Modeling crop growth heterogeneity patterns using soil electrical conductivity maps

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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 field heterogeneity on crop growth. The aim of this study was to relate the EC_a method with measurements of 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 two different years in Germany.

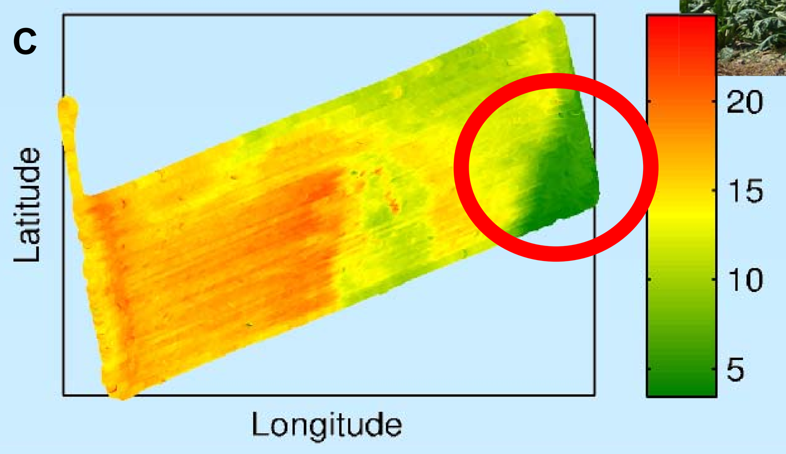


Figure 1: Heterogeneous patterns of crop growth in a sugar beet field in Germany in 2012 during a stress period. A: Unstressed crop in the morning. B: Stressed crop in the afternoon. Under stressed conditions crop heterogeneity patterns are obviously visible due to different soil conditions. C: EC_a map of the same field indicating an EC_a pattern identical with the crop growth pattern.

Experimental Setup and Results

Figure 3: A: RapidEye RGB image of the test sites taken on May 30th, 2011 showing heterogeneous structures at field scale. B: The same RapidEye image as in A overlain with the EC_a maps. EC_a indicates the same spatial patterns like the RGB image.

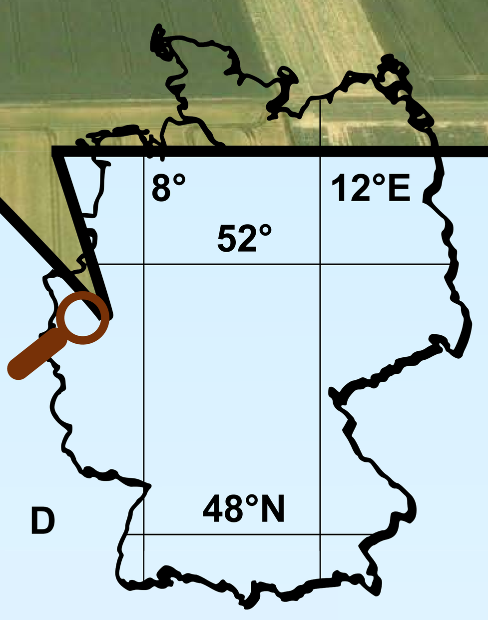


Figure 2: The different test sites at Selhausen with the respective sample points. A: winter wheat 2011 and 2012, B: sugar beet I 2012, C: sugar beet II 2012, D: Map of Germany showing the location of the study area.

Measurement setup

Field experiments for identifying heterogeneous spatio-temporal patterns on 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). Up to eight sampling points were established within each field which represent the range of different soil types in the fields. Measurements of soil electrical conductivity (EC_a) indicating soil water holding capacity were carried out in March 2012 on these test sites (Figs. 2A-C) for obtaining variabilities in soil conditions. The EC_a data shown in Figs. 3 to 5 refers to a soil depth of up to 0.5 m.

