Building the Whole-plant Phenotype: Coupling Geophysically-based Below-ground Measurements with Above-ground Data

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Abstract

Wheat is one of the most widely grown crops and it plays an important role in food production. Currently there is considerable interest in identifying traits that contribute to high yields. Trait selection has mainly focused on the above-ground part of the plant neglecting below-ground processes. Climate change and the greater uncertainty in weather conditions challenge our current food system and create the need to select more varieties with grater resilience against the effects of climate variation. The root system of the plant plays a key part in this resilience, but it is difficult to study at the field-scale which is essential for the effective selection of breeding lines. Geophysical tools such as electromagnetic induction (EMI) and electrical resistivity tomography (ERT) offer the possibility to study the below-ground phenotype of the plant in a non-destructive and high-throughput manner. In this study, changes in soil moisture induced by root water uptake are monitored using time-lapse ERT/EMI surveys. These methods were applied at two scales: (a) at a high-spatial resolution where hundreds of wheat varieties were monitored monthly using EMI in a wheat breeding field trial and (b) at high-temporal resolution where hourly ERT measurements were collected along with above-ground phenotyping traits on a few plots with a field facility (Field Scanalyzer). Coupling these geophysically-based below-ground data with above-ground canopy measurements can increase our understanding of the crop response to its environment. Good correlation was found between leaf area index (LAI) and soil drying inferred from EMI measurements for the high-spatial experiment (a). The ERT monitoring experiment (b) accurately showed the dynamics of two different nitrogen treatments, their interactions with weather conditions and their correlation with above-ground crop growth. Coupling geophysically-based below-ground measurements with above-ground data allows the increased understanding of the whole plant phenotype. This might help to identify useful traits to select for increased crop yield and resilience.

Building the whole-plant phenotype: coupling geophysically-based below-ground measurements with above-ground data

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1. Challenge

- More **resilient wheat varieties** are needed to face food security and climate change
- Below-ground traits play a key role in this resilience
- We need **high-throughput non-invasive** tools to phenotype below-ground traits at the field-scale

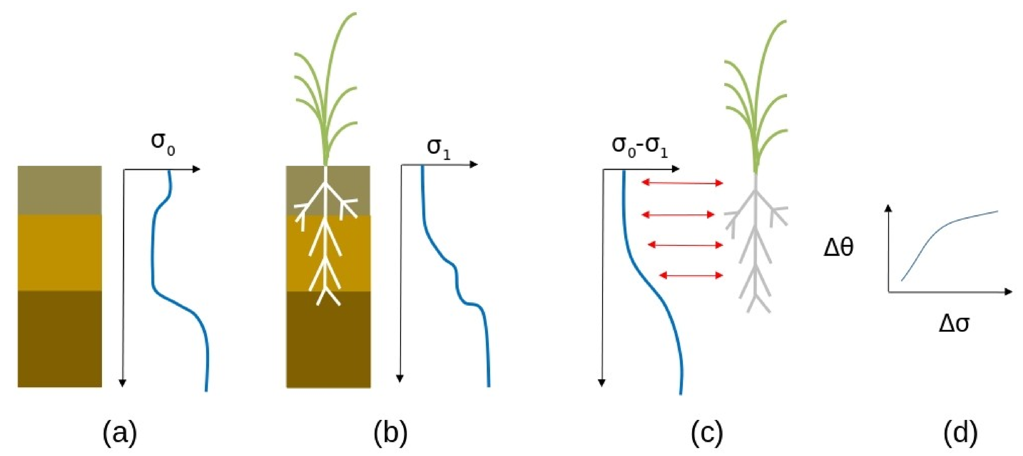
Two experiments demonstrate how geophysics can be used to meet this challenge

