B33G: Agricultural Systems session

# Modeling Effective Electrical Properties of Soil-Root Continuum to Discriminate Root Traits

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Abstract:B33G-2763

## 1. Introduction

- We hypothesize that anisotropy in effective electrical conductivity (EC) of soil-root medium contains information on root architecture 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 (See Methods for details).

## 3. Computing Electrical Anisotropy (EAF) using Finite Element Model

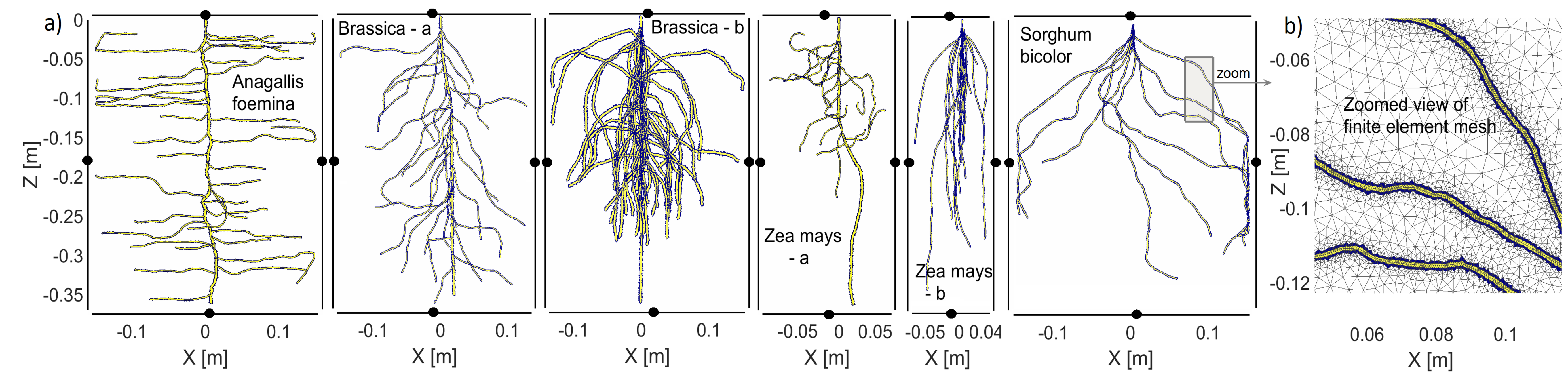


**Figure 2:**
a) Finite element model of root architectures for different plant species. Solid black line represents plate electrode for computing effective anisotropy (EAF-eff) while black circles represents point electrode for computing apparent anisotropy (EAF-app).
b) Zoomed view showing cortex and stele structures. EC of cortex is taken as 1/3 the EC of stele.

## 2. Methods

Synthetic root architecture generation using Crootbox software (Schnepf et al., 2018)

- Six species are considered (see Fig. 3),each having of 100 replicates comprising of a total 600 root systems

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Mesh generation of Root Architecture in Rhizotron geometry using Gmsh. (Geuzaine and Remacle,2009)

Homogeneous soil EC assumed.

EC measurement on real maize root segments.

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Electrical conductivity (EC) distribution

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Electrical Anisotropy Factor computation with EIDORS software (Adler and Lionheart,2006)

- Point electrode model: apparent anisotropy factor (AF-app)
- Plate electrode model: effective anisotropy factor (AF-eff)

(see Fig. 2)

Geometrical indices for Root Architecture:

- Geometrical anisotropic factor using scan lines and sine angles (Zhang and Sanderson, 1995)
- $$GAF = \frac{\sum_{i=1}^{nx} \sin(\gamma_i)}{\sum_{j=1}^{nz} \sin(\gamma_j)}$$
- Box counting dimension, treating root architecture as fractal (Bouda et al.,2016)
- $$D = \lim_{s \to 0}\left(\frac{-\log(N(s))}{\log(s)}\right)$$

