Investigation of Electrical Anisotropy as a Root Phenotyping Parameter: Numerical Study with Root Water Uptake.

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1. Introduction

Imaging soil-root processes and phenotyping root systems are important to improve agricultural yields. We explore the possibility to use electrical anisotropy as a parameter to characterize soil-root system.

We hypothesize that effective electrical conductivity (σ_{eff}) and ratio of σ_{eff} in two perpendicular direction or electrical anisotropic factor (EAF=$\sigma_{effX}/\sigma_{effZ}$) contains information on the geometrical features of soil-root medium.

To test our hypothesis, we performed 2D finite-element modeling of σ_{eff} for soil-root system which had explicit EC distribution for a series of simulated root systems at plant and field scale (2m in length).

2. Methods

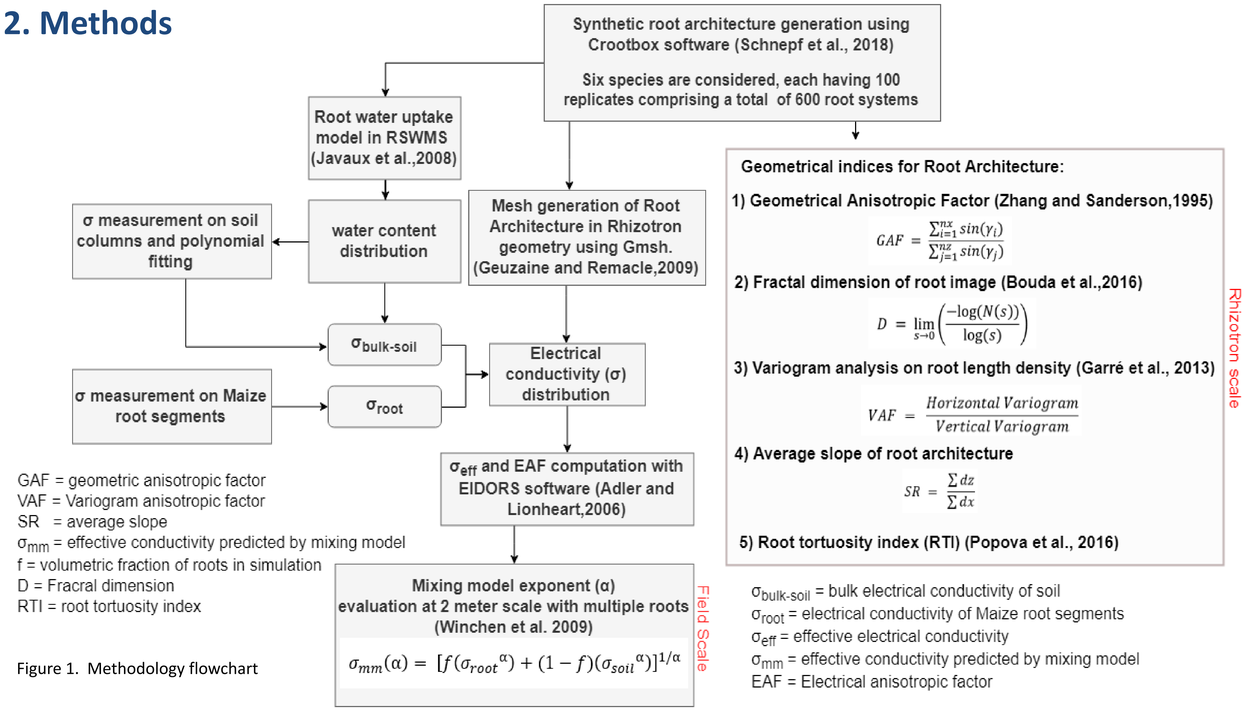

Figure 1. Methodology flowchart

3. Model Parameterization

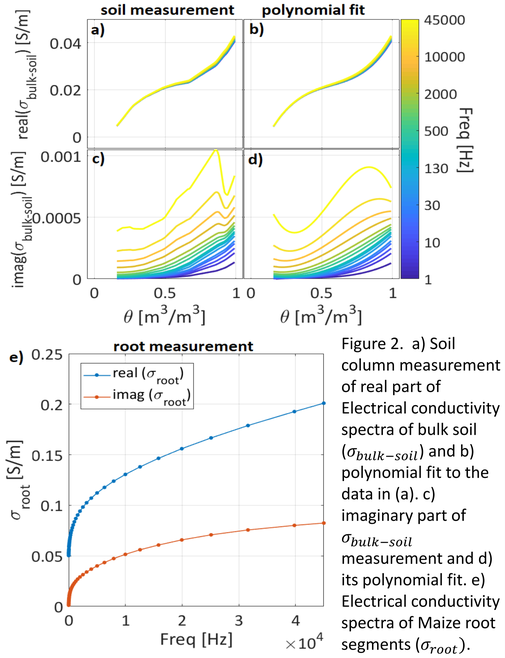

Figure 2. a) Soil column measurement of real part of Electrical conductivity spectra of bulk soil ($\sigma_{bulk-soil}$) and b) polynomial fit to the data in (a). c) imaginary part of $\sigma_{bulk-soil}$ measurement and d) its polynomial fit. e) Electrical conductivity spectra of Maize root segments (σ_{root}).