2. Methods

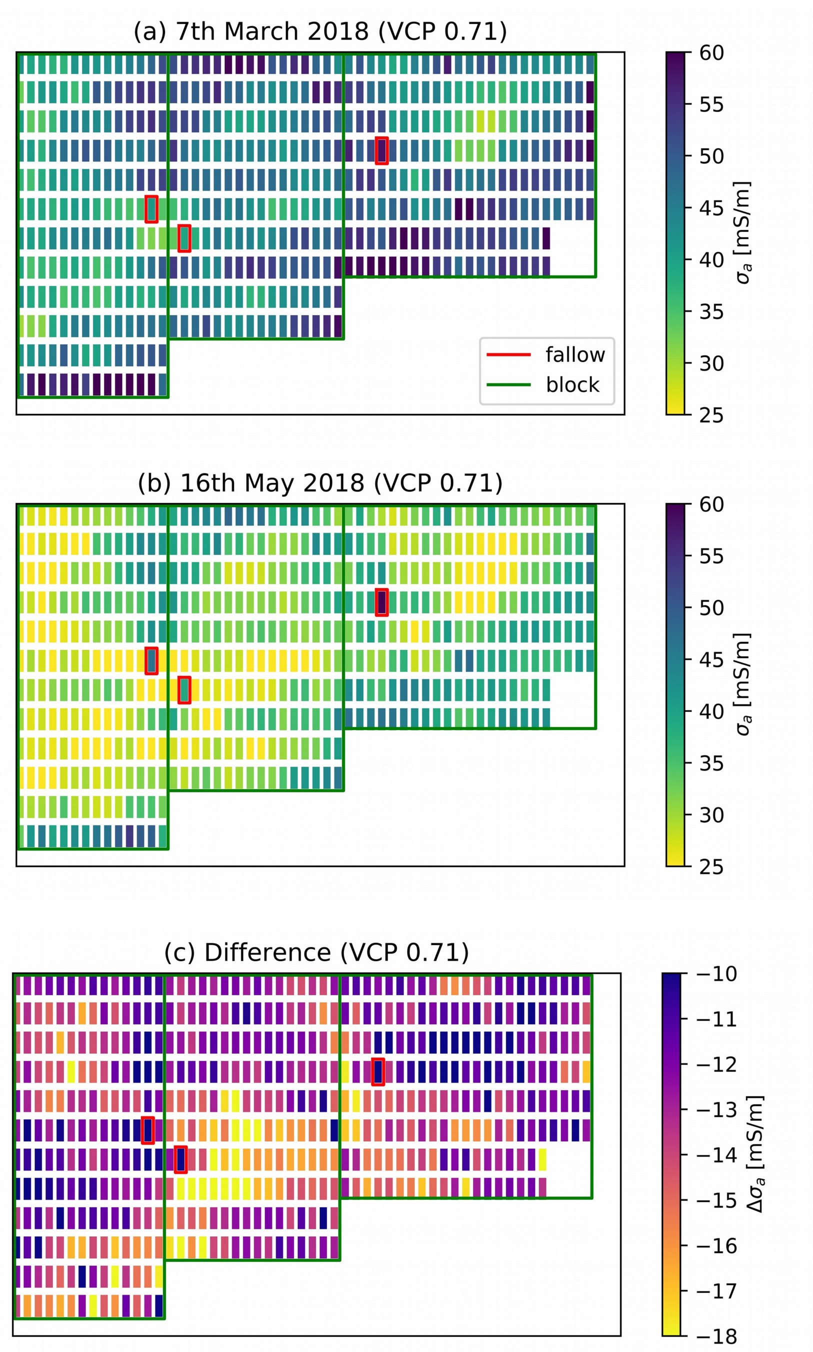
ERT and EMI are used to take time-lapse measurements of the conductivity at regular interval.
The background readings (a) are taken when the crop is small. Further readings are taken when the crop grows (b).
The differences to the background are linked to soil moisture change (c). The electrical conductivity (σ) can be converted to soil moisture (θ) using a relationship (d).

Electrical Resistivity Tomography (ERT)

Electromagnetic Induction (EMI)