↓

Find relation between Geometrical Indices (GAF and D) and Electrical Anisotropy (AF-app and AF-eff)

**Figure 1: Flow chart of method used.**

## 4. Measured EC-root of Maize root segments

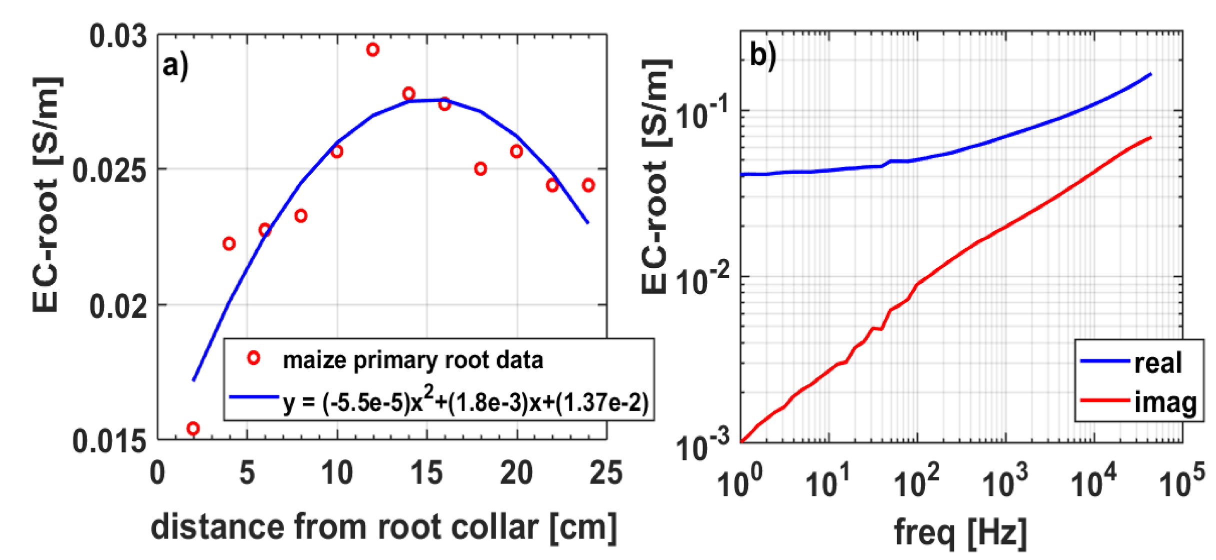


**Figure 3:**
a) Measured maize root DC conductivity data.
b) Measured AC conductivity spectra.

## 5. DC Parameter Results

- Anagallis foemina
- Brassica-a
- Brassica-b
- Zea mais-a
- Zea mais-b
- Sorghum bicolor
- correlation fit

