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Soil water repellency in rangelands of Extremadura (Spain) and its relationship with land management

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ABSTRACT

Soil water repellency reduces infiltration capacity, enhancing overland flow and even runoff production, and may produce patchiness in water infiltration at the hillslope scale. Knowledge about hydrophobicity in rangelands of Mediterranean type climate and its relation with vegetation cover and land management is sparse. The objectives of the present work are to determine the degree and spatial occurrence of soil water repellency and to define its relationship with site characteristics, such as soil, vegetation and land management in rangelands of SW Spain. Field work was conducted in September 2009 in 22 environmental units belonging to 10 farms, distributed throughout the region of Extremadura. The Molarity of an Ethanol Droplet (MED) method was used for measuring water repellency of the soil surface. A total of 725 points were sampled and the study was combined with a detailed vegetation survey, the determination of soil properties and of land use and management characteristics. More than 70% of the measurement points were hydrophilic, however differences between farm units were found. The highest values of hydrophobicity were observed on soil surfaces below the canopy of holm oaks, as compared to the low values found below shrub canopies (*Retama sphaerocarpa*) and in open areas. With respect to ground cover, water repellency was highest at sites covered by holm oak litter. At soil surfaces covered by cork oak litter, dry grass and mosses the degree of repellency was lower. Almost all sites with a bare soil surface were hydrophilic, independent of whether these were located below a tree canopy or in open areas. A significant positive relationship between livestock density and the degree of bare soil existed, and consequently, areas with high animal numbers were dominantly hydrophilic. No significant relationships were encountered between the degree of soil water repellency and soil properties.

1. Introduction

Soil water repellency (SWR) is a natural phenomenon that occurs in many ecosystems ranging from tropical to subarctic regions influenced by biotic and abiotic factors (DeBano, 2000b; Doerr et al., 2000) and has been reported by many authors to reduce infiltration capacity, enhancing overland flow and even runoff production at the catchment scale (Burch et al., 1989; Imeson et al., 1992; Cerdà et al., 1998; Shakesby et al., 2000, among others). Increased amounts of surface flow may enhance soil erosion. On the other hand, the spatial variation of hydrophobicity may produce patchiness in water infiltration at the hillslope scale, especially in semi arid areas and under natural conditions (Imeson et al., 1992). Vegetation changes (species and/or density) may modify the hydrophobic characteristics of the soils and hence provoke changes in water infiltration and overland flow generation (Sevink et al., 1989).

This phenomenon has been traditionally linked to wildfire affected environments (Cerdà and Doerr, 2008; Doerr et al., 1998; Jordán et al., 2010; Llovet et al., 2009; Shakesby and Doerr, 2006) due to waxy substances derived from plant material burning that penetrate into the soil as a gas and condense in cooler soil layers and coat soil aggregates (DeBano, 2000a). However, not only this type of substances is responsible for producing water repellent soils; others derived from several groups of fungi and the activity of microorganisms have also been associated with the occurrence of hydrophobicity (Doerr et al., 2000). Hydrophobicity therefore also affects soils under unburned vegetation. Doerr et al. (2000) cite examples from Australia, USA and Europe. In Mediterranean forest systems high values of SWR were found in areas dominated by eucalyptus (Coelho et al., 2005; Doerr et al., 1998), pines (Arcenegui et al., 2008; Doerr et al., 1998; Mataix-Solera et al., 2007; Zavala et al., 2009) and cork oaks (Zavala et al., 2009), among others.

Few studies exist on the effects of animal activity on soil hydrophobicity. Cammeraat et al. (2002) highlighted the importance of ants and Contreras et al. (2008) demonstrated the role played by latrines of rabbits in SE Spain. Works focused on the effects of livestock on SWR are very sparse as compared to those that analyze other land management practices such as tillage (Hallett et al., 2001) and no-till

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farming (Blanco-Canqui, 2011). Related with livestock grazing, Krümmelbein et al. (2009) compared SWR measured from 4 plots with different sheep grazing intensities in grasslands from Inner Mongolia (China) and reported a tendency of decreasing water repellency at the soil surface with increasing grazing intensity.

Rangelands in the south-western part of the Iberian Peninsula are the result of continuous clearing of the traditional Mediterranean oak forest, composed mainly of the evergreen Holm oak (*Quercus ilex subsp. rotundifolia*) and cork oak (*Q. suber*). They occupy several million hectares of land and are grazed by domestic animals, mainly sheep, cattle and pigs. Tree density varies from treeless pasturelands to savannah-like woodlands with up to 150 trees per hectare. The tree-covered areas are called *dehesas* in Spanish language and are characterized by multiple land use: livestock ranching, forestry (cork, wood) and cultivation. At present, livestock is the most important income, and cultivation of cereals has been abandoned in many areas, due to the low productivity of the soils and adverse climatic conditions for rainfed agriculture. A characteristic feature of many farms is extensive pig ranching, based mainly on the acorns of Holm oaks.

