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Shape and position of rock fragments in a stony soil: how much can they affect soil hydraulic conductivity?

Hana Hlaváčiková (1), Viliam Novák (1), Jirka Šimůnek (2), Ladislav Holko (1), Zdeněk Kostka (1), and Michal Danko (1)

(1) Institute of Hydrology, Slovak Academy of Sciences, Bratislava, Slovakia (hlavacikova@uh.savba.sk), (2) Dept. of Environmental Sciences, Univ. of California Riverside, Riverside, CA 92521, USA

Mountain or forest soils usually contain a large number of rock fragments (RF). The amount of rock fragments, their size, shape, position, and spatial distribution in the soil influence hydraulic properties of stony soils as well as processes like water infiltration, water movement, or the occurrence of runoff. We present measured hydrophysical properties of stony soils from a small mountain catchment, methodology of evaluation of stony soil properties, and numerical assessment of the influence of rock fragments (stoniness), their shape, position and distribution in a soil matrix on the saturated hydraulic conductivity of a stony soil.

Properties of stony soils were measured in the Jalovecký creek catchment, the Western Tatra Mts., Slovakia. Hydrological research conducted in the catchment since the late 1980s proved that subsurface flow often dominates in catchment runoff, catchment response to rainfall is very fast and that the fast response may be enhanced by the high stoniness of the soils (up to 40 – 70 %).

Despite a lot of field and laboratory data, it is still difficult to assess the influence of rock fragments properties on the water flow in stony soils. Therefore, we used numerical model to evaluate the effects of particular properties of stony soils on saturated hydraulic conductivity. The assessment was based on a numerical version of Darcy's classic experiment that involved steady-state flow through a porous material under a unit hydraulic gradient by the HYDRUS model. Three different shapes of hypothetical rock fragments were used: a sphere, an ellipsoid with two different positions, and a pyramid. We tried to find out how would the shape, orientation and distribution (regular and irregular) of RF affect the effective saturated hydraulic conductivity of the soil. Differences in the effective saturated hydraulic conductivities of stony soils simulated by the model were compared with those calculated using existing empirical equations as well. Usefulness of the numerical model in the assessment of the influence of soil matrix texture on the effective saturated hydraulic conductivity of stony soils was also evaluated. Finally, we have attempted to derive relationships between stoniness and the effective saturated hydraulic conductivity for different rock fragments properties.

The modeling also demonstrated spatial distribution of pressure heads, volumetric water contents, and water fluxes in heterogeneous stony soil profiles which may be nearly impossible to measure in practice.