Use of proximal and remote sensing datasets to characterize subsurface soil structures to improve crop productivity

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patchCROP

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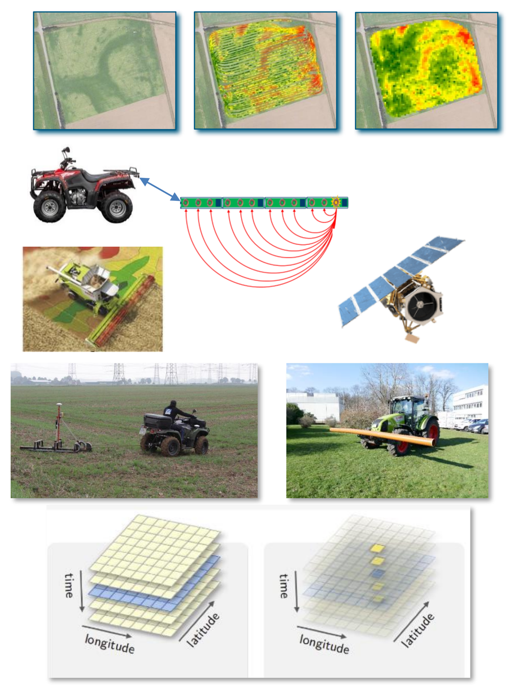
Introduction

Proximal soil sensing through Electromagnetic Induction (EMI) measurements and remote sensing tools both have shown promising results in investigating above and below-surface structures towards precision agriculture.

To derive management zones to support precision agriculture, a comprehensive understanding of the temporal variability of soil properties and crop characteristics within a field is crucial. This work aims to develop innovative observation technology for analyzing above and below-surface variability and characterization by utilizing near-surface geophysical EMI measurements, high-resolution earth observation data, and in-situ datasets to delineate site-specific management zones. The study is divided into three work packages with the following research objectives:

- Investigate and map the within-field influences of subsurface soil patterns.
- Assess the relationship between NDVI and EMI measurements.
- Delineate agricultural management zones by combining multi-source datasets.
- Development of EMI measurement technology to allow data acquisition in the presence of crops using a tractor-mounted system.
- To monitor and understand how soil conditions evolve over-time in different seasons.



Study site and datasets

- This study is conducted at the patchCROP experimental site in Tempelberg, Brandenburg **(Figure. 1)**.
- A large 70 ha field was divided into 30 smaller fields of 0.5 ha (72m x 72m) by considering the small-scale heterogeneity, defined as patches.