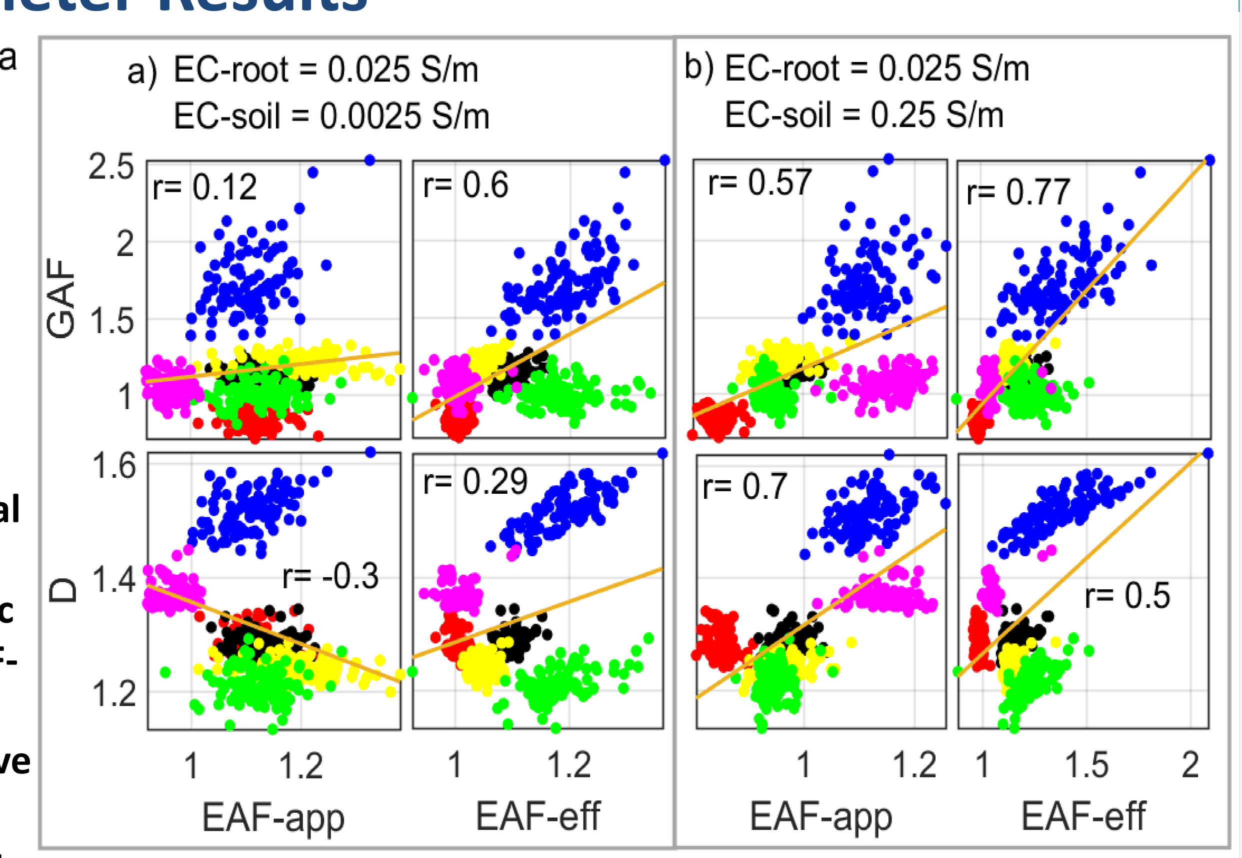


**Figure 4: Relation between geometrical indices (GAF,D) and electrical anisotropic factor (EAF-app, EAF-eff) for: a) Resistive soil and b) conductive soil. Here r is the correlation constant.**