4. Field Scale Simulation

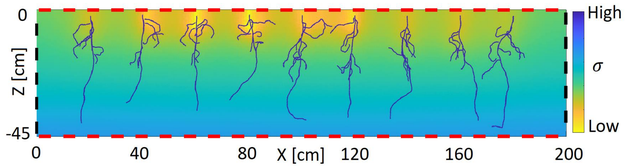

Figure 3. Electrical conductivity (σ) map of nine "root-3" in consecutive rows with Root water uptake simulation. Vertical electrodes for computing σ_{eff} in X-direction (σ_{effX}) (black dashed line at boundary) and Horizontal electrodes (red dashed lines) for σ_{effZ} .

5. Field Scale Mixing Model Result

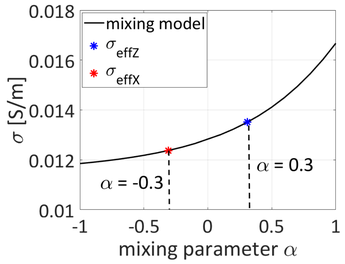

Figure 4: Effective electrical conductivity of mixing model, $\sigma_{mm}(\alpha)$, for f = 6% root volume and σ_{root} = 0.1 [S/m] at freq = 1khz and for σ_{soil} we use the value of effective soil conductivity in Figure 4 without root segments (0.0112 S/m) using plate electrode computation of Figure 4 but only with $\sigma_{bulk-soil}$.

Vertical and horizontal σ_{eff} of soil-root medium (both root and soil present) is shown as blue and red stars in the above figure. The corresponding α-value describes root connectivity in two perpendicular directions.

6. Rhizotron Scale Root Architectures

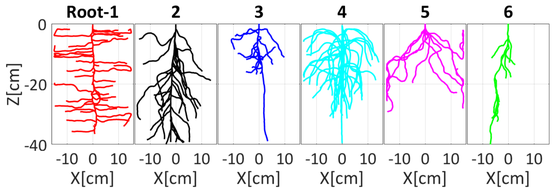

Figure 5. Different rhizotron root architecture generated in Crootbox. Same color code is used to identify different root species in later figures.

7. Rhizotron Scale EAF and Geometrical Indices

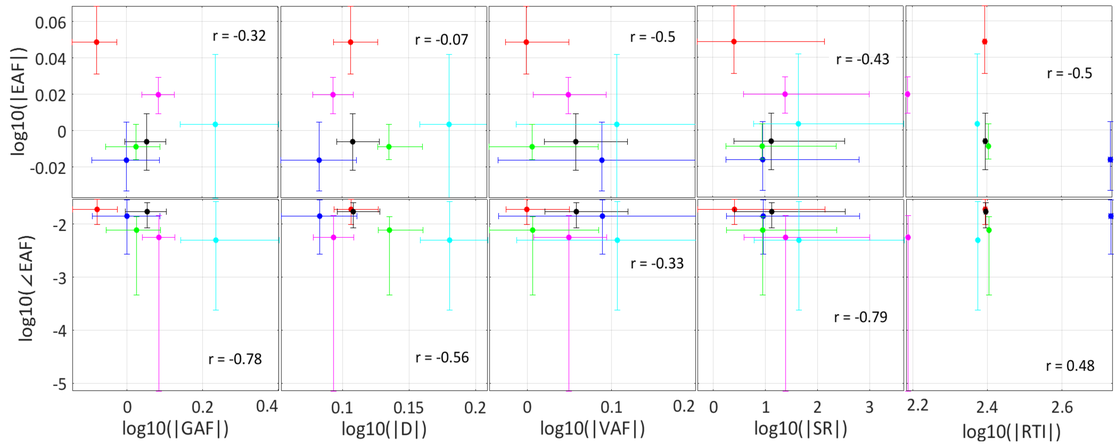

Figure 6. Relation between magnitude electrical anisotropy factor (1st row) vs different geometrical indices (column wise) and phase electrical anisotropic factor in the second row. The electrical conductivity data was chosen at 1kHz. The dot represents average or centroid of 100 root systems within a given species (color coded in Fig.5) while error bar represents the uncertainty or data variability.

8. Conclusions

- Mixing model results in Fig. 4 for field scale simulated maize (Fig.3) indicates that it is possible to deduce root connectivity at field scale knowing the σ_{eff} and root volume in advance.
- We simulated rhizotron scale root systems (Fig.5) of different species for analyzing the connection between geometrical features of soil-root domain and EAF.
- Inspection of simulation data at 1Khz (Fig.6) for rhizotron scale model shows good correlation between phase part of EAF and various geometrical indices as compared to magnitude part.

9. Perspectives

- Since the uncertainty in both EAF and geometrical indices is high enough to blur the systematic relationship that can exist between them (Fig.6), to establish EAF as a promising index for root phenotyping, more experimental data and modeling will be needed.
- Although mathematically simpler mixing model in Fig.4 is able to capture root connectivity for a simulated maize field, for practical application, soil heterogeneity needs to be incorporated into the model and tested with field experiments.

10. Acknowledgment

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11. References

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