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Calibrating a quantitative monitoring system for soil moisture: Combining Electrical Resistivity Tomography (ERT), Vertical Electrical Sounding (VES) and a multi sensor moisture measurement device

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Knowledge of the temporal and spatial distribution of soil moisture is crucial for the understanding of processes in the soil-atmosphere interface and geomorphologic processes. Hence a large variety of approaches, ranging from the use of field devices to satellites, are used for the acquisition of information in different scales. Yet it′s still difficult to determine the spatial distribution of soil moisture on a micro scale, especially regarding its quantity. Promising attempts have been made using electrical resistivity tomography (ERT) in combination with moisture sensors to obtain a 2-D or 3-D image of the subsurface soil moisture pattern, applying the physical relationship between a materials electrical resistivity and its moisture.

Building up on the latter, the aim of this research was to test a ERT-based device, that enables a quantitative monitoring of the two-dimensional distribution of the soil moisture with a high temporal resolution, while being minimally invasive, easy to install and relatively inexpensive. The device consists of three main components. A fixed line of 48 electrodes with a consistent spacing of 50 cm provided 2-D images of the subsurface resistivity patterns. To enable a fast acquisition with high data density, a multiple gradient (MG) sequence was applied. Soil moisture measurements were simultaneously performed along two vertical profiles at six different depths (ranging from 0.1 m to 1 m) using a Profile Probe PR2/6 (Delta-T Devices). To link the latter data sets for calibration, a 14-electrode 1-D vertical electrical sounding (VES) Schlumberger array was placed on each profile, to measure the electrical resistivity in the same depths as the respective moisture sensors.

To calibrate the device, a linear fit between the VES-data and the corresponding moisture content was taken out for each depth level and profile. Although the upper depth levels (0.1 m and 0.2 m) showed acceptable correlations ($R2 = 0.58$ and $R2 = 0.64$), an unacceptable high misfit was observed in the lower levels. Moreover, the transfer of electrical resistivity values originating from different arrays is still challenging. To counteract this, another attempt was performed, correlating the soil moisture values with resistivity values sourced from corresponding virtual boreholes of the 2-D images. This led to a small improvement of the average correlation index for the depth range from 0.1 m to 0.6 m ($R2\_VES = 0.28$; $R2\_MG = 0.36$). Applying the calibration formulas based on MG-data on the ERT-data, a first 2-D image of the soil moisture distribution of the subsurface showed a small average misfit between the calculated and the measured soil moisture (4.3%). Even though there are still challenging problems in the monitoring device, it has potential of improving the surveillance of soil moisture dynamics by its easy and fast setup and it demonstrates, where difficulties can appear in this domain.