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Three-dimensional structure of a highly heterogeneous horizon described by Electrical Resistivity Tomography: consequences on the determination of effective hydraulic properties

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Despite the increasing demand of soil hydraulic properties as input data for soil-plant-atmosphere models, the estimation of hydraulic properties in heterogeneous horizons remains a challenge. One reason is the lack of knowledge of the structure of such horizons, which limits the estimation of effective hydraulic properties at small scale. The aim of this paper is to demonstrate the interest of 3-D Electrical Resistivity Tomography (ERT) to describe the soil structure and to identify the Representative Elementary Volume of a heterogeneous horizon.
The studied soil is an Albeluvisol that exhibits some horizons composed by the juxtaposition of two Elementary Pedological Volumes (EPVs); they can be visually distinguished by their colours (ochre and white) and they have differential hydraulic functioning: the clayey ochre ones conduct less water than the loamy white ones. Local electrical resistivity measurements showed that the ochre and white EPVs could be identified by ERT. Several 3D ERTs with an interelectrode spacing equal to 3 cm were then conducted on a 1 m^2 surface : i) seven Wenner arrays (16 electrodes) spaced of 9 cm and four Wenner arrays (32 electrodes) spaced of 9 cm, perpendicular to the seven previous ones; ii) a square array of 32 electrodes spaced of 3 cm. After these measurements, a 6 cm slice of the studied horizon was removed and the electrical resistivity measurements were recorded again at this second depth, and the whole protocol was recorded a third time. Thanks to all these measurements, the decrease of resolution with depth could be corrected. The data were then interpreted by using the Res2DInv and the Res3DInv softwares by using different strategies: -a- each 2D ERT was interpreted independently and all the interpreted resistivity data were gathered to create a 3-D block by regular kriging, -b- the 3D square array was interpreted and the resulting interpreted data were added to the 2D previous ones, -c- all the apparent resistivity data were associated and interpreted as a whole dataset. We finally got several 3-D blocks of the electrical soil structure of the heterogeneous horizon (say the organisation of ochre and white volume) at a 1 cm resolution on a volume of about 0.5 cm3. These blocks were compared to the real structure described by photographs so that we selected the best one. Several two-dimensional cuts of different sizes were extracted from this 3D block so that we can simulate on them the hydraulic functioning of the horizon by the Hydrus2D software. The equivalent hydraulic properties of the horizon were determined on each 2D cut, especially the unsaturated hydraulic conductivity that requires the knowledge of the structure. We finally discussed the evolution of the equivalent hydraulic properties with the size of the electrical resistivity images and we identified the minimum size of the horizon that must be investigated to contain a Representative Elementary Volume as far as hydraulic properties are concerned.