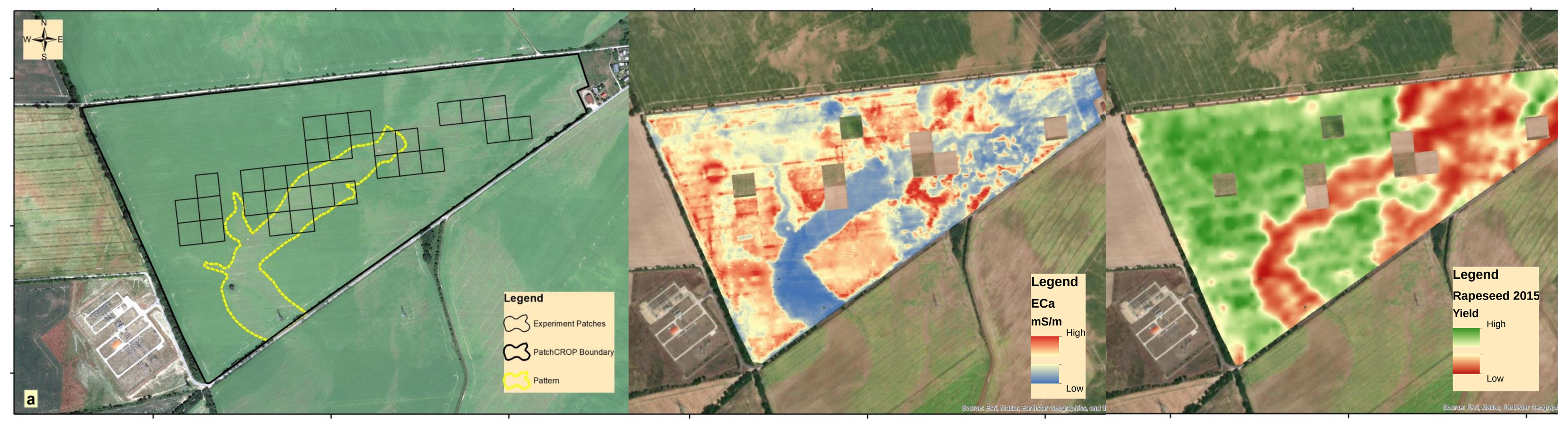


Figure 1(a) shows the study area with 30 small patches, yellow line shows the pattern. (b) shows the apparent electrical conductivity. (c) shows the yield map of Rapeseed.

- In this study high-resolution above and ground datasets are used to derive management zones to improve sustainable crop production **(Table. 1)**.

Table 1: List of datasets used in this work

Data	Detail	Source
Electromagnectic Induction (EMI)	CMD- mini explorer 2 devices with HCP / VCP configuration (6 coils/ 3 coils separation)	IBG-3
Remote Sensing	Planetscope NDVI (3-meter spatial resolution)	ZALF
Yield maps	Yield data collected through combine harvester	ZALF

Preliminary results

Proximal soil sensing based high resolution map

The EMI measurements on the patchCROP field were conducted in three series between August 2022 and 2023.

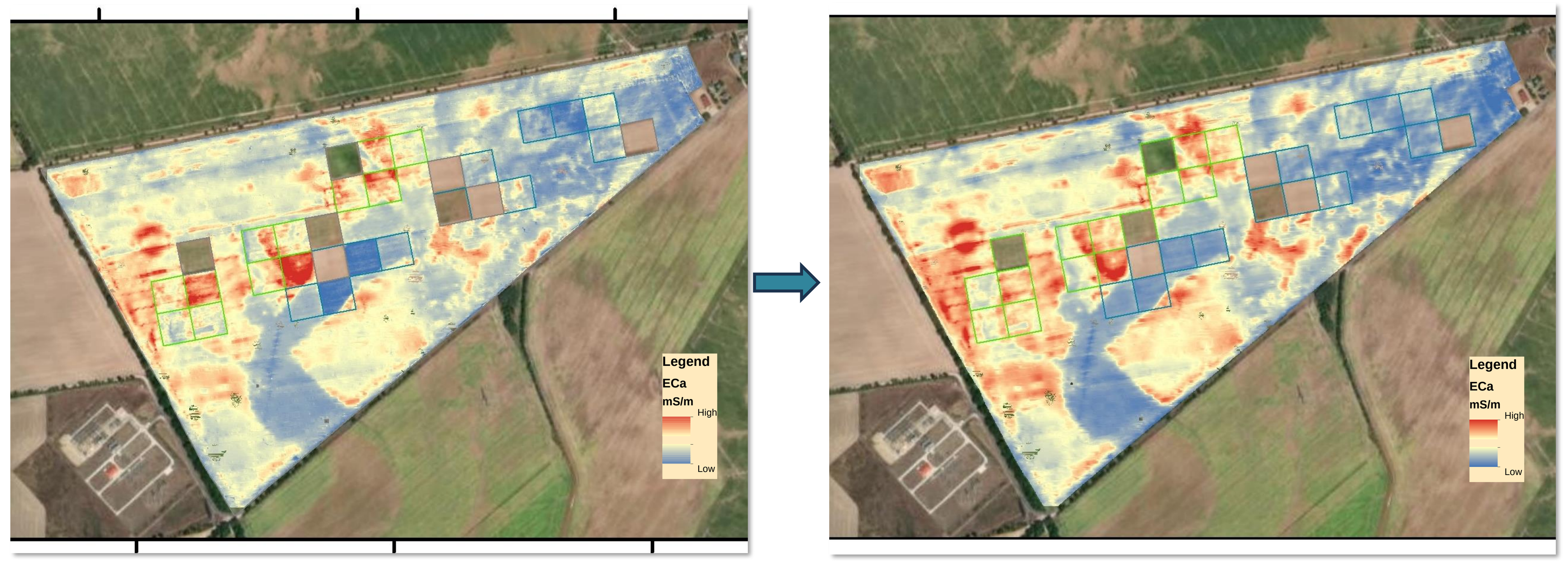


Figure 2(a): The filtered EMI measurements after combining data. (b): The EMI measurements after the normalization.

