Current use of Frequency-domain Electromagnetic Induction in precision agriculture: Knowledge gained from six years of experiments in Portugal

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SUMMARY

Sustainable Agricultural Intensification aims at reducing the environmental footprint of agricultural production by promoting a sustainable use of limited resources to limit the use of agrochemicals, salt accumulation, land degradation and greenhouse gas emissions while increasing productivity and profitability. Such an emphasis requires efficient field-assessments to evaluate continuously the performance of the implemented management strategies. Traditional soil sampling methods, which require boreholes for soil sampling and laboratory analysis, cannot provide a comprehensive answer to this problem as they provide only limited spatial coverage and may therefore lack representativeness at the management scales. Furthermore, they are highly time and work consuming, resulting in costly surveys.

Frequency-domain Electromagnetic Induction (FDEM) provide a non-invasive and cost-effective technology for soil survey and monitoring based on innovative sensors, advanced algorithms for 2D and 3D tomographic imaging, and new technologies for field surveying allowing to assess soil properties in the management scale. Measurements obtained using FDEM can be related to several soil attributes, such as soil mineral composition, clay content, moisture, salinity, organic carbon, and cation exchange capacity (CEC), which are all relevant for agriculture. This technique provides also an opportunity to monitor the processes relevant for agricultural production from the analysis of time-dependent change of water content and soil salinization to the study of soil–root plant interactions.

During the last six years, we conducted several experiments in different regions of Portugal within two national and European projects, SOIL4EVER and SALTFREE, evaluating the application of the FDEM method in plot and field assessments of soil properties. The proposed methodology in these series of experiments consists of 4 main steps: 1) use of time-lapse FDEM surveys to measure the soil apparent electrical conductivity (ECa) and its changes during the experiment period; 2) inversion of time-lapse ECa data to assess the spatiotemporal distribution of the soil electrical conductivity (σ); 3) calibration process consisting of a regression between σ and different soil properties including moisture content, electrical conductivity of the saturated soil paste extract (ECe), sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP), clay content, CEC, and pH; 4) conversion of spatial-temporal distributions of σ into soil properties using calibration equations and properties that are strongly correlated with σ.

Our results indicate that FDEM can be used as strong tool in precision agriculture to monitor soil salinity, sodicity, and moisture content variability, groundwater fluctuation, and to map soil texture and CEC. A high-precision determination of soil properties using FDEM is not always straightforward and feasible. This is because σ is a complex function of several soil properties, which can vary significantly over time and space. The soil salinity dominates the FDEM signal in wet saline soils, and we were able to assess soil salinity dynamics with high precision in our experiments. Clay content, CEC, and water content influence the FDEM signal in non-saline soils, allowing these properties to be predicted.

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