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Electrical Signatures Of Century-Old Biochar Enriched Agricultural Soil At Field And Laboratory Scale

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Motivation

- Biochar amendments of agricultural soils might increase soil fertility and thus to have a positive impact in the crop-yield
- Enhancement potential of century-old enriched soils (long-term impacts) has not been studied
- A methodology able to link small scale physical and chemical characteristics of century-old enriched soil with large scale agro-ecosystem performance is necessary
- Electrical resistivity imaging (ERI) and spectral induced polarization (SIP) geophysical methods might be suitable candidates to that end

Strategies and Objectives

1) To characterize the geophysical electrical response of century-old biochar enriched soil (OBC) and natural reference soil (REF) in the field

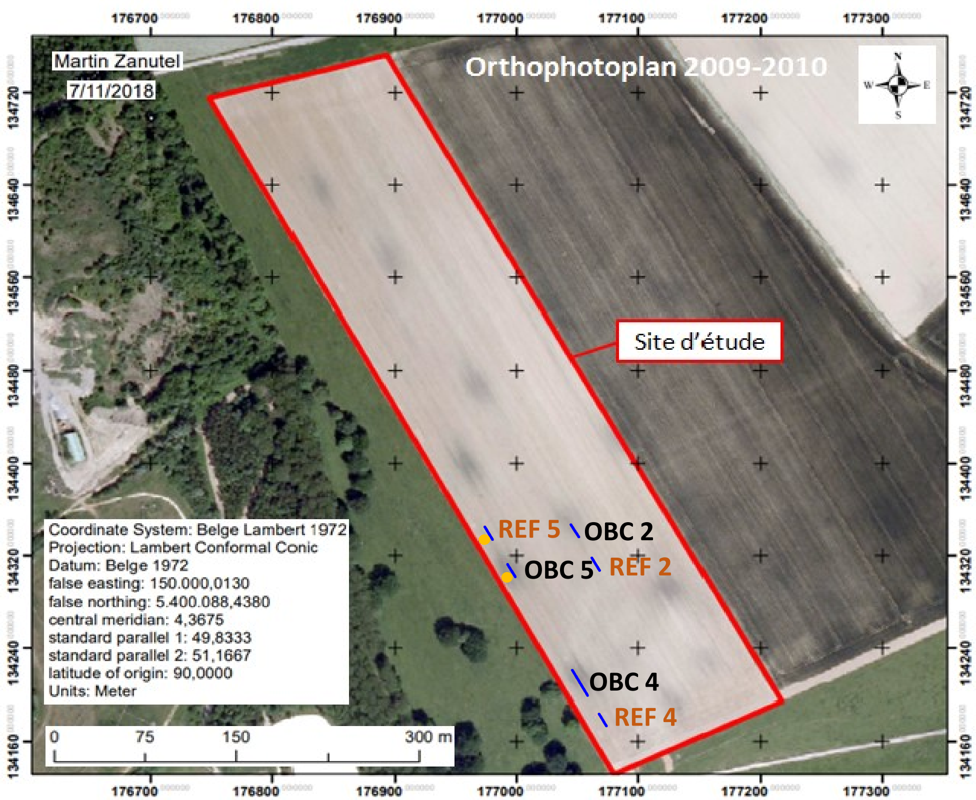
2) To investigate the relationship between soil moisture and the electrical signal at multiple scales and over time

3) To perform controlled desaturation experiments at laboratory scale along with complex conductivity (SIP) measurements to investigate the effects of moisture

