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Quantification of Root Length Density at the Field Scale with Electrical Impedance Tomography: A Numerical Feasibility Study based on Laboratory and Field Data

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The root system is an important component of the biosphere, linking the soil to the vegetation-atmosphere environment. To improve crop breeding, production and management, it is essential to gain a better understanding of root-soil interactions and associated processes. Here, root architecture, growth and activity play a key role. Measurement methods capable of imaging, characterizing and monitoring root structure and dynamics in a non-invasive manner are still lacking, in particular for field-scale investigations. Previous laboratory studies on crop root systems using electrical impedance tomography (EIT), which utilizes low-frequency impedance measurements to image the complex electrical conductivity distribution, provided first insights into the possible monitoring of root system extension and root physiological processes. With a view to establishing EIT as a tool for root system characterization and monitoring at the field scale, we here present a numerical feasibility study. Synthetic 2D complex conductivity models representing a field with crop root systems were generated based on available laboratory and field data, comprising root length density (RLD), soil complex conductivity and water content, to simulate realistic scenarios. Here, the effective soil-root complex conductivity was computed from the individual soil and root complex conductivities via power-law mixing, incorporating the volumetric fraction of roots (determined from RLD based on an appropriately chosen root diameter) and an empirical parameter α. The latter is assumed to depend on root architecture and the direction of current flow, resulting in different values of α for the effective complex conductivity in horizontal and vertical directions and thus an anisotropic final model. Synthetic EIT measurements were then computed using a 2.5D anisotropic complex conductivity modelling code, contaminated with noise and subsequently inverted by means of a tomographic inversion code which assumed isotropic complex conductivities (as commonly used). The imaging capability is assessed by comparing original and reconstructed complex conductivity models respectively RLD models. Our results demonstrate that EIT can reconstruct the original distributions quite well but underestimates RLD values at larger depths ($>$60cm). The study shows that EIT is a promising method for quantification of root length density at the field scale if a model for the upscaling of the individual soil and root complex conductivities has been established and calibrated.