Quantifying and modeling spatio-temporal crop growth variability at field scale

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Hypotheses

1. Crop growth patterns are directly influenced by soil variability which can be detected with soil electrical conductivity measurements

2. Crop growth simulations must consider these structures to be improved at field-scale

Heterogeneity in crop growth, often caused by contrasting soil properties (Fig. 1), is difficult to model not least due to limited data availability. Measurements of the apparent soil electrical conductivity (EC_a) have been proposed to obtain spatially consistent information about soil heterogeneity but have rarely been set into relation to plant measurements. Little work has also been done in validating crop models with respect to their ability to characterize the effect of environmental heterogeneity on crop growth. The aim of this study was to relate EC_a with the green leaf area index (GLAI) and to validate a crop model with respect to its ability to reproduce the spatial variability of GLAI of two crops during vegetation periods in Germany.

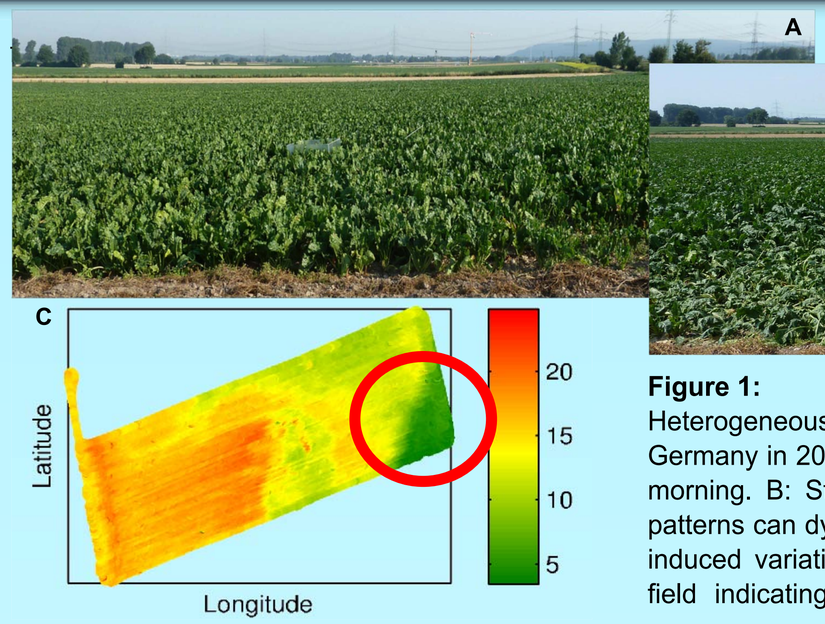

Figure 1:
Heterogeneous patterns of crop growth in a sugar beet field in Germany in 2012 during a stress period. A: Unstressed crop in the morning. B: Stressed crop in the afternoon. Crop heterogeneity patterns can dynamically change during the day due to soil pattern induced variations in water availability C: EC_a map of the same field indicating an EC_a pattern identical with the crop growth

Experimental Setup and Results

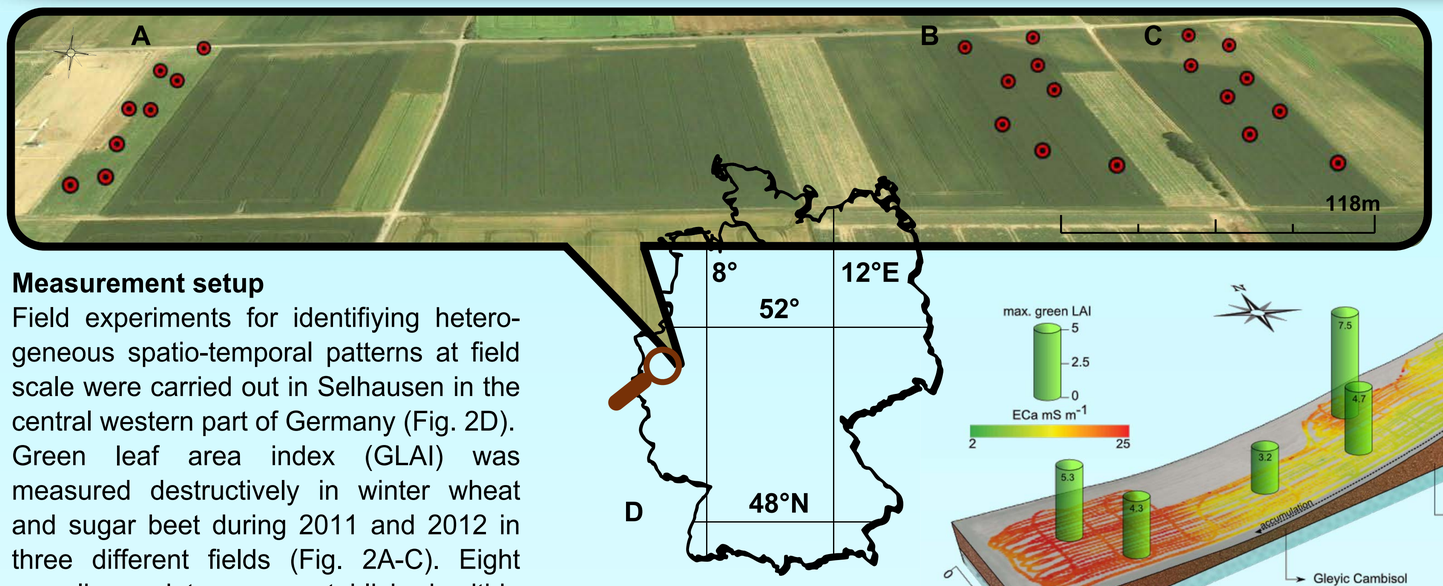

Figure 2:
The different test sites at Selhausen with the respective sample points. A: winter wheat 2011 and 2012, B: sugar beet I 2012, C: sugar beet II 2012, D: Map of Germany showing the location of the study area.

