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EMI surveys under precision irrigation contexts: an orange orchard-case study and methodological challenges

Giorgio Cassiani[1], Ulrike Werban[2], Marco Pohle[2], Simona Consoli[3], Giuseppe Longo-Minnolo[3], Daniela Vanella[3], and **Luca Peruzzo**[1]
[1]Department of Geosciences, University of Padova, Via G. Gradenigo 6, 35131, Padova, Italy
[2]Department of Monitoring and Exploration Technologies, Helmholtz Centre for Environmental Research - UFZ, Permoserstr. 15, 04318, Leipzig, Germany
[3]Department of Agriculture, Food and Environment, University of Catania, Via S. Sofia 100, 95128, Catania, Italy

Electromagnetic induction (EMI) allows time-lapse profiling of electrical conductivity (EC). In recent years, progress has been made in the study of the intra-field variability and soil-plant correlations at the scale of a few meters. Yet, some methodological challenges still hinder the possibility to resolve the spatiotemporal complexity at the smaller scales typically associated with irrigation and evapotranspiration (ET) dynamics, and thus central to the agroecosystems and precision agriculture, particularly in orchard farming.

This study characterizes the 3D EC variability in an orange orchard in eastern Sicily (Italy). To the best of our knowledge, this is the first 3D investigation capturing both irrigation and ET effects at the meter scale. The characterization successfully distinguishes plant rows and interrows dynamics. The EC in the plant rows increases upwards, from the drier root-water-uptake region to the drip irrigation region above. In the interrows, the EC increases downwards from the drier evaporation-dominated layer to the deeper soil where the irrigation water accumulates without significant ET. The intermediate zones, between the plant rows and interrows, show yet another conductivity profile, homogeneous and relatively conductive. Local effects, such as the plant size, further complicate this conceptual model and add both inter- and intra-row heterogeneity.

While the results confirmed the EMI potential, some methodological challenges were equally important. First, a Geophex GEM-2 and a CMD Mini-Explorer were used, the latter in vertical and horizontal configuration. The choice of instruments and surveys appears now suitable for this field site but it is surely not a priori obvious and/or always possible. We highlight how the use of a single instrument would probably lead to misinterpreting the root water uptake or the evaporation contributions.

Second, the quantitative use of the two instruments required alignment and joint inversion. However, a standard GPS system did not provide a reliable alignment of the surveys. Time-consuming GIS corrections were needed for both intra- and inter-dataset shifts. Third, after GPS alignment, the surveys were interpolated over a common grid to allow the joint inversion. Because of the strong anisotropy of the agroecosystems, this required the careful parametrization of a

Kriging algorithm.

Fourth, the individual EMI datasets also differ because of their drift and/or calibration. The lack of convenient alternatives initially motivated an ERT-based calibration, but ultimately two of the twelve datasets were dismissed.

Fifth, noise and instrumental errors required the use of a moving-window median. This common practice poses a trade-off between smoothing and resolution that hinders high-resolution surveys.

Sixth, a sub area of the orchard was investigated at finer resolution. This proved fundamental for the identification of the processes acting at the intermediate zones, between the plant rows and interrows, and other meter-scale details.

Overall, this study presents a state-of-the-art EMI application that focuses on small-scale aspects that were less considered in previous studies. The presented challenges explain the lack of similar studies and should be considered when discussing the EMI convenience and adoption for precision irrigation applications.