## 6. AC Parameter Results (Complex EC)

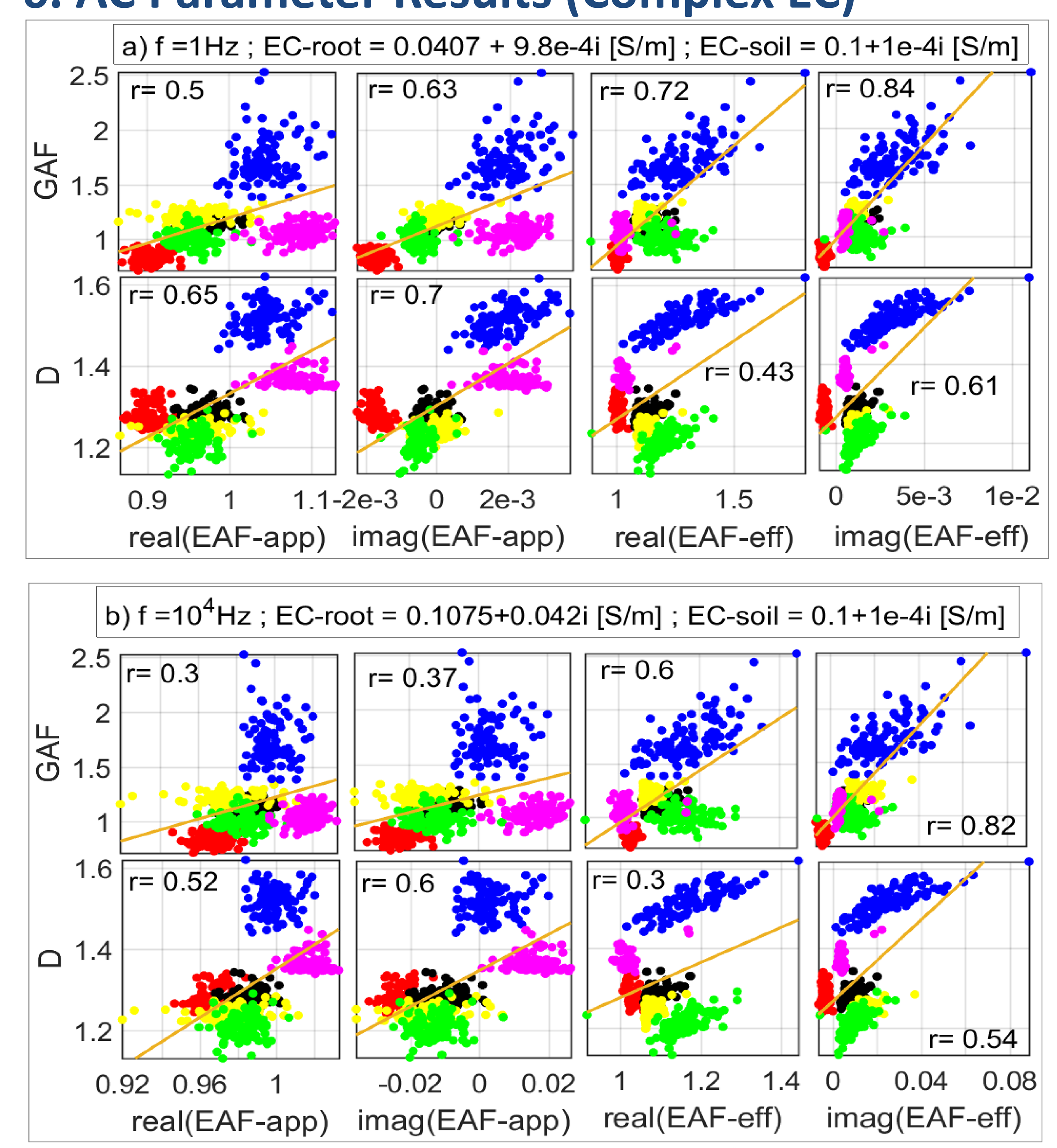


**Figure 5: Relation between geometrical indices (GAF,D) and complex electrical anisotropic factor (EAF-app, EAF-eff) at: a) 1Hz and b) 10000Hz. Color code represents Different species as given in Fig. 4.**

## 7. Conclusions and Perspectives

- Our model with synthetic roots shows, high correlation (>0.6) can exist between the geometrical indices, namely Geometrical Anisotropic factor and Fractal box counting dimension, and the electrical anisotropic factor (EAF). Further, the correlation factor depends on the soil EC contrast.
- It is evident from the model that different root architecture forms cluster on Geometrical index vs Electrical anisotropy plots demonstrating the ability of electrical method to differentiate different root systems.
- Our simulation with point electrode (EAF-app) and plate electrode (EAF-eff) shows similar results, thus it is feasible to partially deduce root geometry with point electrode. Our next step is to validate this study with a real experiment.

## 8. References

(1) Schnepf et al. (2018), Ann Bot. 121(5):1033-1053. (2) Adler & Lionheart (2006), Physiol. Meas. ,27, S25–S42.
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(5) Rao et al. (2018), Biogeosciences Discuss., https://doi.org/10.5194/bg-2018-280, 2018. (6) Al-Hazaimay et al. (2016), Near surface geophysics, 14, 357-369.

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