Measurement setup
Field experiments for identifiying heterogeneous spatio-temporal patterns at field scale were carried out in Selhausen in the central western part of Germany (Fig. 2D). Green leaf area index (GLAI) was measured destructively in winter wheat and sugar beet during 2011 and 2012 in three different fields (Fig. 2A-C). Eight sampling points were established within each field which represent the range of different soil types in the fields. Measurements of apparent soil electrical conductivity (EC_a) indicating soil water holding capacity were carried out in March 2012 at these test sites (Figs. 2A-C) for obtaining variabilities in soil conditions. The EC_a data shown in Figs. 1 and 3 cover a soil depth of up to 0.5 m.

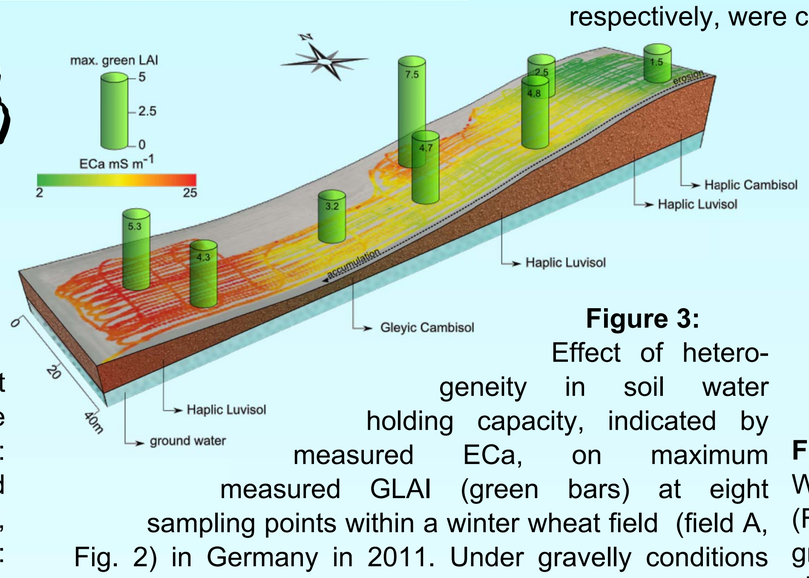

Figure 3:
Effect of heterogeneity in soil water holding capacity, indicated by measured ECa, on maximum measured GLAI (green bars) at eight sampling points within a winter wheat field (field A, Fig. 2) in Germany in 2011. Under gravelly conditions (lwhc, green mapping) GLAI and ECa are considerably lower than in the more loamy part (hwhc, red mapping) of the field

Crop modeling
The Light INTerception and UtiLization simulator (LINTUL2) (van Oijen & Leffelaar 2008), sucessfully used in earlier crop modeling studies, was validated with respect to its ability to reproduce the spatial variabilty of GLAI within a field. The soil model was parameterized for the different soil types measured at the sampling points. GLAI data measured at two sampling points with low water holding capacity (lwhc) and high water holding capacity (hwhc), respectively, were compared with the model output.

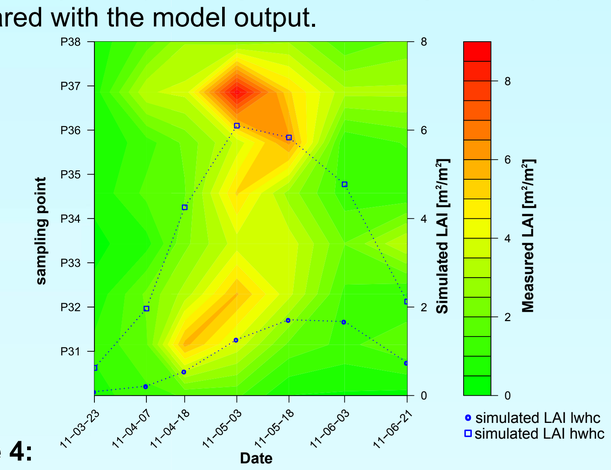

Figure 4:
Within-field variability of winter wheat GLAI in 2011 at field A (Fig. 2). Highest variability was detected during the main growth phase (red colors). The comparison of measured and simulated GLAI for 2011 for two sampling points in a winter wheat field showed that LINTUL2 is able to reproduce the GLAI dynamics at the selected sampling points characterized by a soils with hwhc and lwhc, respectively.

Conclusion and future work

- GLAI correlates with EC_a for winter wheat and sugar beet crops, indicating thereby that differences in soil properties affect GLAI (Figs. 3, 4).
- Crop models applied to heterogeneous fields need to be validated for different parts of the field similar as shown in Fig. 4.
- Sources of inaccurate simulations need to be further investigated. The application of more detailed models such as GECROS could be also considered to test whether simulation errors are reduced.

References

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