7.3 Understanding and Predicting Field-Scale Spatial Variability of Wheat Growth and Yield

Investigators: Ole Wendroth, Dennis Egli, Eugenia Pena-Yewtukhiv, and Greg Schwab - Plant and Soil Sciences

Introduction:

Within agricultural landscapes and within individual fields, crop yield varies tremendously although fertilizer nutrients and pesticides were applied homogeneously across the field. Moreover, the fact that for the same field site, the spatial crop yield pattern is not stable during subsequent years complicates the situation considerably.

In the past, precision farming has mainly been dedicated to the issue of deriving local response functions to various fertilizer or pesticide application rates. The explanation of inherent crop yield variability due to variations in the topography, local water conditions, differences in microclimate has only been addressed in a few attempts.

Since crop growth factors causing are so complex, it is difficult to isolate them. A way of accounting for the complexity of plant growth processes is to apply a computer program that simulates crop growth, such as the DSSAT model. In this model, water and nutrient dynamics are described. Providing adequate weather information to the model, the development of biomass through the growing season can be described. However, the model cannot reflect site specific biomass production due to the complexity of the various processes.

Therefore, in this project, we want to incorporate observations of the site specific vegetation status, as these already integrate the complex history of site specific biomass production. For example, if local soil conditions, microclimate, intermittent air deficiency and many more factors caused a delay in crop development at early stages in some zones within the
field, the following crop development will always be affected by early stage differentiation. The model does not adequately reflect this early-state crop variability and will therefore falsely predict the final crop yield. If instead simple observations can be taken that adequately reflect the spatially differing crop development, an important additional input can be given to the model, and the following calculations will be based on a spatially differentiated pattern. Conceptually this is what the farmer does when he meets decisions for managing locally varying crop stands that were for example affected by locally unfavorable growing conditions during winter time.

The key hypothesis of this study is: Simple observations during the growing season can significantly increase crop yield prediction quality and therefore provide key information for better management in terms of saving fertilizer and prohibiting nutrient losses and ground and surface water contamination. Moreover, if conditions for site-specific crop growth simulation can be improved, we provide ample opportunities for using computer simulation models in scenario calculations for environmentally and economically sustainable management decisions.

With its main goal and hypothesis introduced here, this project has a strong emphasis on natural resource management because it aims at improved and measurement-supported model description of ecosystem processes relevant for biomass production. This concept is not only relevant for improving crop management but certainly our understanding of production rates, transport rates of water and solutes in soils, and transformation rates of nutrients and organic matter in soils, that are difficult to measure. The suggested combined model-measurement approach is anticipated to improve our understanding of these processes.

**Objectives:**

Objective 1 is to evaluate relevant indicator variables, e.g., crop sensor measurements (GreenSeaker, HydroN sensor, Leaf Area Index) with respect to the question:
How often and at what stage of the vegetation do we need observations in order to adequately predict crop yield variability at the field scale?

Objective 2 is to modify an existing computer program for crop growth simulation and associated soil processes in order to incorporate observations and update predictions for a more accurate prediction of the final crop yield. One governing question is: How can sensor information (no units, relative index) be converted into an updating coefficient of simulated current biomass (pounds per acre)?

Objective 3 is to transfer the observation protocol from the main investigation site to a neighboring site and validate the approach at a different less intensively investigated field.

**Background:**

The main motivation for precision farming and precision resources management results from the fact, that spatial domains, that have been considered and treated homogeneously for a long time, exhibit a pronounced spatial variability in biomass production for multiple reasons. The heterogeneous pattern of crop yield in a field even resulting under homogeneous management means a dissipation of resources due to over or under fertilization of the crop and an increased risk of leaching salts.

One way to overcome the problem of inappropriate fertilization rates is to determine the response of the crop to various fertilizer application rates in various zones of the field. However, the spatial variability pattern of a crop and the response to different fertilizer application rates in various parts of the field are not consistent over different years. The coincidence of different factors in different years causes a different spatial pronunciation of biomass production and fertilizer response.
As an alternative, in this study we postulate to apply a computer simulation model (DSSAT) for crop growth. Given some soil and weather information, such a computer model calculates local crop growth, water, and nutrient balance on a daily basis until harvest. It is probably impossible to provide sufficient site-specific information to the simulation model to adequately describe local specific processes so that the simulated yield meets the measured yield for all the specific areas within the field. Therefore the following questions will be addressed in the research project:

- Can the simulation of local crop development during the season be improved by updating the simulated growth with some actual crop status observations taken in the field?
- And since we cannot sample and measure local biomass development for many locations in the field, is there a way to derive the local status of biomass development from sensor observations?
- In addition, if sensor observations indirectly reflect the spatial crop pattern in the field during the vegetation, how can the sensor indices (numbers with no physical unit) be transformed to a crop status unit in pounds per acre biomass?

