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Heterogeneity in soil hydrological response from different land cover types in southern Spain

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ABSTRACT

This paper reports results from the analysis of the soil hydrological response to simulated rainfall in a cork oak forest in Los Alcornocales Natural Park (SW Spain). Four different soil/vegetation units were selected for the field experiments: [1] cork oak woodland, [2] heathland, [3] grassland, and [4] cork oak/olive tree mixed forest. Rainfall simulations tests were performed on circular plots of 1256.6 cm^2 at an intensity of 56.5 mm h^{-1} for 30 min.

Marked differences in the hydrological behavior of the studied vegetation types were observed after the rainfall simulations. The soils under woodland showed low runoff rates and coefficients. The highest runoff rates were measured on the heath and grass-covered parts of the hillslope. Water repellency of the soil, measured from water drop penetration tests, reduced infiltration (especially under the heathland), and seems to be the cause of fast ponding and runoff generation during the first stages of rainstorms.

The mosaic of different patterns of hydrological response to rainfall, such as runoff generation or infiltration, is governed by the spatial distribution of vegetation and its influence on the soil surface.

1. Introduction

Land degradation is a major environmental question (UNEP, 1991) whose processes have shown different patterns in place and time in the Mediterranean basin for the last 4000 years (Brandt and Thornes, 1996).

Land use determines spatial patterns of soil water dynamics by influencing infiltration and runoff rates (Kosmas et al., 1997), or evapotranspiration, particularly during the growing season (Francis et al., 1986). Hydrological processes are currently being investigated in cork oak forests in southern Spain in order to shed light on soil erosion processes and the magnitude of soil loss. Although there are many studies focusing on different aspects, such as management (Ibarra, 1993), biodiversity (Marañón et al., 1999; Ojeda et al., 2000; Ajbilou et al., 2006) and ecology (Jordano et al., 2001; Hampe and Arroyo, 2002), the hydrological implications of traditional and modified forestry land uses have received little attention. However, some authors have demonstrated that Mediterranean oak forests are a vulnerable system because of runoff generation and soil losses (Schnabel, 1997; Ceballos and Schnabel, 1998; Cerdà et al., 1998; Shakesby et al., 2002). Mediterranean ecosystems dominated by evergreen sclerophyll species are well-adapted to local environmental conditions, but extreme climatic changes or human activities may cause instability (Kosmas et al., 2000).

Los Alcornocales Natural Park is dominated by the evergreen cork oak (*Quercus suber*) through more than 10,000 ha of an extraordinary ecological and economical importance. There is a great environmental heterogeneity because of topography, microclimatic differences, and biodiversity (Arroyo and Marañón, 1990; Ibarra, 1993; Ojeda et al., 1995). Because of the great variation in natural resources, the natural park is characterized by multiple land use practices, including forestry, cork harvesting, hunting, and livestock. This forest system presents a high biodiversity and constitutes an exception inside the Mediterranean landscape, which shows a strong deforestation.

The objective of the present work is to evaluate and compare the hydrological response of soils to rainfall under different vegetation types in Los Alcornocales Natural Park (SW Spain), a natural protected area. Rainfall simulations were performed to characterize the hydrological response of the different land cover types studied. Due to the low wettability of the soil, especially under heathland, measurements of the top horizon hydrophobicity were carried out using the water drop penetration time (WDPT) test. The four studied vegetation types (cork oak forest, heathland, grassland, and forest of mixed cork oak and olive tree) are representative of situations commonly found throughout this Mediterranean system.

2. Study area

This study was carried out in the Sierra de Ojén, in Los Alcornocales Natural Park (SW Spain), approximately on the coordinates 36.13° N and 5.58° W and with an elevation ranging from 287 to 604 m (Fig. 1). The area is part of the El Aljibe mountain system. The relief has a very irregular topography. The highest elevation is 1092 m (El Aljibe). The

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lithological substrate is mainly composed of Oligo-Miocene sandstone, which produces acidic, nutrient-poor soils (mainly Cambisols, Regosols, and Leptosols, according to FAO, 2006; Jordán, 2000) with frequent rocky outcrops and a high proportion of stones. The climate is Mediterranean, with cool, humid winters and warm, dry summers. The total annual rainfall ranges from 665 mm in the lowlands to 1210 mm in the mountains. The mean air temperature is mild, 16–18 °C. The mean maximum air temperature is 31 °C and mean minimum 5 °C. In summer, these mountains intercept moisture from the air of SE-prevailing winds coming directly from the Mediterranean Sea, which reduces the severity of drought to some extent.

The vegetation distributes on the hillslopes following a patchy pattern. Most of the hillslope is dominated by a dense forest of the evergreen *Q. suber* (cork oak), while the semi-deciduous *Q. canariensis* is a locally abundant tree. The sandstone ridges and hilltops are covered by open heathland dominated by *Erica australis*, *Calluna vulgaris*, *Cistus*, and *Genista tridentata*, among other species. *Q. suber* and *Olea europaea* constitute mixed woodlands in the valleys, where soils are clayey and deeper. Herbaceous vegetation covers most of the valley.

The main economic activities are cork extraction from *Q. suber* trees, (their bark is stripped off every 5–9 years), free-range livestock (cattle), hunting (deer), and eco-tourism (Blanco et al., 1991).

