Identification of problem grids within a wheat and corn field by the implementation of a process-oriented precision farming crop growth model

Johanna Link[1], William David Batchelor[2], Simone Graeff[1], Wilhelm Claupein[1]

[1] Department of Crop Production and Grassland Research
University of Hohenheim
Fruwirthstr. 23
70599 Stuttgart
jlink@uni-hohenheim.de
graeff@uni-hohenheim.de
claupein@uni-hohenheim.de

[2] Agricultural and Biological Engineering
Mississippi State University
105 Lloyd Ricks
P.O. Box 9760
MS 39762, USA
bbatchelor@abe.msstate.edu

Abstract: The objective of this study was to use the process-oriented precision farming crop growth model APOLLO to identify problem grids for crop production within a field. The model was calibrated for a wheat and a corn field. During the calibration process soil parameters were adjusted iteratively for each grid within the fields, using a simulated annealing algorithm. This procedure gave good yield estimates for most of the grids within the fields. However, simulated yields in some grids of the field remained as outliers and thus did not fit the 1:1-line of the model calibration. The data points were categorized based on the standard deviation between measured and simulated yields to identify outliers. Thus the model calibration provided information about soil parameters causing yield variability in some grids and identified grids in the field with unknown reasons for yield variability. Based on these results crop models can be used to identify grids in the field where the variation in yield is not caused by soil properties or other processes incorporated into the crop model.

1 Introduction

Process-oriented crop growth models are often used to simulate crop growth and development over the season at different spatial scales, ranging from field level [Ga99] to region [JJ02]. They are also used to evaluate different management strategies, as nitrogen application rate [Sa04] and timing of sowing [An05] for example. Recently, several researchers have used process-oriented crop growth models to study site-specific yield variability and management strategies [Pa00]. The objective of this study was to use the process-oriented precision farming crop growth model APOLLO [BPT04] to identify problem grids for crop production within a field.

2 Material and Methods

The data for this analysis were based on wheat and corn fields at the Ihinger Hof experimental station of the University Hohenheim. The Ihinger Hof is located north west of Stuttgart (48°74`N; 8°93`E), 490 m above sea level and is characterised as cool and dry climate. The mean temperature is 8.1° C, the mean annual precipitation is about 694 mm and the mean daily solar radiation is about 10.83 MJ m^{-2}. The soil is mainly heavy calcareous brown earth with high clay content; soil texture is described as silty clay and clayey silt. Locally parabrown earths developed and at eroded parts hard rock material is present in small depth. Overall, the soil characteristics vary within the field over short distances.

The selected fields "Mohren" for wheat and "Riech" for corn were grown with different wheat and corn cultivars over a period of three years, respectively. Both fields were managed uniformly using the producer's current management practices. Wheat was planted between October and December with about 350 seeds m^{-2}, and corn was planted end of April with 9,000 seeds ha^{-1}. Fertilizer and pesticides were broadcast on demand. A conventional combine harvester was used for the harvest.

For the purpose of this study both fields were virtually divided into 80 grids. Based on those grids the input files for the process-oriented precision farming crop growth model APOLLO were developed. For the calibration process detailed information about soil, climate, management and site-specific yield data for three different years were needed as input data to the crop growth model. The APOLLO precision farming crop growth model was calibrated for the selected wheat field "Mohren" and corn field "Riech", respectively. During the site-specific calibration process several soil parameters (as hardpan, rooting depth, available soil water) were adjusted over a plausible range iteratively for each grid in the field, using a simulated annealing algorithm. Using this procedure, a unique set of soil properties were computed for each single grid that minimized the root mean square error (RMSE) between measured and simulated yields over the three-year period within each grid. The calibration of the model for wheat and corn was evaluated based on coefficient of determination (R²) and RMSE for measured and simulated yields.

The results of the model calibration were categorized by the standard deviation (Std.Dev.) between measured and simulated yields. Differences in yield data <+/-0.5 Std.Dev. were defined as category 0, <+/-1.5 Std.Dev. as category 1, <+/-2.5 Std.Dev. as category 2 and >+/-2.5 Std.Dev. as category 3. Data belonging to the category 2 and 3 were defined as outliers, indicating problem areas in the field.

