Field heterogeneity as a crucial factor for improving crop growth simulations

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Introduction

Heterogeneity in crop growth, often caused by contrasting soil properties (Fig. 1), is difficult to measure and to model not least due to limited data availability. Measurements of apparent electromagnetic conductivity (ECa) 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. This study was to relate the ECa 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.

Hypotheses

1. **Crop growth patterns are directly influenced by soil variability which can be detected with soil electromagnetic measurements**
2. **Crop growth simulations must consider these structures to be improved**

Materials and Methods

Field experiments

Field experiments for identifiying heterogeneous spatio-temporal patterns on field scale were carried out in Selhausen in the central western part of Germany (Fig. 2D).

GLAI was measured destructively in winter wheat and sugar beet during 2011 and 2012 in three different fields (Fig. 2A-C). Up to eight sample points were established within each field which represent the range of different soil types in the fields. Measurements of ECa 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 ECa data shown in Figs. 4 and 5 refers to a soil depth of up to 0.5 m.

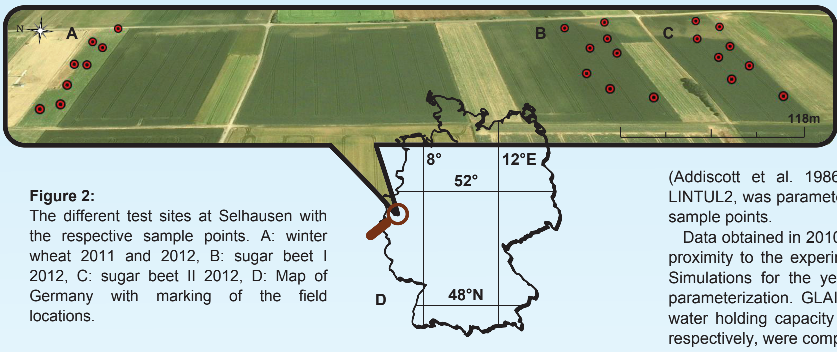


Figure 2:
The different test sites at Selhausen with the respective sample points. A: winter wheat 2011 and 2012, B: sugar beet I 2012, C: sugar beet II 2012, D: Map of Germany with marking of the field locations.

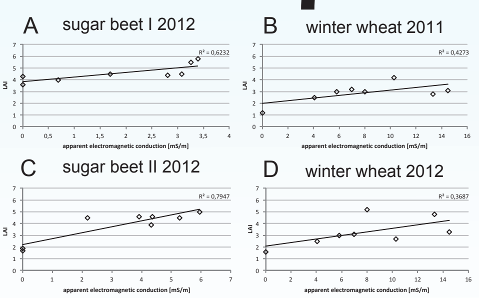
Crop modeling

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 sample points.

Data obtained in 2010 in a winter wheat crop (Fig. 2D) located in close proximity to the experimental sites were used for calibrating LINTUL2. Simulations for the years 2011 and 2012 were carried out with this parameterization. GLAI data measured at two sample points with low water holding capacity (lwhc) and high water holding capacity (hwhc), respectively, were compared with the model results.

Results

Figure 3:
Correlations between measured LAI and ECa for different sample points in fields with winter wheat and sugar beet in Germany in 2011 and 2012. Sugar beet shows a stronger relation to ECa than the LAI of winter wheat.



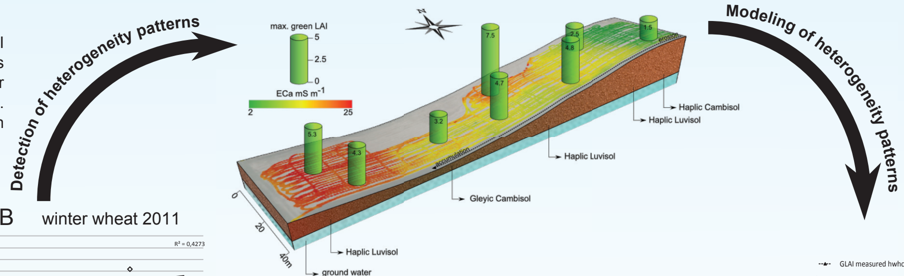
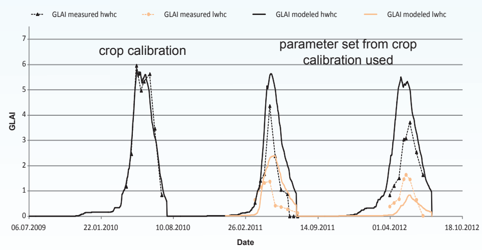


Figure 4:
Effect of heterogeneity in soil water holding capacity, indicated by measured ECa, on maximum measured GLAI (green bars) at eight sample points within a winter wheat field in Germany in 2011. Under gravelly conditions (lwhc, green mapping) GLAI and ECa are considerably lower than in the more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

Figure 5:
Comparison of measured and simulated GLAI for the years 2010 (calibration) and 2011 and 2012 (validation) for two sample points in a winter wheat field. The results show that LINTUL2 is able to reproduce the GLAI dynamics of a selected sample point characterized by a soil with hwhc. The site-specific parameterization of the soil model leads to improved results at the point with lwhc. However, the results of this study show that also season specific influences have to be considered.



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. 3, 4).
- Crop models applied to heterogeneous fields need to be validated for different parts of the field as shown in Fig. 5.
- 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.

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Acknowlegment

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 Sebastian Rudolph of the CROP.SENSe.net project for providing the ECa measurement data and to Nils Borchard from the Research Center Jülich for identifying the different soil types.

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