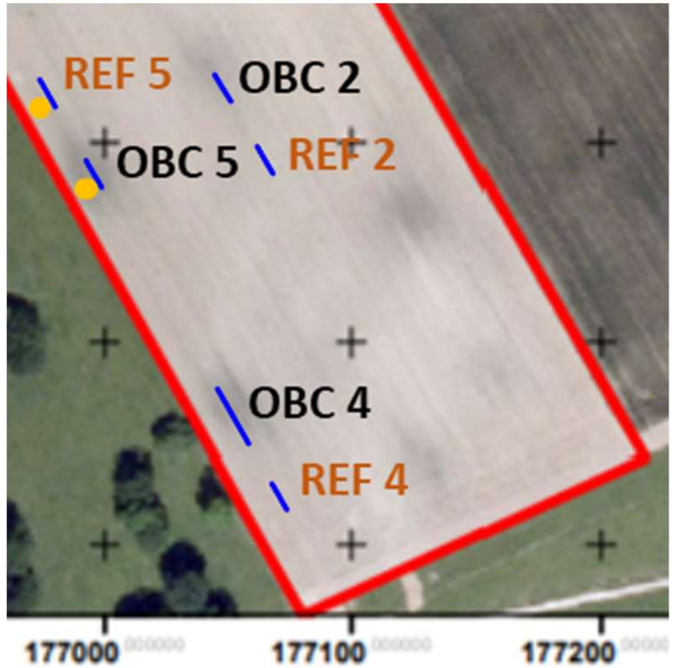
5) To integrate field (ERI) and laboratory (SIP) scale electrical signatures to develop petrophysical models

Study Site

- ~13 ha surface area agricultural field
- ~0.30 m thick x ~25 m diameter century-old biochar enriched soil (OBC zones)
- ~0.30 m thick organic matter of natural top soil (REF zones)

