and OM.

2. Material and methods

2.1. Study area

The study was carried out in SE Spain, more specifically in the southern mountains in the province of Albacete (Fig. 1). Two areas with

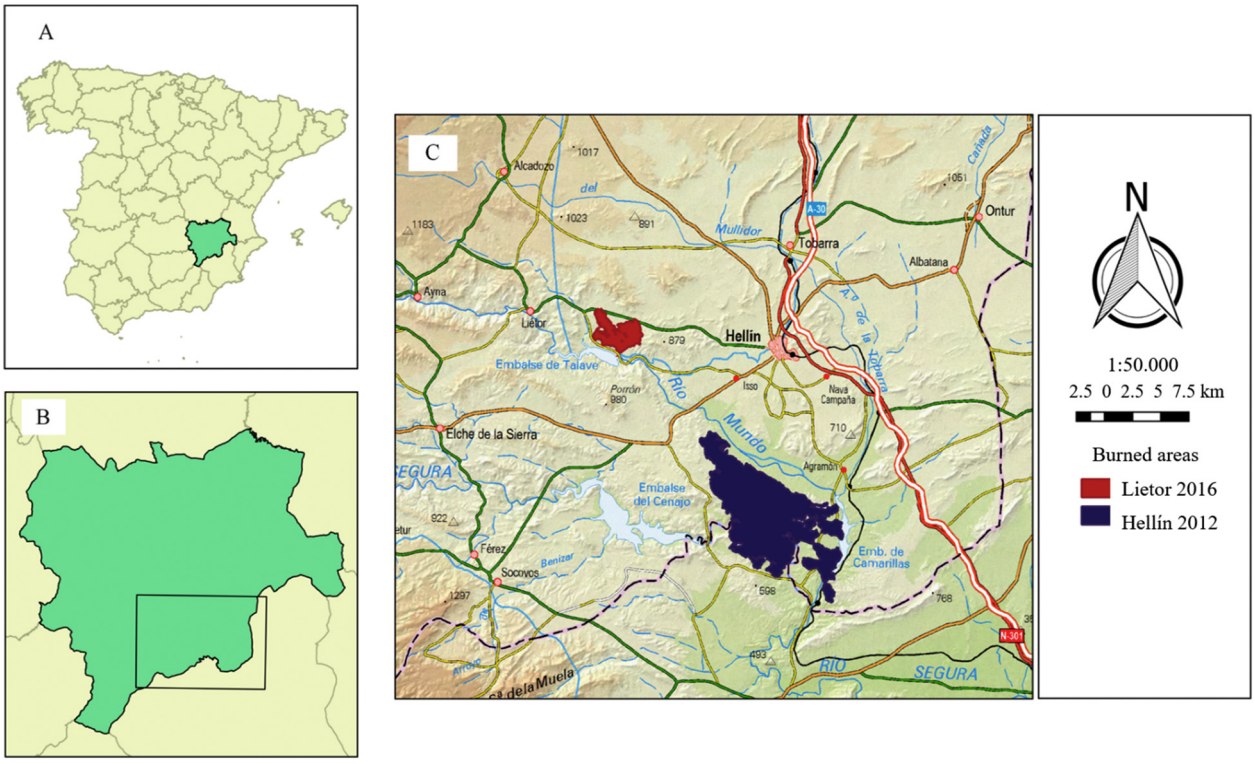

Fig. 1. (a) General location map. Spanish region of Albacete in blue (b) location of the study area in Albacete. (c) Burned areas location. Lietor 2016 (1YAF) with 832 ha and Hellín 2012 (5YAF) with 6500 ha. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)