3. Trial (high spatial resolution)

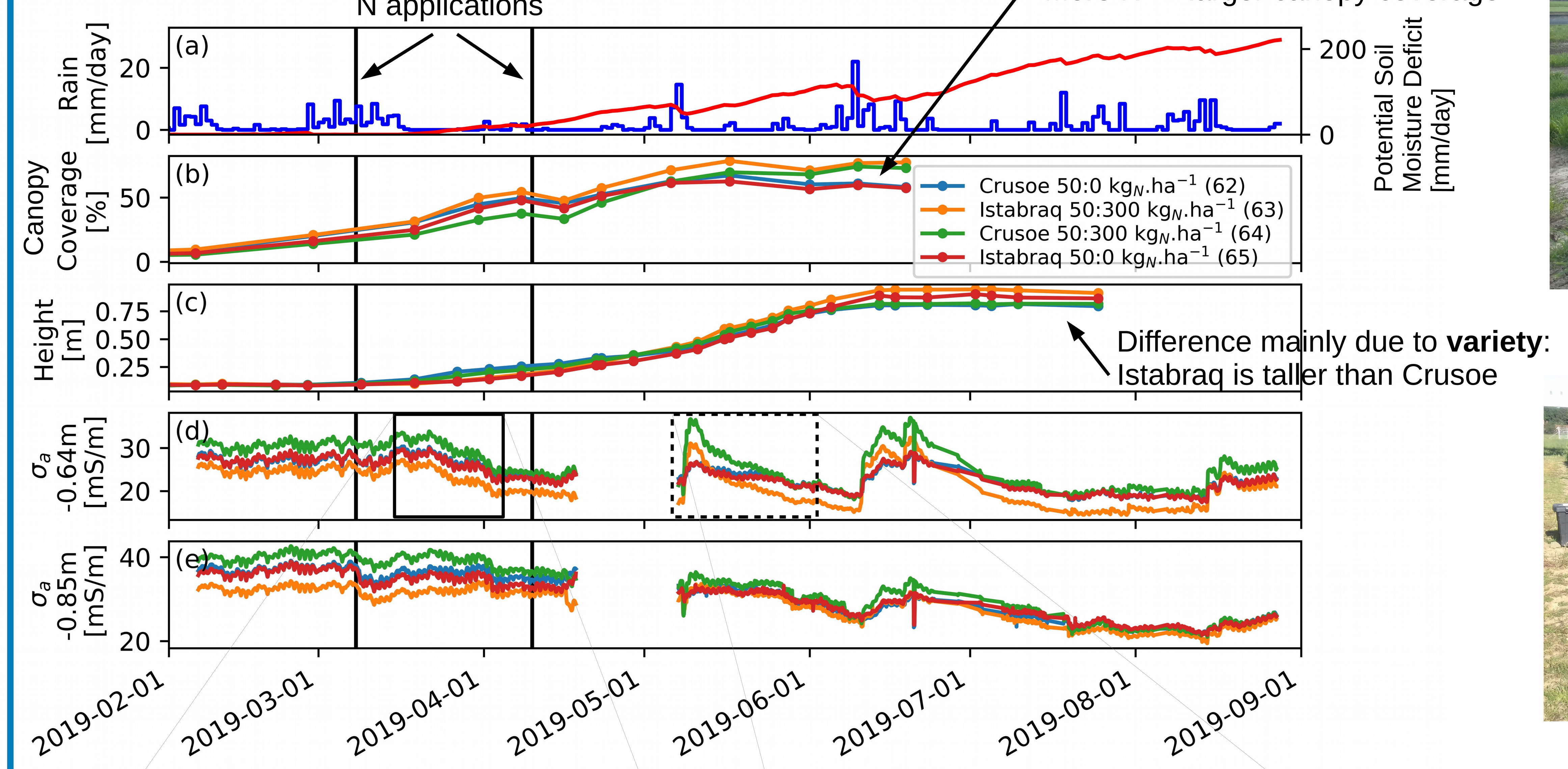


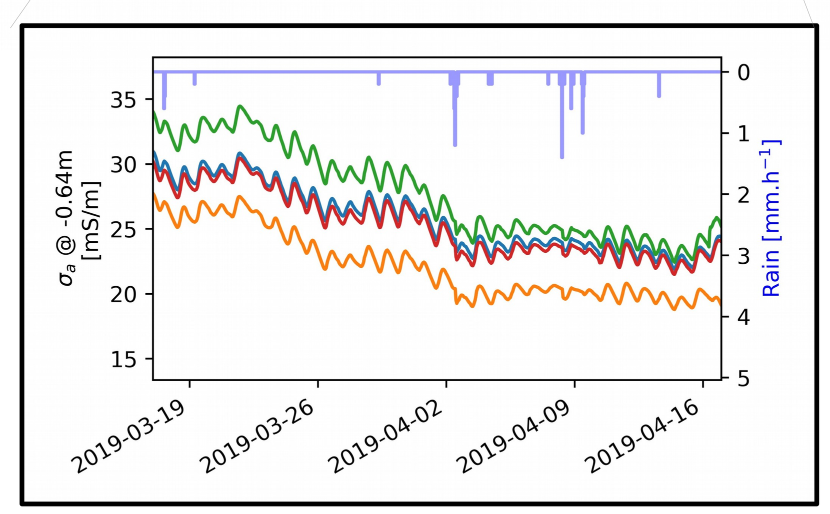
EMI measurements were taken in March (a) and May (b) 2018 on this commercial field trials of 504 plots (167 wheat lines + 1 fallow in 3 blocks). Each plot is 9 by 1.8 m.

