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Unsaturated hydraulic conductivity in limestone dolines: Influence of vegetation and rock fragments

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ABSTRACT

Vegetation and rock fragments have a profound impact on runoff generation in the dolines of the Sierra de Gádor, southeastern Spain. This study investigated the effect of vegetation and rock fragments on unsaturated hydraulic conductivity [*K(h)*] in three limestone dolines and examined whether variation in *K (h)* was consistent with differences in runoff from simulated rainfall. Tension infiltrometers were used to measure unsaturated hydraulic conductivity at three pressure heads *(h)* of −30, −60 and −120 mm at 70 locations within the three dolines. Generally, the trends of the *K(h)* were consistent with the simulated rainfall data and accounted for difference in runoff for the vegetated surfaces. Vegetation resulted in high infiltration with unsaturated hydraulic conductivities at −30 and −60 mm are significantly greater for the vegetated surface than for the rock fragment covered surface and bare soil surface. Rock fragments had no obvious effect on soil hydraulic conductivity as compared with bare soils. The *K(h)* of the non-crusted soil were 2–5 times higher than that of the crusted soil. The *K(h)* decreased with increasing tensions, *K(60)* and *K (120)* were only 8.4 and 0.89%, respectively, of *K(30)* for the vegetated surfaces, and were about 30 and 8.7%, respectively, of *K(30)* for both rock fragment covered surfaces and bare soils, suggesting that pores in the 0.5- to 1-mm diameter range dominate flow under unsaturated conditions. There were significant differences in *K(h)* among the different topographic units of the dolines, and *K(h)* tended to be higher in the upper position than in the lower position of the doline.

1. Introduction

The semiarid zones of the Mediterranean are often characterized by the heterogeneity of terrain, soil and surface cover conditions, and the high spatial and temporal variability of precipitation (Wilson and Guan, 2004). The infiltration process and the runoff generation mechanisms in Mediterranean environments occur in a non-uniform way in space and time (Calvo-Cases et al., 2003). Previous studies have demonstrated that Mediterranean slopes behave as a mosaic of runoff generation and infiltration patches (Yair and Klein, 1973; Yair, 1983; Yair and Lavee, 1985; Yair and Enzel, 1987; Lavee et al., 1998) depending enormously on the morphometrica characteristics of the slopes, the lithology, the different development of the soils and the land uses (Yair and Lavee, 1985; Solé-Benet et al., 1997; Cantón et al., 2002; Calvo-Cases et al., 2003). Rainfall simulation experiments have particularly shown the importance of vegetation and stone cover on infiltration and runoff. Vegetation generally decreases overland flow and increases infiltration. In the vineyards of southern France, significant amounts of overland flow were generated on bare plots, whereas from grass-covered plots the runoff was drastically reduced (Wainwright, 1996; Leonard and Andrieux, 1998; Lange et al., 2003). Along a Mediterranean climatological gradient on Spanish limestone terrain, runoff coefficients of up to 50% were measured (Boix-Fayos et al., 1998). Infiltration capacity was always higher on vegetated than on bare plots. Also in Spain, Cerda (1997) found that soils on a north-facing slope with a vegetation cover of 80–90% had infiltration rates of 49 mm h^{-1}, whereas infiltration rates on a south-facing slope (vegetation cover 70–75%) were significantly lower (27 mm h^{-1}). Rock fragment cover has an ambivalent effect on overland flow and infiltration rate depending on various factors such as position, size and cover of rock fragments as well as structure of the fine earth (Poesen and Ingelmo-Sanchez, 1992; Poesen and Lavee, 1994). These may occur because surface vegetation or stone cover can affect runoff either by altering surface characteristics (e.g., surface roughness, litter absorption) or subsurface characteristics (e.g., hydraulic conductivity) (Wilcox et al., 1988; Abrahams and Parsons, 1991; Wilcox et al., 2003; Calvo-Cases et al., 2003).

The limestone areas represent a high percentage of the ecosystems surrounding the Mediterranean Basin. Many studies are mainly concerned with the effect of surface characteristics on runoff, but less attention has been paid to subsurface characteristics (e.g., hydraulic

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