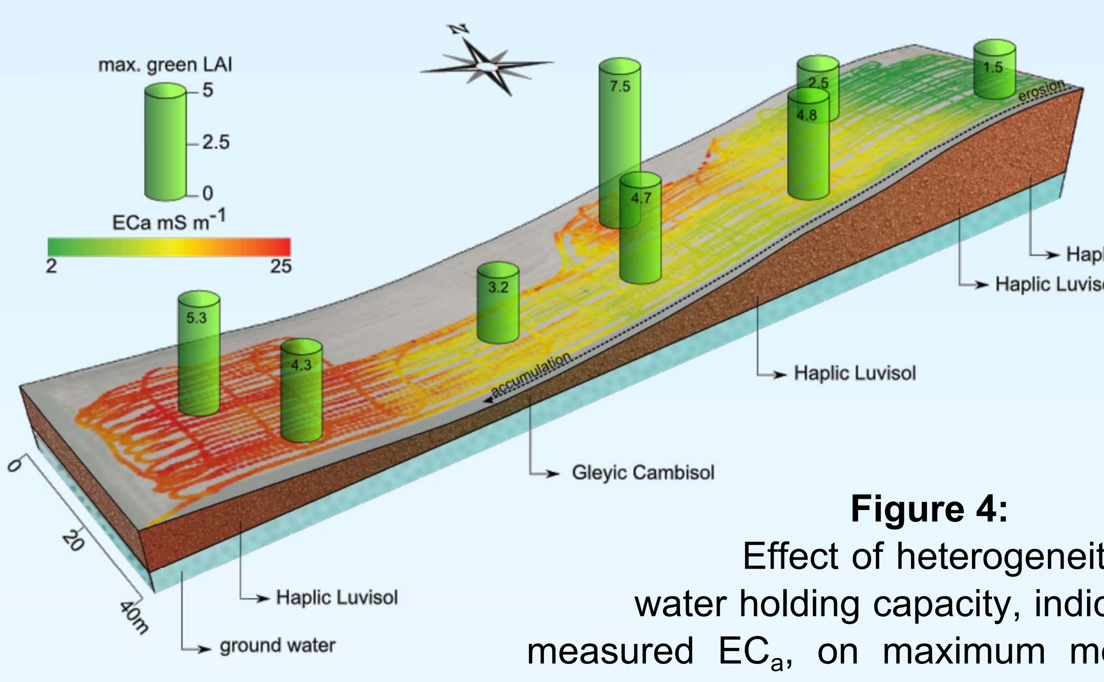


Figure 4: Effect of heterogeneity in soil water holding capacity, indicated by measured EC_a, on maximum measured GLAI (green bars) at eight sampling points within a winter wheat field (field A, Fig. 2) in Germany in 2011. Under gravelly conditions (lwhc, green mapping) GLAI and EC_a are considerably lower than in the more loamy part (hwhc, red mapping) of the field.