The change of conductivity between the two dates (c) is dominated by the heterogeneity of the soil texture despite the time-lapse approach.

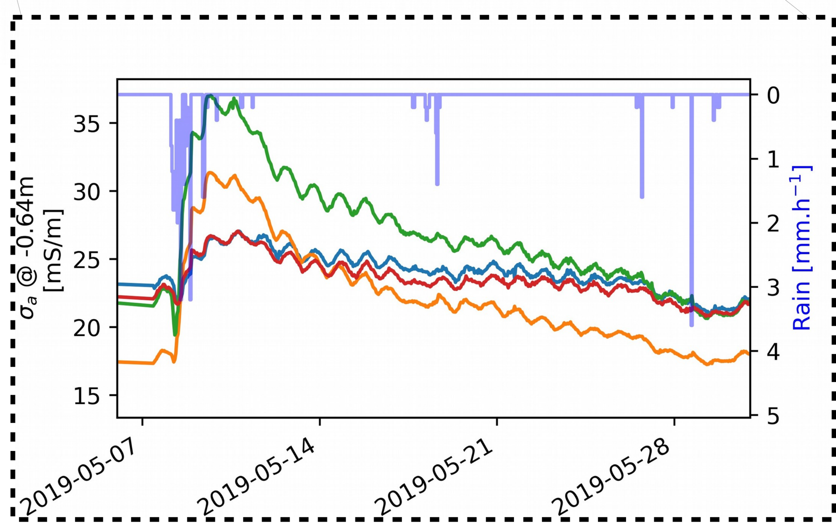
This is actually a limitation of the time-lapse approach as we need plant related changes to be larger than soil related effects.
Another limitation is that we only have a snapshot of the conductivity in time but we cannot see how its changing over the growing season.

