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Comparing bulk electrical conductivities spatial series obtained by Time Domain Reflectometry and Electromagnetic Induction sensors

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The ability to determine and monitor the effects of salts on soils and plants, are of great importance to agriculture. To control its harmful effects, soil salinity needs to be monitored in space and time. This requires knowledge of its magnitude, temporal dynamics, and spatial variability. Conventional ground survey procedures by direct soil sampling are time consuming, costly and destructive. Alternatively, soil salinity can be evaluated by measuring the bulk electrical conductivity (σb) directly in the field. Time domain reflectometry (TDR) sensors allow simultaneous measurements of water content, θ, and σb. They may be calibrated for estimating the electrical conductivity of the soil solution (σw). However, they have a relatively small observation window and thus they are thought to only provide local-scale measurements. The spatial range of the sensors is limited to tens of centimeters and extension of the information to a large area can be problematic. Also, information on the vertical distribution of the σb soil profile may only be obtained by installing sensors at different depths. In this sense, the TDR may be considered as an invasive technique.

Compared to the TDR, other geophysical methods based for example on Electromagnetic Induction (EMI) techniques are non-invasive methods and represent a viable alternative to traditional techniques for soil characterization. The problem is that all these techniques give depth-weighted apparent electrical conductivity (σa) measurements, depending on the specific depth distribution of the σb, as well as on the depth response function of the sensor used. In order to deduce the actual distribution of the bulk electrical conductivity, σb, in the soil profile, one needs to invert the signal coming from EMI.

Because of their relatively lower observation window, TDR sensors provide quasi-point values and do not adequately integrate the spatial variability of the chemical concentration distribution in the soil solution (and of the water content) induced by natural soil heterogeneity. Thus, the variability of TDR readings is expected to come from a combination of smaller and larger-scale variations. By contrast, an EMI sensor reading partly smoothes the small-scale variability seen by a TDR probe.

As a consequence, the variability revealed by profile-integrated EMI and local (within a given depth interval) TDR readings may have completely different characteristics.

In this study, a comparison between the variability patterns of σb revealed by TDR and EMI sensors was carried out. The database came from a field experiment conducted in the Mediterranean Agronomic Institute (MAI) of Valenzano (Bari). The soil was pedologically classified as Colluvic Regosol, consisting of a silty loam with an average depth of 60 cm on a shallow fractured calcareous rock. The experimental field (30m x 15.6 m; for a total area of 468 m2) consisted of three transects of 30 m length and 4.2 width, cultivated with green bean and irrigated with three different salinity levels (1 dS/m, 3dS/m, 6dS/m). Each transect consisted of seven crop rows irrigated by a drip irrigation system (dripper discharge q=2 l/h.). Water salinity was induced by adding CaCl2 to the tap water. All crop-soil measurements were conducted along the middle row at 24 monitoring sites, 1m apart. The spatial and temporal evolution of bulk electrical conductivity (σb) of soil was monitored by i) an Electromagnetic Induction method (EM38-DD) and ii) Time Domain Reflectometry (TDR). Herein we will focus on the methodology we used to elaborate the database of this experiment. Mostly, the data elaboration was devoted to make TDR and EMI data actually comparable. Specifically, we analysed the effect of the different observation windows of TDR and EMI sensors on the different spatial and temporal variability observed in the data series coming from the two sensors.

After exploring the different patterns and structures of variability of the original EMI and TDR data series the study assessed the potential of applying a Fourier's analysis to filter the original data series to extract the predominant, high-variance signal after removing the small- scale (high frequency) variance observed in the TDR data series.