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Spectral induced polarization imaging applied to map the extension of root systems in Agroforests

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In agroforests, trees are planted on agricultural fields, which helps to reduce the risk of crop failure due to climate change, resulting for example from drought severity, as trees can improve the water supply and increase the amount of organic matter in the soil. Geophysical methods are used to non-invasively characterize the root system, including the root density, architecture, and growth as well as to monitor their activity to better understand the interactions between trees and agricultural fields. Electrical methods have demonstrated their potential for assessing the rhizosphere as the root presents a resistive barrier to current flow, resulting in lower conductivity values in the subsurface when roots are present. The spectral induced polarization (SIP) method provides information about the conductive and capacitive properties of the subsurface and its frequency dependence (commonly below 1 kHz). Laboratory investigations of the SIP method have shown that the conductivity of the roots depends on the root mass density, whereas the polarization effect and its frequency dependence is related to the root activity. The effect is due to the accumulation of charges at the electrical double layer (EDL) formed at the interface between roots and water, as well as within the root cells due to the plasma membrane. Consequently, changes in the electrical conductivity and induced polarization values at lower frequencies (< 100 Hz) can be used to delineate the extension of the root system. Moreover, we hypothesize that changes in the SIP data can be used to discriminate between the roots of trees and those from farming crops. In this study, SIP imaging measurements were conducted at four locations in Austria. The objective of the SIP survey is to delineate the geometry of the tree roots and to investigate changes in soil properties due to root activity based on the frequency dependent nature of the induced polarization. Measurements were conducted in a frequency range of 0.5 to 225 Hz at four sites to evaluate changes in the SIP response due to varying tree age and soil properties. We developed 3D geometries consisting of four lines crossing each other at the centre, where the tree under investigation is located. We used different electrode spacings to reach different resolutions and depths of investigation. Our results reveal that conductivity images can delineate the roots of the different trees, which always revealed the lowest conductivity values. In the area of the roots, the highest IP response is observed at lower frequencies (<5 Hz) and close to the surface (within 30 cm depth), which we interpret as the combined response of the organic carbon and roots. At larger depths, the IP response decreases, likely due to the reduced organic carbon and root activity. A few meters away from the tree, we observe an increase in the

conductivity and moderate IP values, with the latter increasing with the frequency, indicating the presence of fine textures (i.e., clay and silts).