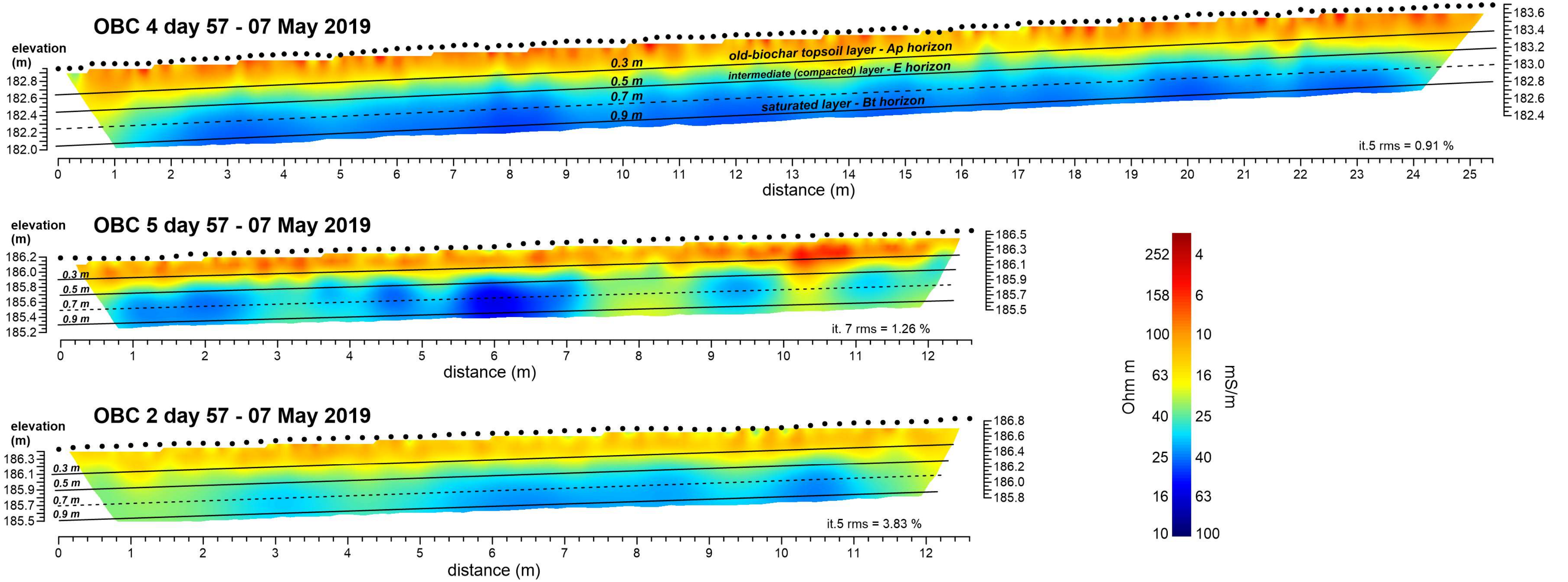


Field setup

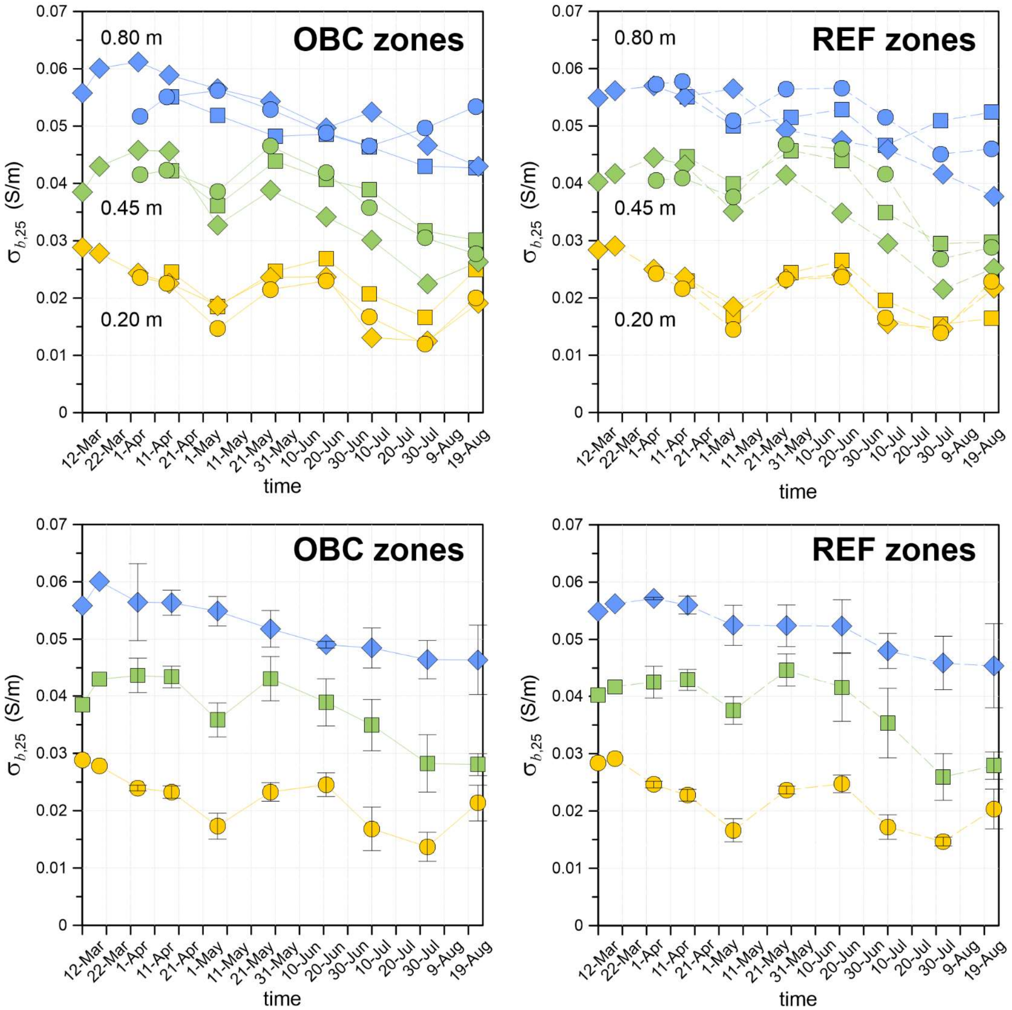


- 6 ERI transects, 5 x 12.6 m and 1 x 25.4 m long (blue lines)
- 2 Experimental trenches (1.8 m L x 1 m W x 1.1 m D) in OBC 5 and REF 5 monitoring zones (yellow dots)
- Undisturbed soils samples at 0.20 m depth from OBC 5 and REF 5 trenches

Field-scale results: ERI characterization of 1 m thick soil profile in OBC monitoring zones



ERI characterization of 1 m thick soil profile at OBC 2, 4 and 5 monitoring zones on day 57 (07-May-2019). Inverted resistivity values at 0.20, 0.45, and 0.80 m depth all along the transects were extracted and converted to conductivity, σ_b, adjusted at T = 25 °C and averaged at each depth afterwards, $\sigma_{b,25}$, for its analysis. Similar results of inverted ERI sections were obtained during the whole monitoring campaign not shown here for simplicity