In this project, sensor information will be gained from equipment that has been granted through previous funds within the same program: The HydroN sensor (Dr. Tom Mueller), and the Green Seeker (Dr. Greg Schwab).

With the current state of this technology, we feel comfortable that the measurements of sensors are reliable and relevant. Compared to satellite or airborne remote sensing, vehicle-based sensor observations can be taken at a fine spatial resolution and can be scheduled according to our research needs. Both, the resolution and the scheduling would be prohibitive with satellite or
air-borne remote sensing, and it is rather realistic to anticipate, that vehicle-based sensors will be increasingly used by farmers during their regular management operations.

If remote sensing information can successfully be combined with computer simulations, the computer program will become a valuable tool for the farmer to run different weather scenarios for the remaining part of the season and weigh different fertilization options with respect to the amount and the local distribution.

**Procedures:**

The experiments will be conducted at two field sites on the farm of Donnie and Trevor Gilkey, located in Caldwell County close to the Princeton Experimental Station.

During the first period of the project, the selected field site will be analyzed with respect to the inherent spatial variability based on existing soil and crop yield maps. A detailed survey will yield a digital elevation model. In addition to existing soil information, soil texture will be analyzed on a grid basis with approximately 150 ft by 150 ft sampling distances and additional sampling points with shorter distances in order to obtain a range of structured variability of textural fractions (nested sampling). An available instrument will be used to monitor the electrical conductivity (EC) of the field site. During the winter season, a weather station and 16 soil water content sensor access tubes will be installed according to landscape position. At one access tube, soil water content will be monitored continuously. At the other tubes, soil water content will be measured twice a week with the profiler tube.

In the main vegetation season, NDVI and biomass will be monitored with the GreenSeeker and/or the HydroN sensor. In addition, the leaf area index (LAI) will be measured with the portable Liquor system at specific locations. The final grain yield will be obtained from the farmer’s combine harvester yield monitoring system.
From the beginning of the project, the graduate student will become acquainted with the computer program DSSAT and will learn its features and details. The principal investigator (Wendroth) will provide guidance for the design of updating modules. Different options of updating implementation will be explored and their implications for the simulation of other variables.

In the second year of the investigation, five 150 by 150 ft areas will be defined that remain completely unfertilized. The behavior of measured variables and the capability of the model to address these extreme sites within the field will be critically evaluated. This will also be an examination step for the model performance. Moreover, in the second year, a second site will be investigated where the experimental protocol and the model routine will be evaluated. During the final year of the project, results will be published and the graduate student will write the PhD thesis.

**Expected Benefits:**

One anticipated benefit will result from the adaptation of an existing crop growth model to locally varying field conditions and for better understanding local crop performance. A significant innovation of the approach is the capability of the modified computer algorithm to account for sensor observations of land surface processes (soil and crop status). This provides the opportunity of model-based resources management and will stimulate further precision management research.

The use of remote sensing available from on-farm sensor observations to be added to crop growth models is beneficial to improve the model result, and supports crop yield prediction with many important implications.
Applying the modified crop growth model in nitrogen fertilization decisions will save the farmer about 20 to 40 pounds/acre of nitrogen. It is difficult to determine the monetary benefit of prohibiting ground and drinking water pollution with nitrate, but farmers can prove their responsible management of water resources.

Farmers will gain an improved vision of how to incorporate seasonal weather conditions in their management decisions.

Findings from this project can be used in future projects for the expansion to further crops, e.g. corn (Zea Maize, L.)

**Deliverables:**

- Publication on the modification of the program code
- Publication on the efficiency of various integrative and indicative state variables to the prediction of biomass production
- Publication on the use of simply-observable on-farm variables for improved crop yield prediction
- PhD thesis
- Program module for the updating algorithms, incorporated in the DSSAT computer model.