3 Results and Discussion

The procedure of model calibration gave good yield estimates for most of the grids within the fields (Figure 1). For both fields the soil parameters hardpan, soil available water and rooting depth were considered as yield limiting factors in the calibration process. As shown in the results these parameters explained about 69 % of yield variability within the wheat field and about 85 % of the yield variability within the corn field.
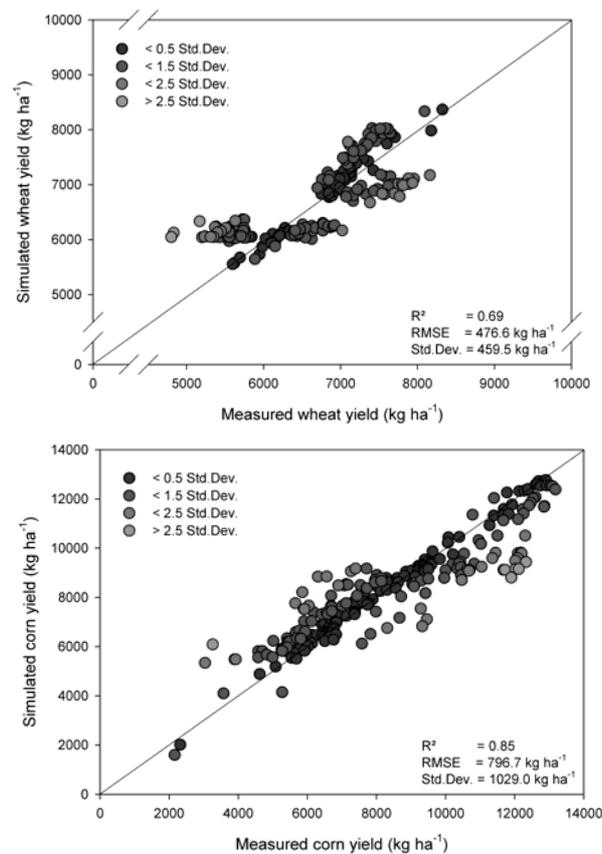

Figure 1: Site-specific calibration of predefined soil parameters for the wheat field „Mohren" (top) and the corn field „Riech" (down) using three years of base data.

In the wheat field about 27 % of the yield data fell into Category 0 and about 60 % in Category 1, indicating a good calibration for the wheat field. For the corn field similar results were found. About 50 % of the data fell in Category 0 and about 36 % in Category 1. However, simulated yields in some grids of the field remained as outliers and thus did not fit the 1:1-line of the model calibration. Less than 15 % of the yield data were categorized as outliers (Category 2 = 12.1 %, Category 3 = 1.3 %) in the wheat field. In the corn field Category 2 contained 12.5 % of the data and Category 3 about 2.5 %, thus 15 % of the grids were categorized as outliers.

4 Conclusion

Based on the results of model calibration, two different kinds of conclusions could be drawn. On the one hand the yield data points close to the 1:1-line seem to belong to grids within the field where the yield variability was very likely caused by the predefined soil parameters selected for the calibration process. On the other hand the yield data points which remained as outliers in the calibration scenario could be identified as problem grids in the field, without any further information about yield causing parameters. In order to identify the yield limiting factors in those grids, a more detailed investigation of those grids will be necessary.

Beside, the model calibration provided two different categories of information: identification of soil parameters causing yield variability in some grids of the field and identification of grids in the field with unknown reasons for yield variability. We conclude that crop models can be used to identify grids in the field where the variation in yield is not caused by soil properties or other processes (e.g. potassium or phosphorous deficiency) incorporated into the crop model.

Literaturverzeichnis

[An05]   Anapalli, S.S.; Ma,L.; Nielsen, D.C.; Vigil, M.F.; Ahuja, L.R. 2005. Simulating planting date effects on corn production using RZWQM and CERES-Maize models. Agron. J. 97.

[BPT04] Batchelor, W.D.; Paz, J.O; Thorp, K.R.: Development and evaluation of a decision support system for precision farming. In: Proceedings of the 7th International Conference on Precision Agriculture. Minneapolis, MN, 2004.

[Ga99]   Garrison, M.V.; Batchelor, W.D.; Kanwar, R.S.; Ritchie, J.T. 1999. Evaluation of the CERES-Maize water and nitrogen balances under tile-drainaged conditions. Agric. Systems 92:189-200.

[JJ02]   Jagtap, S.S.; Jones, J. W. 2002. Adaptation and evaluation of the CROPGRO-soybean model to predict regional yield and production. Agriculture, Ecosystems and Environment, 93:73-85.

[Pa00]   Paz, J.O. 2000. Analysis of spatial yield variability and economics of prescriptions for precision agriculture: a crop modeling approach. Dissertation, Iowa State University, Ames.

[Sa04]   Saseendran, S.A.; Nielsen, D.C.; Ma, L.; Ahuja, L.R.; Halvorson, A.D. 2004. Modeling nitrogen management effects on winter wheat production using RZWQM and CERES-Wheat. Agron. J. 96:615-630.