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# Soil hydraulic properties in a marly gully catchment (Draix, France)

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**Abstract**

Runoff is one of the main factors controlling gully development. Concentrated flow erosion occurs where flow discharge and velocity exceed critical values. In Southern French Alps, in black marl gully catchments, runoff from hillslopes occurs in the form of Hortonian overland flow because rainfall intensities exceed the infiltration capacity of the soil. In such a situation, spatial variability of infiltration capacities is critical for describing the runoff production.

This study reports detailed field measurements of near-saturation and saturated infiltration properties: capillary sorptivity ($S$) and hydraulic conductivity ($K$). A total of 140 infiltration tests were conducted using tension disc and ponded ring infiltrometers on 6 different regoliths (weathering profile) encountered in a marly gully catchment. The main objectives were to improve our knowledge of the spatial variability of infiltration in black marl areas and to compare different field and data analysis methods. Hydraulic conductivity values $K(h)$ at supply pressure heads ($h$) ranging from $h=-100$ up to $h=0$ mm were calculated using steady state flow and Wooding's equation [Wooding, R.A., 1968. Steady infiltration from shallow circular pond. Water Resour. Res. 4 (6), 1259–1273]. $K(h=0$ mm) was also estimated from the ponded ring infiltrometer data set. The estimation of sorptivity was based on transient flow and the solution of Haverkamp et al. [Haverkamp, R., Roos, P.J., Smettem, K.R.J., Parlange, J.Y., 1994. Three dimensional analysis of infiltration from the disc infiltrometer. 2. Physical based infiltration equation. Water Resour. Res. 30 (11), 2931–2935]. Three methods were used to analyse tension disc infiltrometer data: multiple radii, multiple potential and single test.

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Only the multiple radii method was found not suitable in our context due to a large spatial variability in the infiltration properties over small distances. The other methods gave similar estimates of the hydraulic conductivity. The hydraulic conductivity $K(h)$ ranged up to two orders of magnitude. This result confirms the role played by structural voids when the regolith is at near saturation. The dispersion of the estimates of field saturated hydraulic conductivity is larger than unsaturated values. The spatial differences found are explained by the topographical position and by the regolith structure observed for the 6 sites. An analysis based on the ponding time show that the regolith type plays an important role in the dynamic of the runoff production.


*Keywords:* Tension disc and ring infiltrometers; Soil surface fatures; Runoff generation; Ponding time; Spatial variability

## 1. Introduction

In the Southern French Alps, the Black Marl formation, or "Terres Noires" in French, covers a large area. The Mediterranean and mountainous climate, with frost in winter and high intensity rainfall in summer, leads to "badlands" topography, gully development and high solid transport, bringing heavily loaded floods downstream. Hillslope runoff occurs predominantly as Hortonian overland flow process. In that environment, knowledge of the spatial variability of infiltration is essential to understand the surface runoff and the sediment production yields.

In black marl regoliths and outcrops rapid flows of water in structural voids may decrease the surface runoff. Therefore the knowledge of near saturation hydraulic conductivity, $K(h)$ ($LT^{-1}$), is important to understand the influence of macropores and structural voids on the water infiltration at the ground surface and useful to define the soil hydraulic properties in relation to runoff production modelling.

The capillary sorptivity $S$ ($LT^{-1/2}$) represents the capacity of the soil to absorb or desorb water by capillarity (Philip, 1957). The determination of $S$is important because other hydraulic properties such as macroscopic capillary length (White and Sully, 1987) and hydraulic conductivity can be inferred from the estimation of $S$ (White and Perroux, 1989). Capillary sorptivity is derived from early-time infiltration, because this stage is dominated by capillary forces within the soil (Cook and Broeren, 1994; Vandervaere et al., 2000).

For more than twenty years, tension disc infiltrometers (Clothier and White, 1981; Perroux and White, 1988; Ankeny et al., 1988; White and Perroux, 1989; Smettem and Clothier, 1989; Ankeny et al., 1990, 1991; Reynolds and Elrick, 1991; Thony et al., 1991; Vandervaere et al., 2000) have been used to estimate in situ soil near saturation hydraulic properties. Different methods were developed in order to calculate sorptivity and hydraulic conductivity from water flux emanating from disc infiltrometer measurements (Scotter et al., 1982; Smettem and Clothier, 1989; Ankeny et al., 1991; Reynolds and Elrick, 1991; White et al., 1992; Warrick, 1992; Haverkamp et al., 1994; Vandervaere et al., 2000). These methods include single test measurement using one disc radius and one supply pressure head (White et al., 1992; Vandervaere et al., 2000), the multiple radii approach