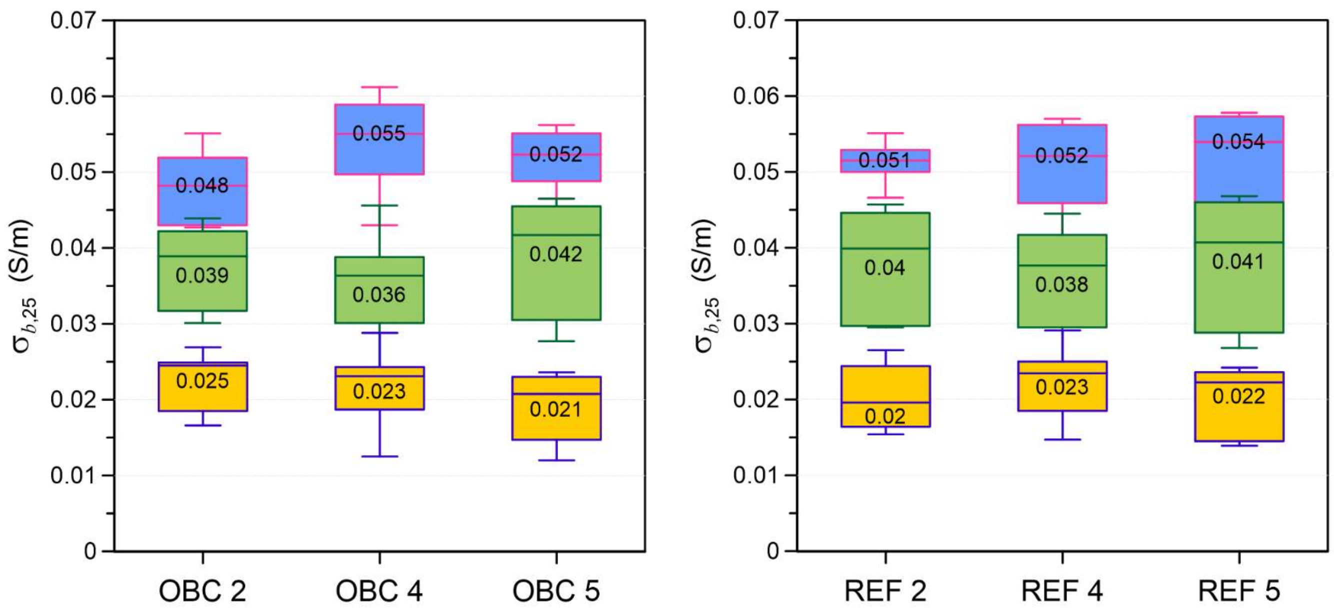


Field-scale results (1/2): Evolution of averaged conductivity in 1 m thick soil profile throughout a winter wheat growing season

Top panel: temporal variations of averaged and temperature adjusted conductivity values, $\sigma_{b,25}$, at monitoring depths of 0.20 m, 0.45 m and 0.80 m in OBC 2, 4 and 5 and REF 2, 4 and 5 monitoring zones from ERI measurements, respectively

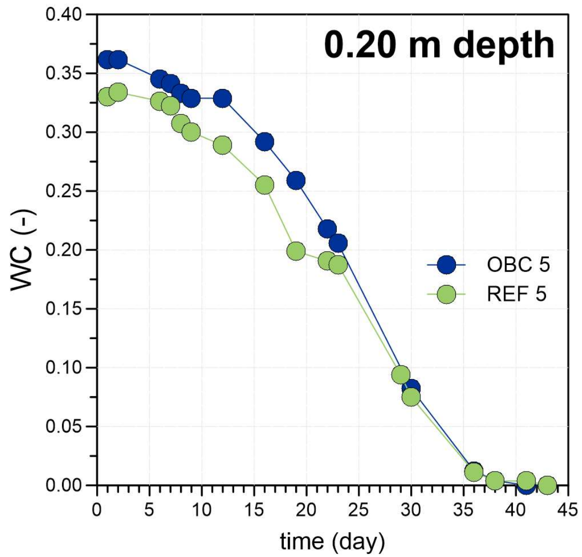
Bottom panel: temporal variations of averaged $\sigma_{b,25}$ values at measuring days and monitoring depths for the ensemble of OBC and REF zones, respectively (errors bars show the standard deviation at each measuring day)

Field-scale results (2/2): Comparison of median conductivity values between OBC and REF zones throughout the winter wheat growing season