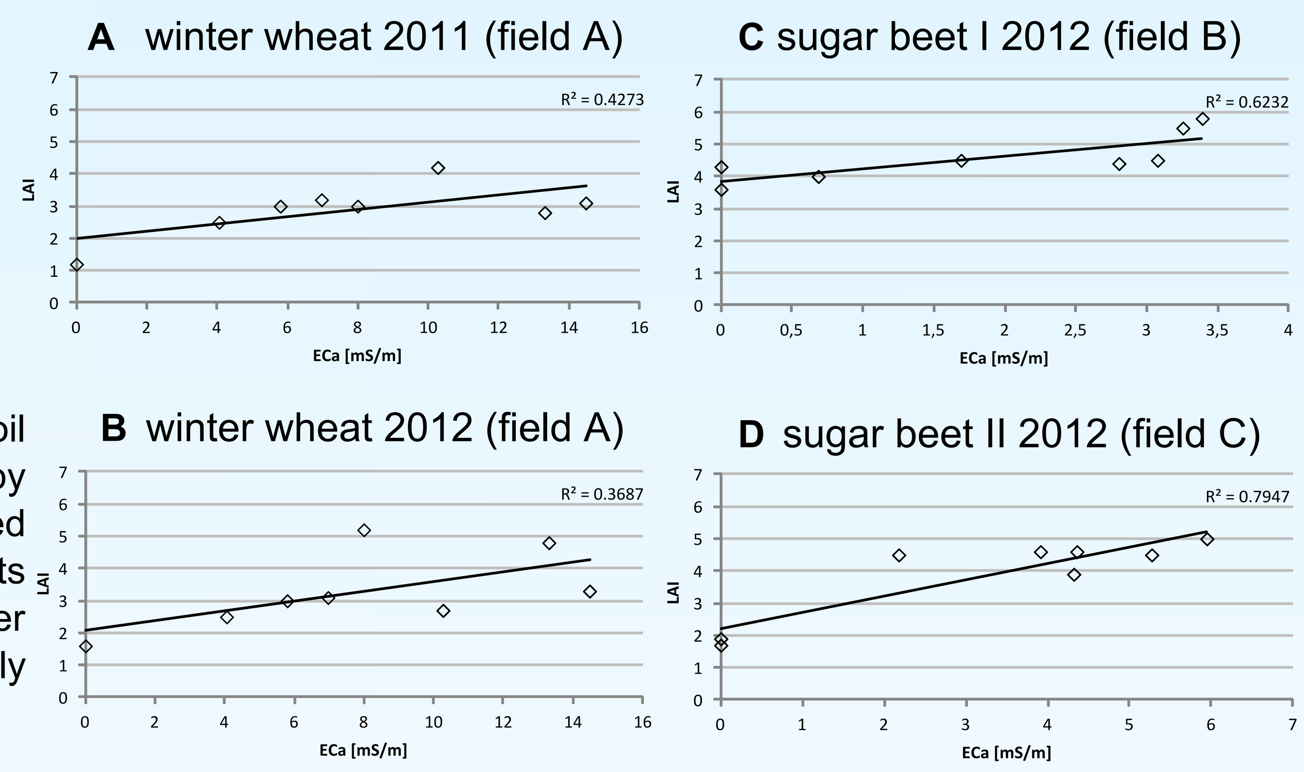
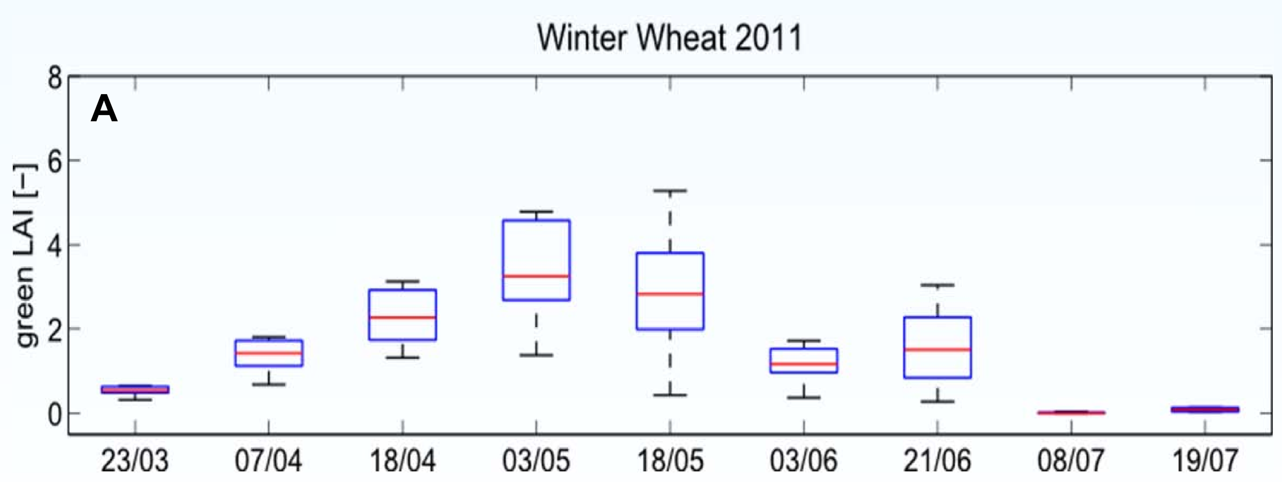


Figure 5: Correlations between measured maximum GLAI and EC_a in fields cropped with winter wheat and sugar beet in Germany in 2011 and 2012. The results indicate that the maximum GLAI of sugar beet has a stronger relation to EC_a than the maximum GLAI of winter wheat.