For each field campaign, a z-transformation normalization technique was applied to standardize the EMI data from different times to a consistent scale for further processing **(Figure. 2)**. After normalization and interpolation, a multiband raster was created using apparent electrical conductivity (ECa) maps with increasing coil separation **(Figure. 3)**. Unsupervised classification was performed to create clusters. Initial experiments were performed for the HCP mode.

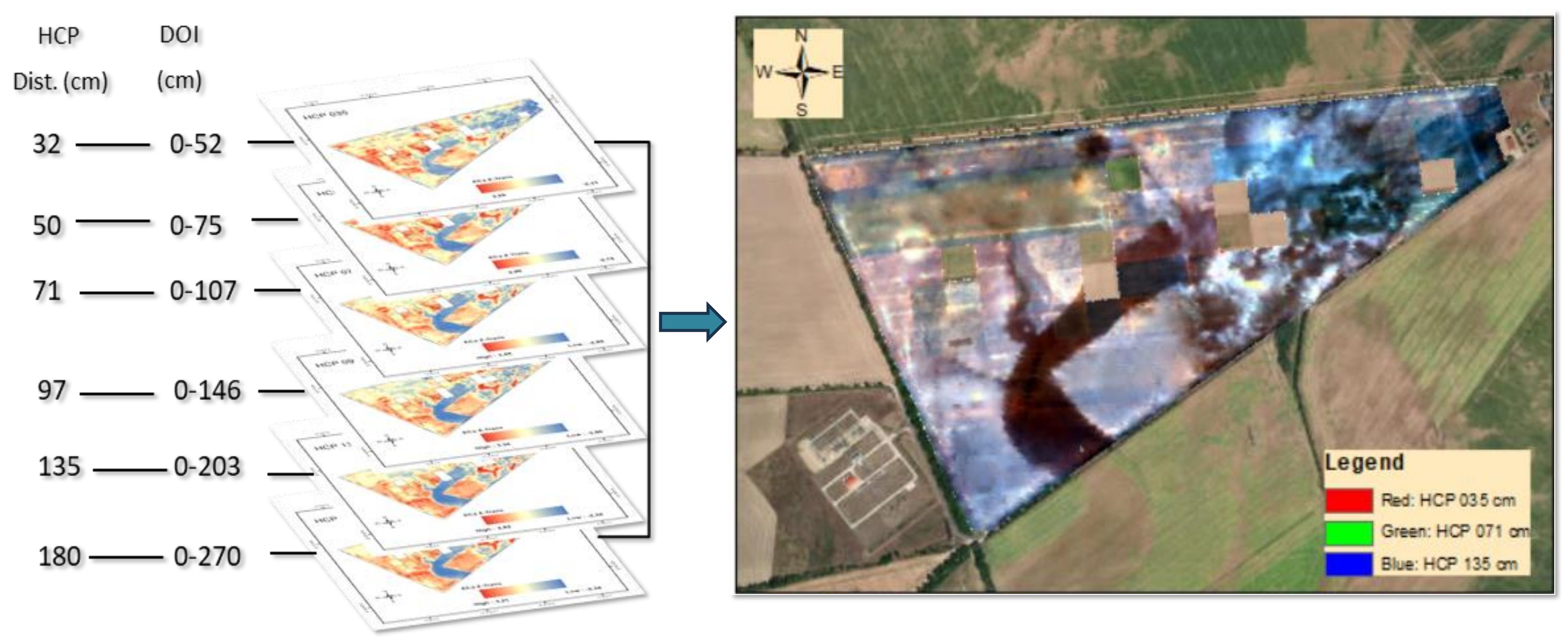


Figure 3: creation of multiband raster for both configuration (HCP) and (VCP) from ECa interpolated maps.