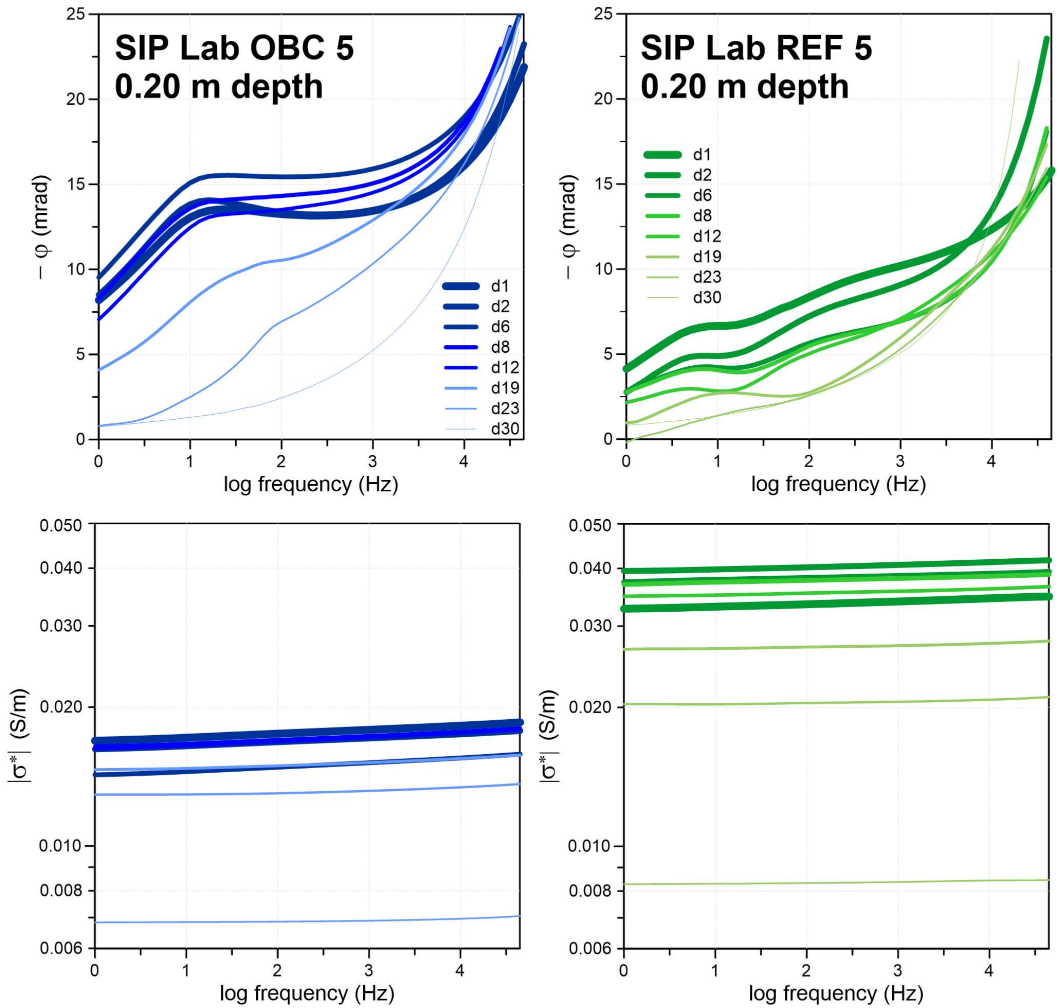


Comparison of median values $\sigma_{b,25}$ (labels and middle horizontal line) at monitoring depths of 0.20 m (bottom) , 0.45 m (middle), and 0.80 m (top) at each OBC and REF zones; the bars show the minimum and maximum $\sigma_{b,25}$ values, the color bars show the percentile rage (25 – 75)

