SOIL MINERAL NITROGEN AND CROP BIOMASS DYNAMICS OF WINTER WHEAT IN SPACE AND TIME IN A FARMER'S FIELD

O. Wendroth[1], G. Schwab[1], D. Egli[1], and L. Murdock[2]
Plant & Soil Sciences Department
University of Kentucky, Lexington[1] and Princeton[2], KY 42445
PH: (859) 257-4768; Email: owendroth@uky.edu

INTRODUCTION

Previous years' results showed that the spatial distribution of grain yield in a farmer's field is related to early season remotely sensed canopy measurements with e.g. the GreenSeeker, HydroN sensor, Leaf Area Index "Canopy Eye", etc. The question remained to what extent optical scanners can reflect nitrogen deficiency situations that could indeed be incorporated into a nitrogen fertilization recommendation.

OBJECTIVE

The objective of this study was to artificially establish different levels of nitrogen deficiency in a farmer's field and to accompany crop monitoring with soil measurements. Finally, a crop growth computer simulation should be tested about its capability of describing crop growth, soil water and nitrogen processes observed in the field.

MATERIALS AND METHODS

The experiment was performed in the wheat field of the farmer Trevor Gilkey, Princeton, which was under winter wheat after corn in the 2008/2009 growing season. The experimental strip is 90 feet wide and approximately 2200 ft long. This strip was monitored at two different growth stages using the GreenSeeker, the HydroN sensor, a new active laser scanner for identifying biomass (ALS sensor), and hand harvest of above ground biomass at different vegetation stages. Along the main strip, six rates of nitrogen between 0 and 150 lb/acre were applied with 50 % at each of two dates, i.e., March 3, and April 5, 09 (Figure 1). These varying amounts of nitrogen were applied to 43 plots each being 45 feet long by 90 feet wide. Hence plots represent an area that could be managed individually or site specifically. Plots receiving different amounts of nitrogen were spatially arranged in a sine-oidal pattern (Figure 1). Along this track, measurements of the red/infrared ratio (RIRR) were taken defined as

$$RIRR = \frac{\rho_{670}}{\rho_{780}}$$

where ρ_{670} and ρ_{780} are the light reflectances of the visible red and invisible infrared light, respectively. Also, a biomass index was measured using the ALS sensor.

The site specific nitrogen was applied and the sensor measurements obtained using a high-clearance platform remote sensing vehicle. This vehicle has adjustable wheel width between 6 and 10 feet and height above ground of up to 7 feet. Thousands of sensor data including automatic yield monitoring were aggregated (60ft width by 24 ft length) around the central location of each of the 43 plots using self-developed software.

What we learn from our experiments:

1. **Canopy reflectance measurements indicate nitrogen deficiency of the crop.**
2. **Reflectance measurements are sensitive to show soil differences that underlie nitrogen deficiency.**
3. **Different reflectance measurements are consistent with each other and with hand harvested biomass measurements.**
4. **The computer simulation model shell DSSAT reflects soil nitrogen processes and crop development in time for different nitrogen fertilization scenarios. The model captures basic processes and its parameterization needs further specification.**

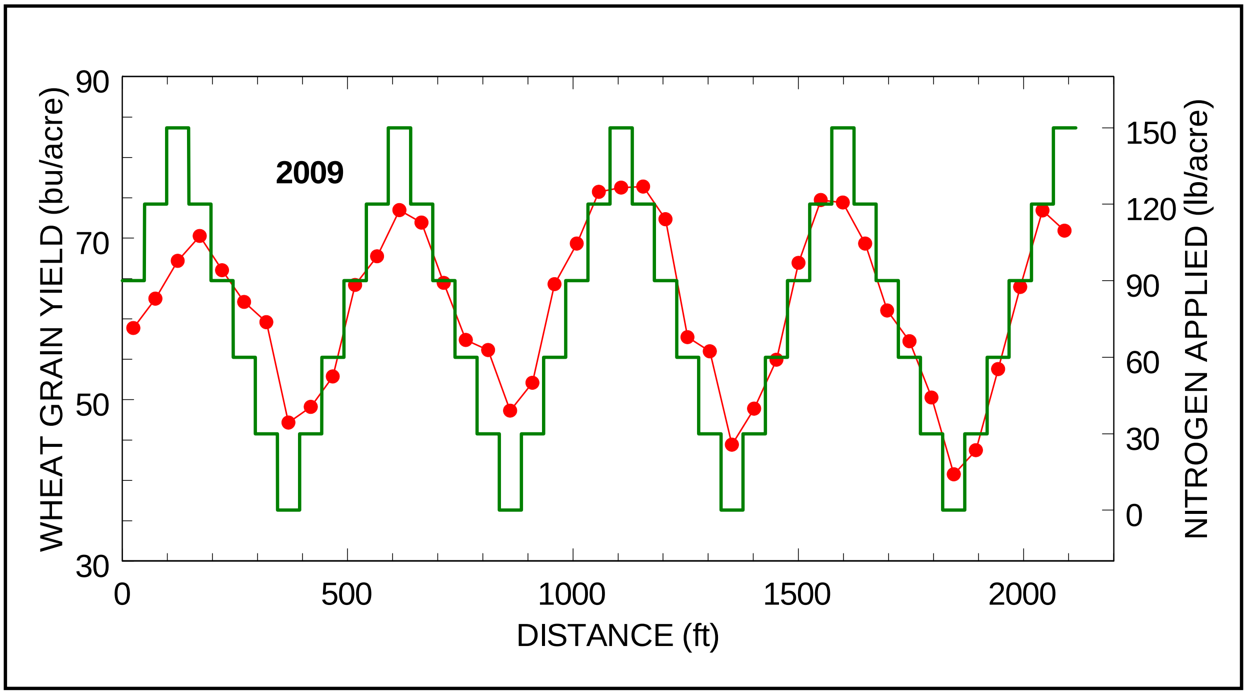

Figure 1. Spatial design of the fertilizer application rate and wheat grain yield measured in summer 2009.

