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Investigation of Electrical anisotropy as a root phenotyping parameter: Numerical study with root water uptake

Sathyanarayan Rao (1), Félicien Meunier (2), Solomon Ehosioke (3), Maximilian Weigand (4), Andreas Kemna (4), Frédéric Nguyen (3), Sarah Garré (5), Johan Alexander Huisman (6), Mathieu Javaux (1,6)

(1) Université catholique de Louvain, Earth and Life Institute, Louvain-la-Neuve, Belgium (sathyanarayan.rao@uclouvain.be), (2) Computational and Applied Vegetation Ecology lab, Ghent University, (3) Applied Geophysics, Université de Liège, Chemin des Chevreuils 1, 4000 Liege, (4) Geophysics Section, Institute of Geosciences and Meteorology, University of Bonn, Germany , (5) Université de Liège, Gembloux Agro-Bio Tech, TERRA Research and Teaching Center, Passage des déportés 2, 5030 Gembloux, Belgium, (6) Agrosphere, IBG3, Forschungszentrum Juelich GmbH, Germany

Electrical anisotropy is a typical feature observed in geology and can be used to characterize sub-surface heterogeneity (Al-Hazaimay et al., 2016). In soil-root medium, the effective electrical anisotropy factor (EAF) in electrical conductivity (EC) is due to root processes such as root water uptake, root architectural evolution, exudation and solute uptake. Under homogeneous soil conditions, (i.e. well irrigated scenario and no water uptake pattern in the soil) and with root water uptake (Javaux et al., 2008), we hypothesize that EAF of soil-root medium could contain information on root architecture (geometrical indices) and thus can be used for phenotyping root systems.

To support our hypothesis, we performed 2D finite-element modeling of these properties in terms of EC distribution for a series of simulated root systems, with explicit representation of the root architecture in the finite-element mesh. We then find the correlation between geometry of root network and EAF and assess under what condition will there exist high correlation and hence EAF could provide information on root architecture. Root architecture was explicitly resolved in the finite element mesh along with root water uptake (Javaux et al., 2008). To parameterize the model, we measured complex conductivity of Maize root segments at different frequencies (IP spectra). The roots elements in the finite element mesh had frequency dependent electrical properties, including the resolution of cortex and stele. Effective electrical anisotropy and geometrical anisotropy are examined for different synthetic root architecture generated in Crootbox software. We then relate the modeled effective electrical anisotropy to the geometrical anisotropy of root structure. To formulate geometrical anisotropy, we discuss different approaches. We also demonstrate high correlation between geometrical anisotropy of root networks and simulated electrical anisotropy of effective conductivity of soil-root continuum. The understanding of relation between geometry of root network, electrical conductivity contrast between soil-root and effective electrical property of soil-root continuum is very important to monitor rooted zone via electrical methods and our modeling results helps to give insight.

References:

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