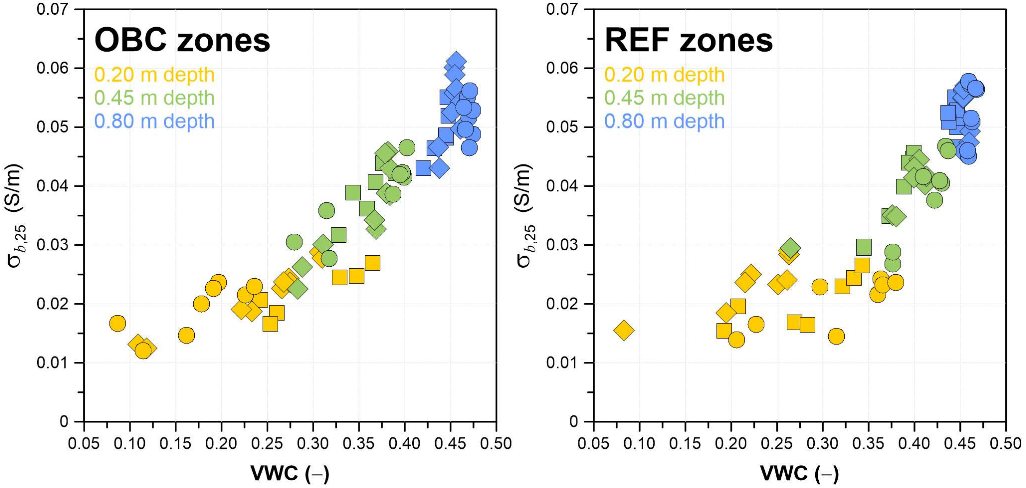
Laboratory-scale results: influence of WC on phase shift (φ) and magnitude (σ*) of complex conductivity (SIP) response of undisturbed soil samples



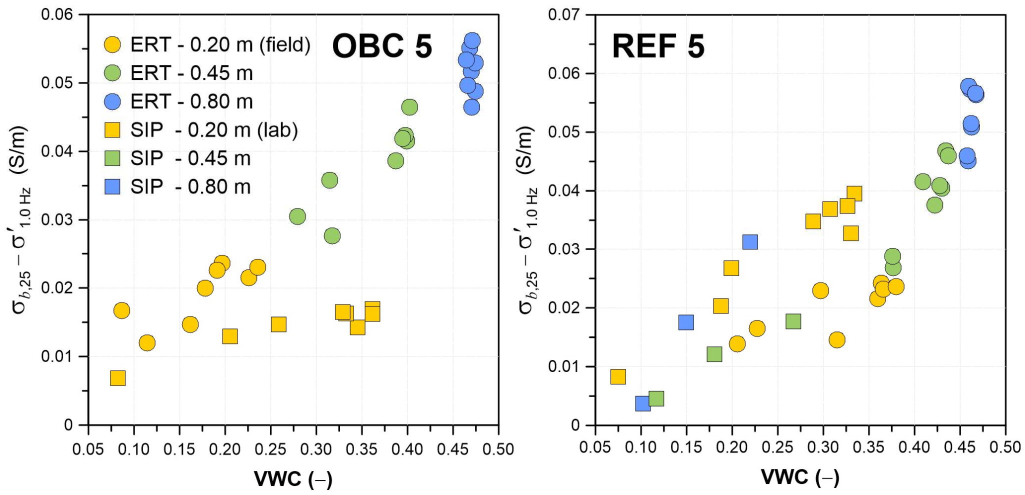
Left: water content (WC) variation from controlled desaturation experiment at room temperature in OBC 5 and REF 5 undisturbed soil samples collected at 0.20 m depth in trenches. ***Right:*** associated phase shift, $-\varphi$, and magnitude, $|\sigma^{*}|$, spectra from SIP measurements.



Field-scale ERI *vs.* Lab-scale SIP (1/2): influence of water content on electrical conductivity

