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Geophysical characterization of soil moisture spatial patterns in a tillage experiment

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Knowledge on the spatial soil moisture pattern can improve the characterisation of the hydrological response of either field-plots or small watersheds. Near-surface geophysical methods, such as electromagnetic induction (EMI), provide a means to map such patterns using non-invasive and non-destructive measurements of the soil apparent electrical conductivity (EC$_a$. In this study EC$_a$ was measured using an EMI sensor and used to characterize spatially the hydrologic response of a cropped field to an intense shower.

The study site is part of a long-term tillage experiment in Southern Spain in which Conventional Tillage (CT), Direct Drilling (DD) and Minimum Tillage (MT) are being evaluated since 1982. Soil EC$_a$ was measured before and after a rain event of 115 mm, near the soil surface and at deeper depth (EC$_{as}$ and EC$_{ad}$, respectively) using the EM38-DD EMI sensor. Simultaneously, elevation data were collected at each sampling point to generate a Digital Elevation Model (DEM). Soil moisture during the first survey was close to permanent wilting point and near field capacity during the second survey.

For the first survey, both EC$_{as}$ and EC$_{ad}$, were higher in the CT and MT than in the DD plots. After the rain event, rill erosion appeared only in CT and MT plots were soil was uncovered, matching the drainage lines obtained from the DEM. Apparent electrical conductivity increased all over the field plot with higher increments in the DD plots. These plots showed the highest EC$_{as}$ and EC$_{ad}$ values, in contrast to the spatial pattern found during the first sampling. Difference maps obtained from the two EC$_{as}$ and EC$_{ad}$ samplings showed a clear difference between DD plots and CT and MT plots due to their distinct hydrologic response. Water infiltration was higher in the soil of the DD plots than in the MT and CT plots, as reflected by their ECad increment. Higher EC$_a$ increments were observed in the depressions of the terrain, where water and sediments accumulated. On the contrary, the most elevated places of the field showed lower EC$_a$ increments. When soil is wet topography dominates the hydrologic response of the field, while under drier conditions, hydraulic conductivity controls the soil water dynamics. These results show that when static soil properties, e.g. clay content, are spatially uniform, EC$_a$ can detect changes in dynamic properties like soil moisture content, characterizing their spatial pattern.