3. Methods

All experiments and sampling were carried out during September 2006. The experimental plots were selected with regard to plant cover, physiographic situation (hillslope or valley bottom), and vegetation (cork oak, open heathland, grassland, and olive tree woodland). Ten experiments were carried out on four different land cover types:

- Cork oak forest (C). These plots were located on the hillslope and were covered by cork oak trees (*Quercus suber*). The soil texture is sandy clay loam. Human activities are limited to cork extraction every 5–9 years.
- Heathland (H). Most of the plots in this class were located on the ridges and upper parts of the hillslope, where the slope is steep. The dominant species are *Erica australis*, *E. arborea* and *Calluna vulgaris*. The soil texture is loam. No management practices are applied.
- Grassland (G). This unit represents the valley bottom. The soil texture is clay or silty clay. Soils are loose and deep, and the slope is generally low. No management practices are applied.
- Mixed forest of cork oak and olive trees (O). The plots of this class were located on the lowest part of the hillslopes, where cork oaks and olive trees constitute a mixed forest. The soil texture is sandy clay loam or clay loam. No plowing or other management practices are applied.

Cattle and deer grazing pressure is intense in the study area, especially in the valley grasslands. Plant and litter cover at each plot were determined using a 50×50 cm^2 grid with cells of 6.25 cm^2. The slope angle of the soil surface at each plot was determined using a clinometer.

3.1. Rainfall simulation

We used a rainfall simulator similar to that described by Navas et al. (1990). The structure, in the shape of a truncated pyramid, is supported on metal legs. The simulator was covered with a plastic curtain to protect the experiments against the wind. The legs are telescopic so that the simulator can be leveled when placed on a sloping surface. At the top of the structure (3.5 m high) there is a single nozzle (Lechler 460.608), which is connected through a rubber pipe to a mobile automatic pump (1.8 kg cm^{-2} pressure).

The water from the nozzle falls onto a circular area of 1256.6 cm^2 that is delineated by a steel ring (40 cm in diameter), as in Arnaez et al. (2007). The ring was carefully tapped into the soil following the slope to prevent leakage and direct the runoff flow to the outlet of the plot. Before the experiments, rainfall intensity was measured by five rain gauges (10 cm in diameter) distributed uniformly over the plot. The

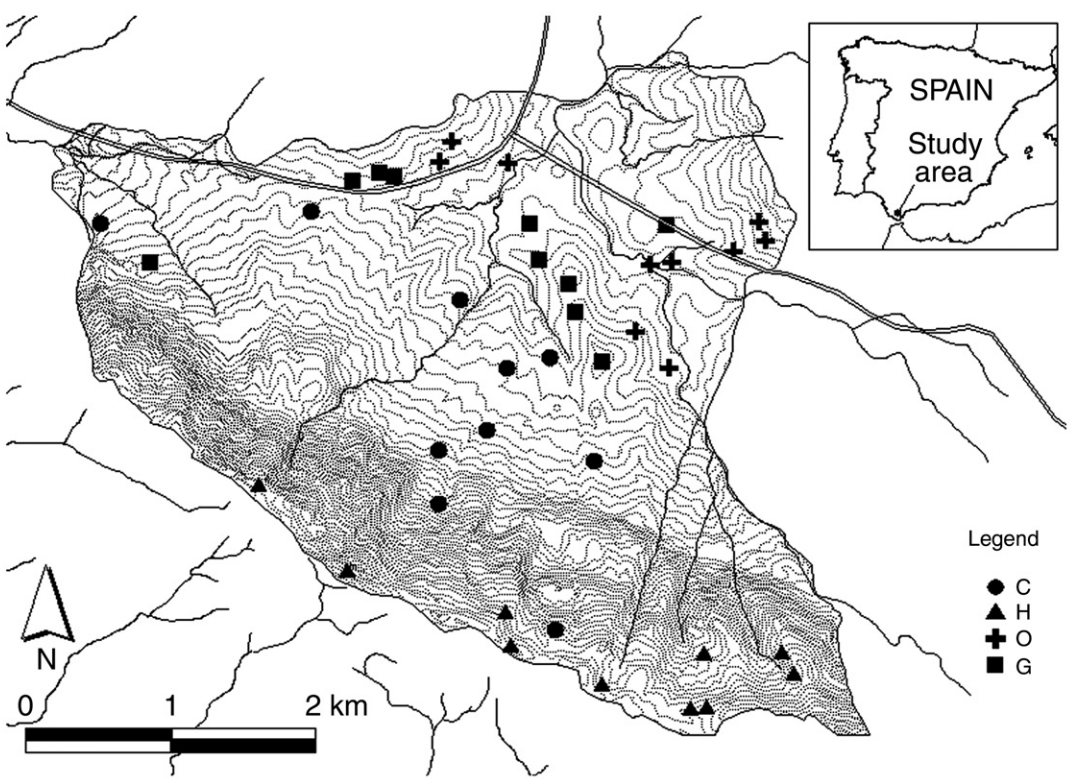

Fig. 1. Study area. C: plots under cork oaks; H: plots under heathland; G: plots under grassland; O: plots under cork oaks and olive trees.