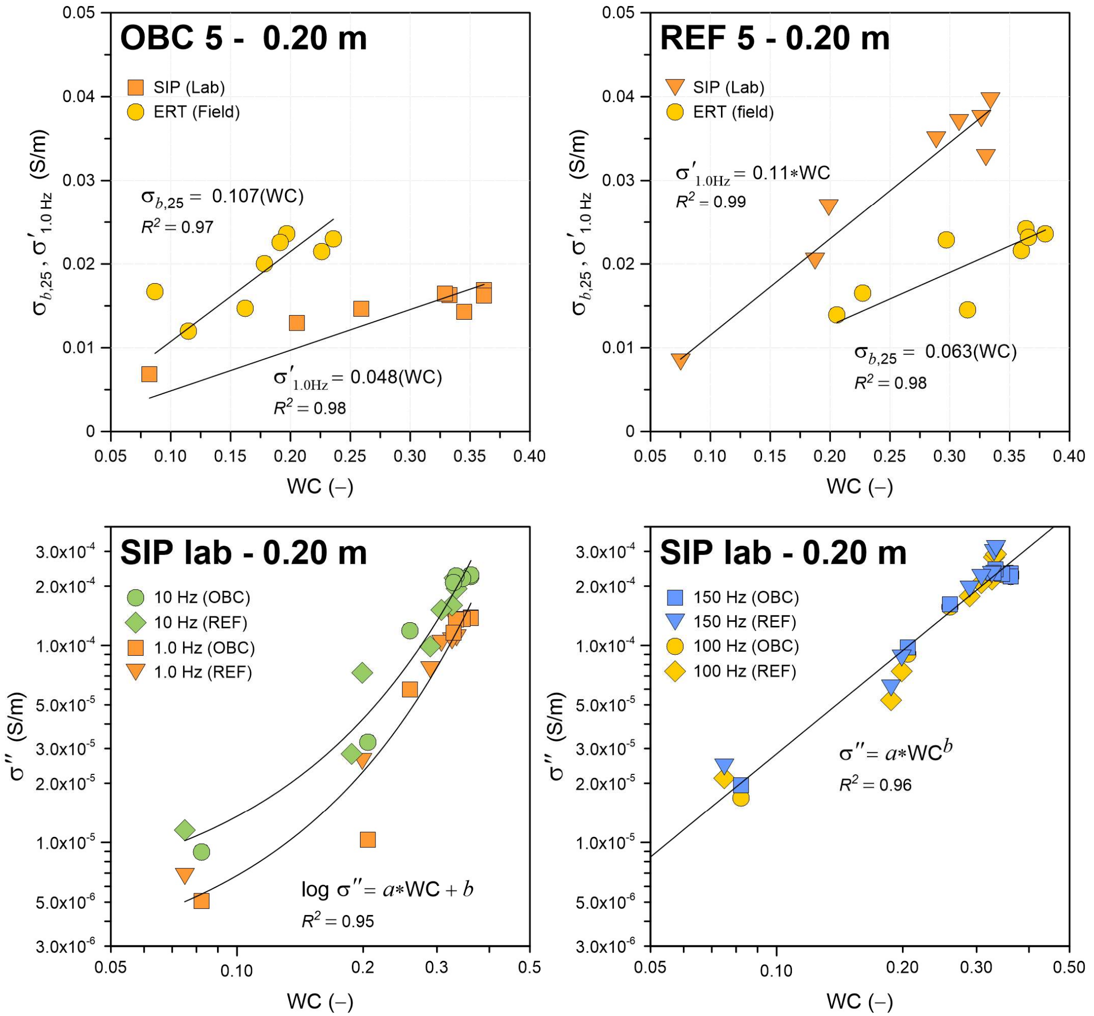


Top panel: relationship between temporal variations of averaged and temperature adjusted conductivity values, $\sigma_{b,25}$, and WC for the entire ensemble of OBC and REF zones, respectively



Bottom panel: comparison of electrical conductivity-water content relationships between $\sigma_{b,25}$ values from ERI (field-scale) and in-phase conductivity at 1 Hz (σ'_{1Hz}) from SIP (lab-scale) in OBC 5 and REF 5 zone

Field-scale ERI *vs.* Lab-scale SIP (2/2): influence of water content on electrical conductivity



Top panel: correlations between $\sigma_{b,25}$ (field-scale), σ'_{1Hz} (lab-scale) and WC at 0.20 m depth in OBC 5 and REF 5 zones

Bottom panel: correlation between quadrature, σ''_{1Hz} (polarization) and WC at 0.20 m depth in OBC 5 and REF 5 zones from SIP lab-scale measurements

Conclusions and Perspectives

1) ERI method was suitable to characterize and monitor soil water dynamics in 1 m thick soil profile throughout a winter wheat growing season

2) Phase shift, complex conductivity magnitude and in-phase conductivity from lab-scale SIP measurements show significant contrast between OBC and REF soil types in function of WC variations, which bulk conductivity from ERI (at field scale) does not show

3) Physical (petrophysical) model of polarization is still required to evaluate its potential sensitivity to link with physical and chemical properties of century-old biochar enriched soils

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