Dehesas has undergone a situation of economic crisis since the decade of 1970 that caused serious problems of degradation, mainly related to soil and to the regeneration of trees (Campos et al., 2010). The loss of soil protection from vegetation removal by shrub clearing, cultivation or overgrazing, has supposed an important factor of land degradation, particularly in the driest years (Schnabel, 1997). Soil water repellency can boost soil losses by water erosion (mostly sheet erosion) at the beginning of autumn with the arrival of the first rains of the hydrologic year.

A study carried out by Cerdà et al. (1998) found high values of water repellency in soils from these ecosystems, particularly beneath the canopies of Holm oak. This work, however, shows some limitations, because sampling was carried out in only one small area and under drought conditions.

The present work belongs to a broader study on land degradation in rangelands of SW Spain, where past researches indicate that soils and their quality greatly varies even on the same lithology. The objectives of this paper are: [1] to characterize the spatial occurrence of soil water repellency in rangelands of SW Spain, [2] to analyze the relationships of hydrophobicity with vegetation cover and soil properties, and [3] to evaluate whether land use and livestock management have an influence on SWR.

2. Material and methods

2.1. Study areas

Research was carried out in ten privately-owned farms distributed throughout the region of Extremadura (SW Spain) (Fig. 1), representing the most important types of rangelands in the region, i.e. including treeless pasturelands and dehesas. It was decided to work at the farm scale because some farm specific attributes, such as land use and management practices, lead to differences with respect to vegetation cover, livestock species composition and agricultural activities.

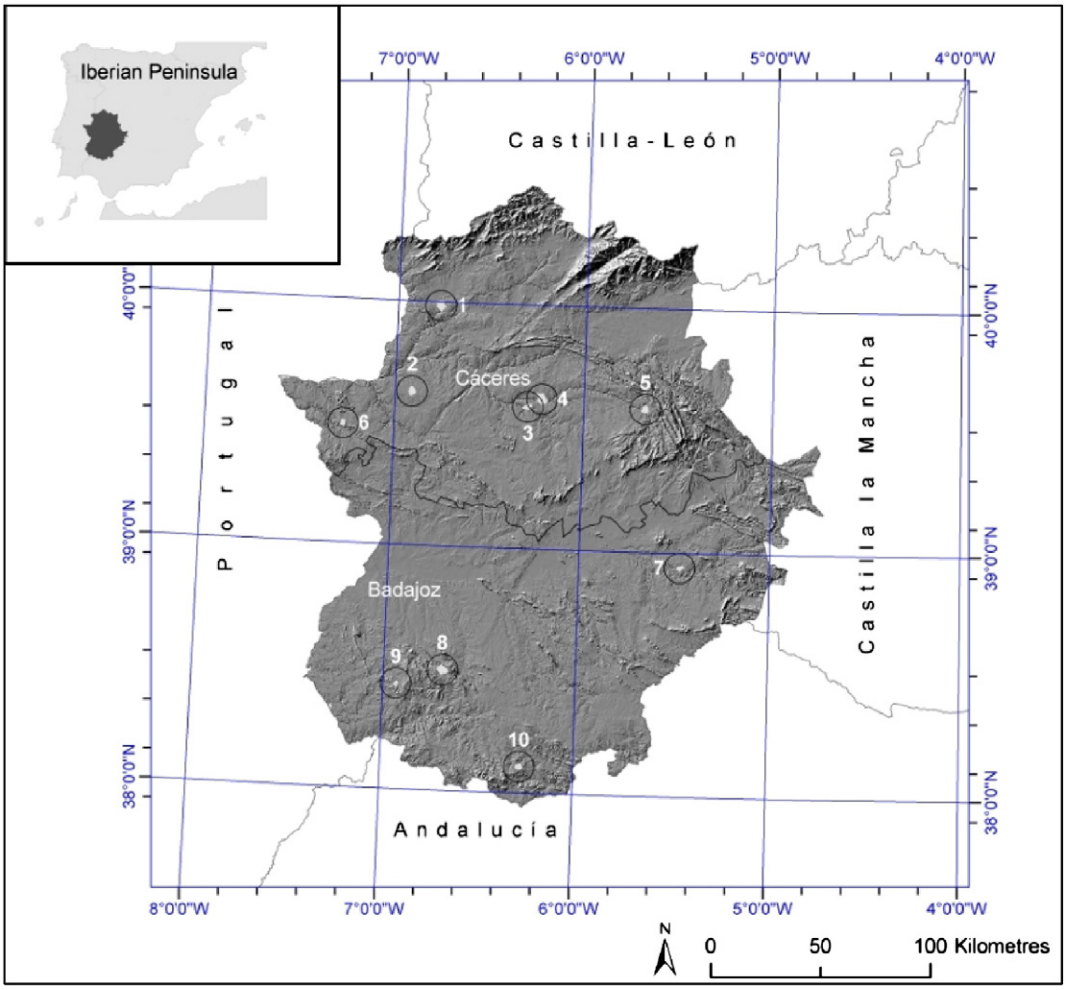

Fig. 1. Location of the study farms in the region of Extremadura (Spain).