PlanetScope NDVI

High-resolution planetScope imagery is used to derive Normalized Difference Vegetation Index (NDVI) to analyze crop performance and combine this with EMI for clustering analysis. NDVI time series of 2019 was extracted when winter rye was sown **(Figure. 4)**.

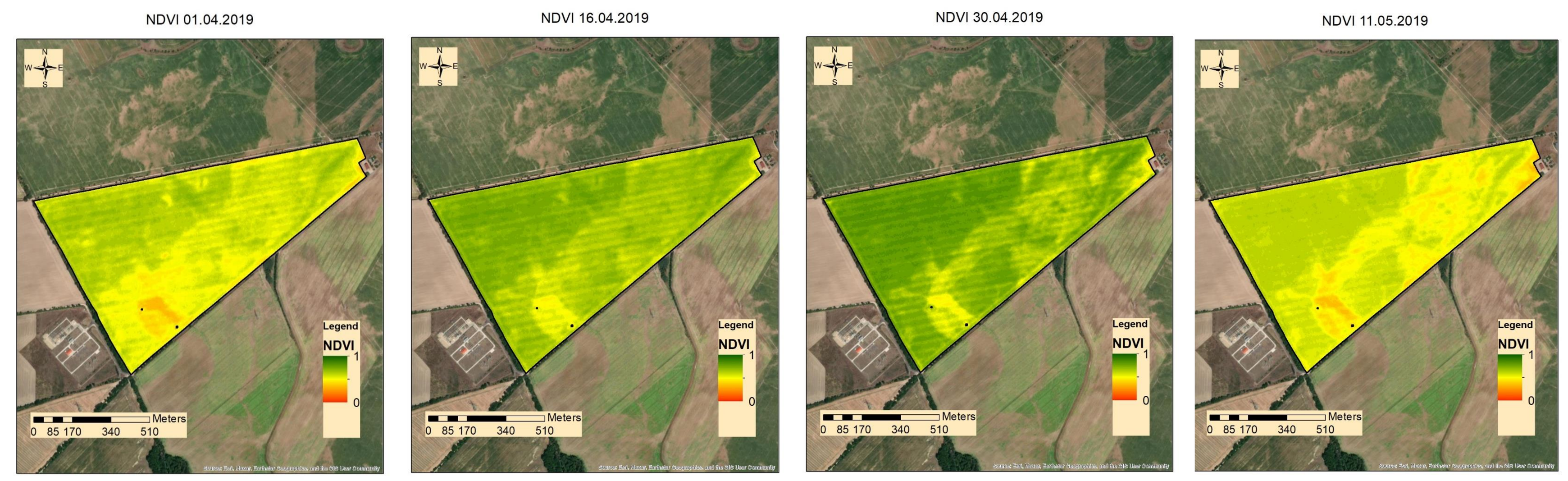


Figure 4: Patterns in NDVI of winter rye 2019 during growing season.

EMI – Yield relations and classification

- 3 clusters were created using an unsupervised classification algorithm using EMI and yield maps, further analysis is in progress **(Figure. 5)**.
- R^2 was analyzed between ECa and Rye Yield / NDVI **(Table. 2 / Figure. 6)**.