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 SLIM (Solute Leaching Intermediate Model) (Addiscott et al. 1986, Addiscott & Withmore 1991), coupled with LINTUL2, 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.



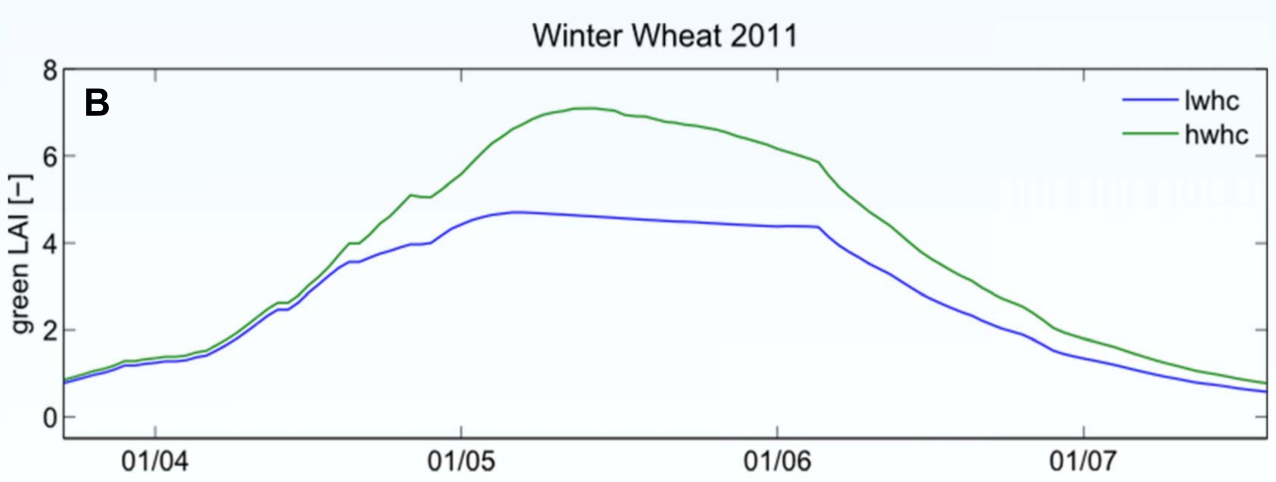


Figure 6: A: Within-field variability of winter wheat GLAI in 2011 at field A (Fig. 2). Highest variability was detected during the main growth phase. B: Comparison of measured and simulated GLAI for 2011 for two sampling points in a winter wheat field (field A, Fig. 2). The results show that LINTUL2 is able to reproduce the GLAI dynamics of the selected sampling points characterized by a soils with hwhc and lwhc, respectively. Simulation results reflect the intra-annual variability patterns found with the measurements.

Conclusion and future work

- GLAI correlates with ECa for winter wheat and sugar beet crops, indicating thereby that differences in soil properties affect GLAI (Figs. 4, 5).
- Crop models applied to heterogeneous fields need to be validated for different parts of the field as shown in Fig. 6.
- Sources of inaccurate simulations need to be further investigated. To which extent more detailed soil and crop physiological models, like GECROS, improve the model accuracy should be tested.

References

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Acknowledgment

This research is part of the Transregional Collaborative Research Center 32 Patterns in Soil-Vegetation-Atmosphere-Systems (TR32), funded by the German Science Foundation (DFG). Special thanks goes to Nils Borchard from the Forschungszentrum Jülich for identifying the different soil types.

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