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Combination use of electrical resistivity imaging and a new combined penetrometer-moisture probe for measuring water content distribution in hillslopes

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Electrical resistivity imaging (ERI) as a method for effectively evaluating soil water content distribution on natural hill slopes was validated in site by combining ERI technique with the invasive measurement of volumetric water content (θ) using a newly developed combined penetrometer–moisture probe (CPMP) in two head-water catchments underlain by weathered granite and weathered granite porphyry. The moisture sensor of a CPMP adopts time-domain reflectometry (TDR) and the probe, which is attached at the tip of the soil penetrometer, consists of two stainless steel wires coiled along grooves in acrylic pipe. The CPMP is a highly maneuverable technique and could provide simultaneous measurements of the penetration resistance and water content of soil layers. There was some reasonable correlation between θ and ρ within each slope, indicating the potential of ERI for at least qualitatively evaluating moisture conditions within soil layers of natural hill slopes without directly measuring θ using any invasive method. These $\theta - \rho$ datasets of two catchments with different geological condition were both roughly consistent with fitted functional models (Archie's equation), indicating the possibility of quantitatively evaluating θ of soil layer on natural hill slopes using ERI based on field-scale calibrations with invasive methods. The difference of the fitted functional models between the two catchments seems attributable to a difference in geological and soil conditions. Inconsistencies between θ and ρ within each dataset of the two catchments may be significantly attributable to not only limitations on spatial resolution of ERI technique related to the issue of representative volumes of the technique and inversion analysis to obtain ρ profiles but also the assumption that soil properties and pore-water resistivity of the entire slope are homogeneous. Using a CPMP as invasive method, detecting heterogeneous θ distribution more accurately than ERI technique, together with ERI is one of the most reasonable ways of effectively complementing the spatial resolutions of ERI as well as quantifying soil water content distribution on natural hill slopes.