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Assessing the value of multi-receiver low-frequency electromagnetic-induction (EMI) measurement for assessing variation in soil moisture content in field experiments with winter wheat (Triticum aestivum)

Peter Shanahan (1), Andrew Binley (1), Ian Dodd (1), Richard Whalley (2), Chris Watts (2), Rhys Ashton (2), and Eric Ober (2)

(1) Lancaster Environment, Lancaster University, Lancaster, United Kingdom (p.shanahan@lancaster.ac.uk), (2) Rothamsted Research, Harpenden, Hertfordshire, United Kingdom (richard.whalley@rothamsted.ac.uk)

In large plant breeding field trials with multiple genotypes, measuring soil water status (an indicator of crop water uptake) by conventional techniques (e.g. core extraction and penetration resistance) is limited by the cost and effort needed to achieve sufficient replication to apply robust statistical analysis. Geophysical methods may provide a more cost-effective means of more assessing valuable information about soil water status for such studies. We present here results from a field experiment using geophysical techniques for remote mapping of soil water content on sandy loam and silt loam soils in spring/summer 2013 in the UK. The aim of the study was to assess electromagnetic-induction (EMI) conductivity measurements for sensitivity to variations in shallow soil electrical properties and the spatial and temporal mapping of soil water. The CMD Mini-Explorer (GF Instruments) operates with three receiver coils at fixed distances from a transmitter coil (0.32 m, 0.71 m, 1.2 m). Measurement of magnetic field quadrature in horizontal coplanar (HC) and vertical coplanar (VC) of the three receiver coils provides six depths of investigation for the given coil spacing cumulative sensitivities. At the two field sites the instrument was applied to measuring apparent electrical conductivity (ECa) below 7.0 x 1.8 m plots consisting of 23 rain fed winter wheat cultivars and bare soil fallow control plots. These plots were sown in March 2013 and organised into a randomised block design. Electrical resistivity tomography (ERT) surveys along 15 m transects were also conducted at the two sites in order to compare EMI measured ECa.

Our results show that progressive soil drying at both sites due to crop uptake significantly decreased ($p<0.05$) soil ECa. The difference in soil ECa as a result of water uptake between cultivars was found to be significant ($p<0.05$) from one of the coil configurations (coil spacing 1.8m in HC mode), and only at the silty loam site (no significant difference was found in data from the sandy loam site). The difference in soil ECa over time was expected owing to crop root development and low rainfall during the growing season. It was expected that soil ECa between certain cultivars in the June and July would differ over all investigation depths at both sites. It was not possible in this study to produce calibrations for EMI measured ECa from the ERT data.

Our study confirms the suitability of multi-core EMI devices for efficient and repeatable measurements of soil ECa in trials of winter wheat cultivars, providing data on soil ECa with minimal user requirements and instrument error. Differences in soil ECa as a result of crop water uptake was, however, not fully conclusive, since water extraction by the different cultivars is difficult to detect with the instrument, especially on sandy textured soils. The full-depth of investigation (1.8 m) of the instrument used on silt loam soil textures can provide qualitative data on crop performance. Over time, with gradual soil drying, the instrument detected reductions in ECa at all depths of investigation in both sandy and silt textured soils. Further analysis will be done using profiles of electrical conductivity determined from inversions of measured ECa values. ERT data calibration of EMI measured ECa was not possible due to lower than expected variation in ECa measured along the 15 m transect over the field season. This has meant a change in the methodology by having transects crossing soil with greater vertical variation in ECa (determined from field EMI surveys) and surface conditions (e.g. bare and cropped soil).