4. Scanalyzer (high temporal resolution)

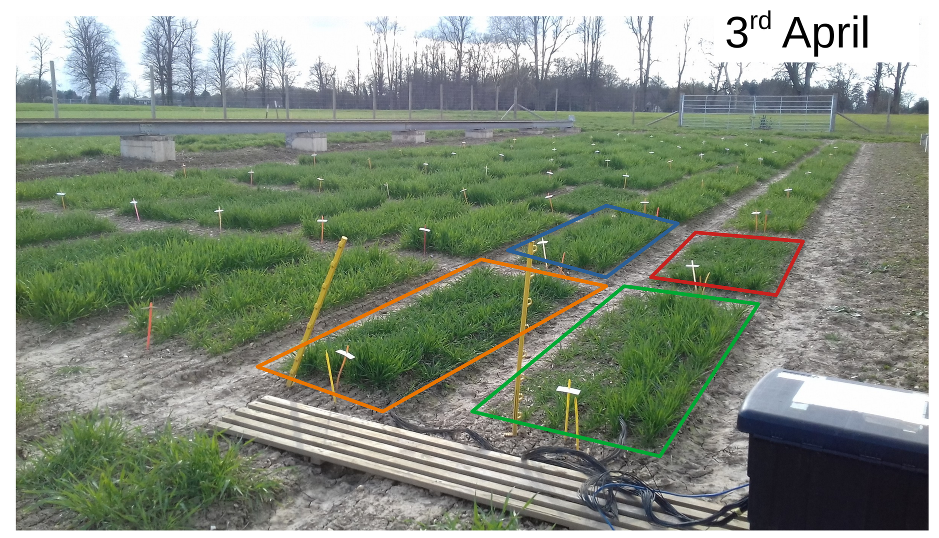


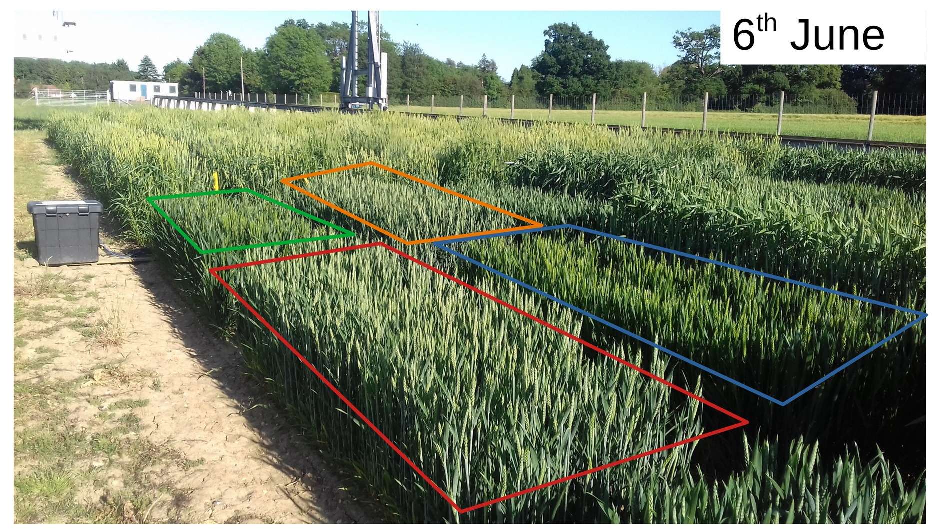


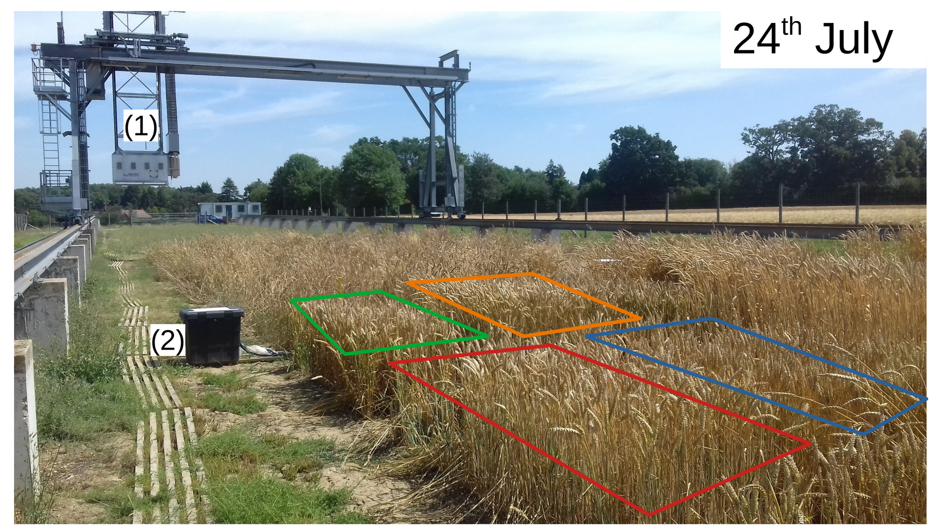
Increase water use for high N crops



Faster dynamics for high N crops







Experimental setup with four plots of wheat with 12 electrodes (0.15m spacing) per plot. (1) The Scanalyzer takes regular above-ground measurements and the ERT monitoring system (2) record the ground electrical conductivity every hour.

- high temporal resolution ERT monitoring coupled with the regular measurements of the Scanalyzer platform (height, coverage) provide a unique environment to study both above and below-ground traits
- ERT shows sudden increase related to heavy rainfall and constant decrease related to root water uptake
- both canopy coverage and electrical conductivity are influenced by the N treatment. More N → larger canopy → larger decrease in conductivity after rain event
- The heights of the crop is more related to the variety even if inside the variety an effect of the treatment can still be observed for Istabraq only

5. Key Points

- EMI enable us to collect minimally invasive measurements on large field trials (> 300 plots) offering a high spatial resolution alternative
- EMI didn't reveal any effect of the varieties but was too strongly influenced by the heterogeneity of the soil texture
- ERT monitoring (hourly in this case) provided a high temporal resolution image of the below-ground processes
- The dynamics of the conductivity under the Scanalyzer is tightly linked to weather conditions and the effects of the N treatment on the crop
- EMI and ERT provide high-throughput informations about below-ground processes that if dominated by crop response can help to select more resilient varieties