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Modelling the effect of rock fragment on soil saturated hydraulic conductivity

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Stoniness may be a key factor in determining the soil hydrological properties. Nevertheless, how coarse fraction takes part in some important processes (e.g., runoff, infiltration and percolation) is not univocally recognized, mainly because of the difficulties in obtaining reliable experimental data and, secondarily, for the employment of different approaches to evaluate the role of the coarse fraction.

With that regard, equations developed by hydrogeologists to account for water fluxes in porous media, consider permeability as mere function of grain size distribution (particles $>$2 mm included), with permeability values increasing when passing from sand to gravel. Conversely, soil scientists consider the saturated hydraulic conductivity (K_{sat}) of soil exclusively as function of the fine-earth fraction and attribute a contrasting effect to the coarse fraction, both in relation to the decrease of porosity and to the increase of flow path tortuosity. Nevertheless, the Soil Survey Handbook includes all fragmental soils (gravel content $\geq$35% by weight) into the highest class of soil hydraulic conductivity, and this partly disagrees with the mostly adopted soil scientists' approaches. At the same time, lab- experiments carried out by engineers on particle mixture point out that the addition of increasing amounts of coarse material to finer grains progressively reduces the overall porosity until a critical threshold is reached; beyond this level, the void proportion rises again.

In relation to the engineers' results, the present paper attempts to conceptually approach the dual effects of rock fragment content on K_{sat} by considering a decay of the water transmission properties of the fine-earth fraction at low gravel contents and, conversely, a drastic improvement of the conductivity whenever the porosity increases. For that purpose a data set of 50 soils of different textural classes is used to define the procedure by virtually increasing the rock fragment fraction (SK) up to 99% by weight, meanwhile calculating the corresponding statistical descriptors (e.g., d_{10}, dg, $\sigma\phi$) of grain size distribution (GSD). For each sample of the data set, the procedure is based on the K_{sat} computation for increasing gravel content provided by both soil scientists' and hydrogeologists' approaches. Given that the two methods generate curves with different direction and slope, an intersection is obtained. Such a point indicates the minimum saturated hydraulic conductivity value, that can be conceptually interpreted as the minimum porosity (or the maximum density of the mixture) experimentally observed by engineers. Therefore, the procedure for assessing the resulting K_{sat} consists in adopting the soil scientists' approach until the intersection is reached and then following the hydrogeological curve beyond such threshold. The findings provided by two other approaches are compared with our results and discussed.