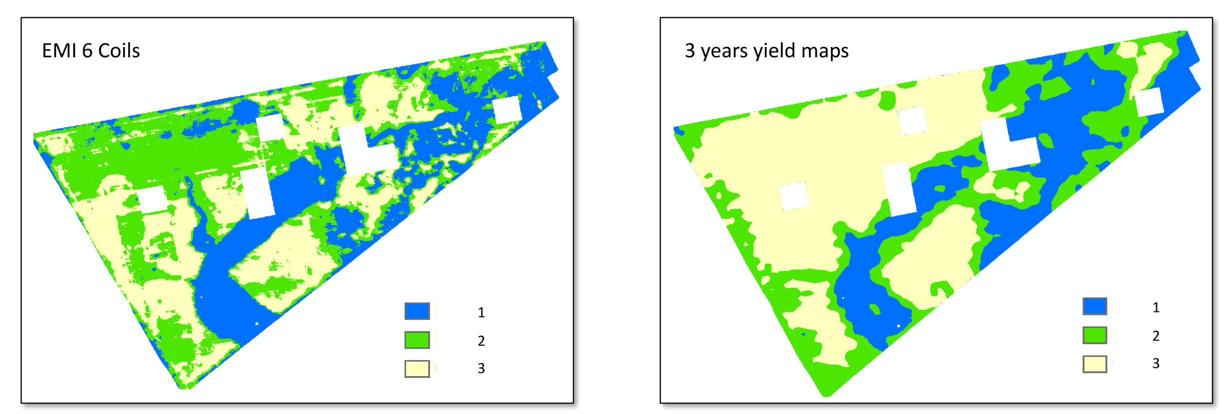


Figure 5: Unsupervised classified maps with 3 clusters

Table 2 shows the R^2 result between ECa and Yield/ NDVI

Data	Time	C1 (0-52)	C2 (0-75)	C3 (0-107)	C4 (0-146)	C5 (0-203)	C6 (0-270)
Yield Winter Rye	2019	0.33	0.30	0.21	0.15	0.10	0.10
NDVI	30.04.2019	0.31	0.34	0.28	0.21	0.17	0.18
	12.06.2019	0.39	0.36	0.27	0.20	0.14	0.13
	24.06.2019	0.31	0.32	0.23	0.15	0.11	0.10

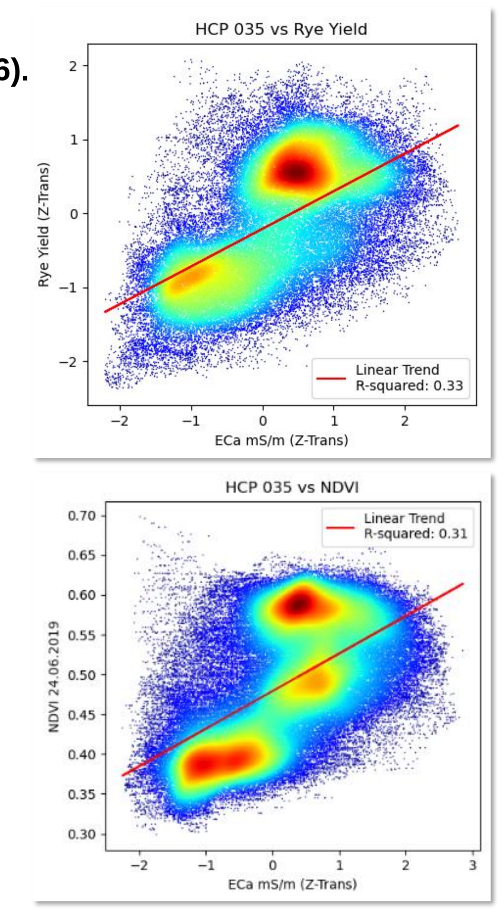


Figure 6: Linear regression of EMI measurements with Yield and NDVI.

Outlook

- Regression analysis will be performed to assess the relationship between EMI, Yield, and NDVI.
- Selection of representative NDVI images for clustering analysis.
- Clustering for different combinations of the available datasets.
- Test different classification methods and find the optimal number of clusters from algorithms.
- Process and analyze the EMI measurements obtained through prototype EMI system.

Reference

Large-scale soil mapping using multi-configuration EMI and supervised image classification. *Brogi, C., Huisman, J. A., et al., (2019)*

Simulation of spatial variability in crop leaf index and yield using agrosystem modeling and geophysics-based quantitative soil information. *Brogi, C., Huisman, J. A., et al., (2020)*

Toward high-resolution agronomic soil information and management zones delineated by ground-based electromagnetic induction and aerial drone data. *von Hebel, C., Reynaert, et al., (2021)*

An agricultural diversification trial by patchy field arrangements at the landscape level: The landscape living lab "patchCROP." Aspects of Applied Biology, Intercropping for sustainability *Grahmann, K., Reckling, M., et al., (2021)*

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