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Measuring lateral saturated soil hydraulic conductivity at different spatial scales

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Among the soil hydraulic properties, saturated soil hydraulic conductivity, K_s, is particularly important since it controls many hydrological processes. Knowledge of this soil property allows estimation of dynamic indicators of the soil's ability to transmit water down to the root zone. Such dynamic indicators are valuable tools to quantify land degradation and developing 'best management' land use practice (Castellini et al., 2016; Iovino et al., 2016). In hillslopes, lateral saturated soil hydraulic conductivity, $K_{s,l}$, is a key factor since it controls subsurface flow. However, $K_{s,l}$ data collected by point-scale measurements, including infiltrations tests, could be unusable for interpreting field hydrological processes and particularly subsurface flow in hillslopes. Therefore, they are generally not representative of subsurface processes at hillslope-scale due mainly to soil heterogeneities and the unknown total extent and connectivity of macropore network in the porous medium. On the other hand, large scale $K_{s,l}$ measurements, which allow to average soil heterogeneities, are difficult and costly, thus remain rare. Reliable $K_{s,l}$ values should be measured on a soil volume similar to the representative elementary volume (REV) in order to incorporate the natural heterogeneity of the soil. However, the REV may be considered site-specific since it is expected to increase for soils with macropores (Brooks et al., 2004).

In this study, laboratory and in-situ $K_{s,l}$ values are compared in order to detect the dependency $K_{s,l}$ from the spatial scale of investigation. The research was carried out at a hillslope located in the Baratz Lake watershed, in northwest Sardinia, Italy, characterized by degraded vegetation (grassland established after fire or clearing of the maquis). The experimental area is about 60 m long, with an extent of approximately 2000 m^2, and a mean slope of 30%. The soil depth is about 35 to 45 cm. The parent material is a very dense grayish, altered substratum of Permian sandstone that exhibits very low drainage, thus preventing deep water percolation (Castellini et al., 2016).

In the laboratory, small-scale lateral and vertical saturated hydraulic conductivity, $K_{s,v}$, were determined by the constant-head permeameter method (Klute and Dirksen, 1986) on 20 soil cubes of 1331 cm^3 of volume (Bagarello and Sgroi, 2008), allowing determination of mean K_s anisotropy for the hillslope.

In the field, small-scale $K_{s,v}$ was determined by infiltration runs of the BEST (Lassabatere et al., 2006) type carried out using a ring with an inner diameter of 0.15 m. The BEST-steady algorithm, proposed by Bagarello et al. (2014), was used to analyze the cumulative infiltration curves in order to decrease the failure rate of the BEST algorithms (Di Prima et al., 2016). The in situ $K_{s,l}$ at an intermediate spatial scale was estimated by a trench test (Blanco-Canqui et al., 2002) carried out on a monolith 50 cm wide, 68 cm long and 34.5 cm deep (the depth to substratum). Finally, the large spatial scale (hillslope-scale) $K_{s,l}$value was estimated from the outflow of a 8.5 m large drain and from the perched water table levels monitored in the hillslope, following the methodology of Brooks et al. (2004).

Anisotropy was not detected, since the soil cube experiments did not revealed significant differences between $K_{s,v}$ and $K_{s,l}$ values. The differences between the K_s datasets measured by the cube and the BEST methods were not statistically significant at p = 0.05. These methods yielded K_s values 6.4 and 5.8 times lower than the hillslope-scale $K_{s,l}$, respectively. The $K_{s,l}$ value obtained by the trench experiment in the soil monolith was 1440 mm h^{-1}, which was only 1.5 times higher than the hillslope-scale $K_{s,l}$. Probably, the chosen size of soil monolith was sufficient to properly represent the spatial heterogeneity of the soil in the hillslope. This finding need to be confirmed by further trench tests in soil monoliths to be carried out in the studied hillslope.

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