Soil information was obtained using a motor driven soil sampler for soil textural analysis, mineral soil nitrogen and soil water content in each of the 43 plots. Mineral soil nitrogen was sampled at three times, October 1, 2008, i.e., before planting, January 21, 2009, and April 23, 2009.

As a tool to simulate crop growth and ongoing soil dynamics of nitrogen and water, the DSSAT model was used. This model uses soil and agronomic input information (planting, fertilization etc.) as well as daily weather data. The model results are time series of, e.g., aboveground biomass, grain yield, mineral soil nitrogen content and nitrate leaching, soil water content and many other variables (Figure 2).

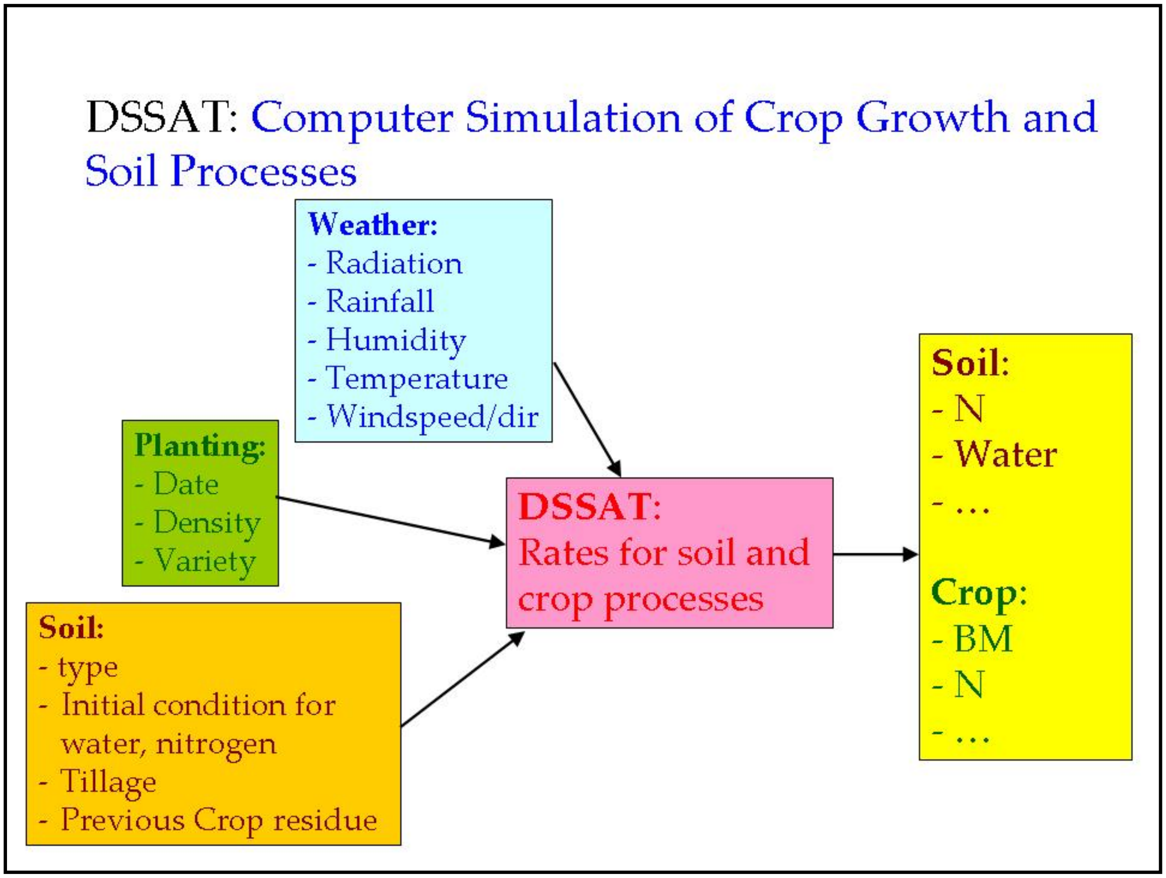

Figure 2. Scheme for the computer simulation model DSSAT used for describing crop growth and soil processes.

RESULTS

Grain yield showed a distinctive pattern overall following the nitrogen application rate (Figure 1). Notice, that there is a slight tendency of decreasing yields from the left to the right hand side of the experimental field. This result was also observed two years ago at a slightly different location along this field. Obviously, the soil quality decreased from the left to the right hand of the field.

The nitrogen demand manifested by the *RIRR* is shown in Figure 3 for two different times in the spring season, i.e., March 21 and April 24, 2009. The nitrogen demand is strongly inversely related to grain yield and nitrogen application pattern. Overall, the demand is much larger on March 21 than on April 24, the latter being measured already three weeks after the second fertilizer application. Notice also, that the indicated demand is increasing from the left to the right hand of the experimental field (Figure 3). This result on the spatial difference of nitrogen demand coincides with the earlier observation of spatial soil changes causing yields to generally decrease from the left to the right hand of the field.

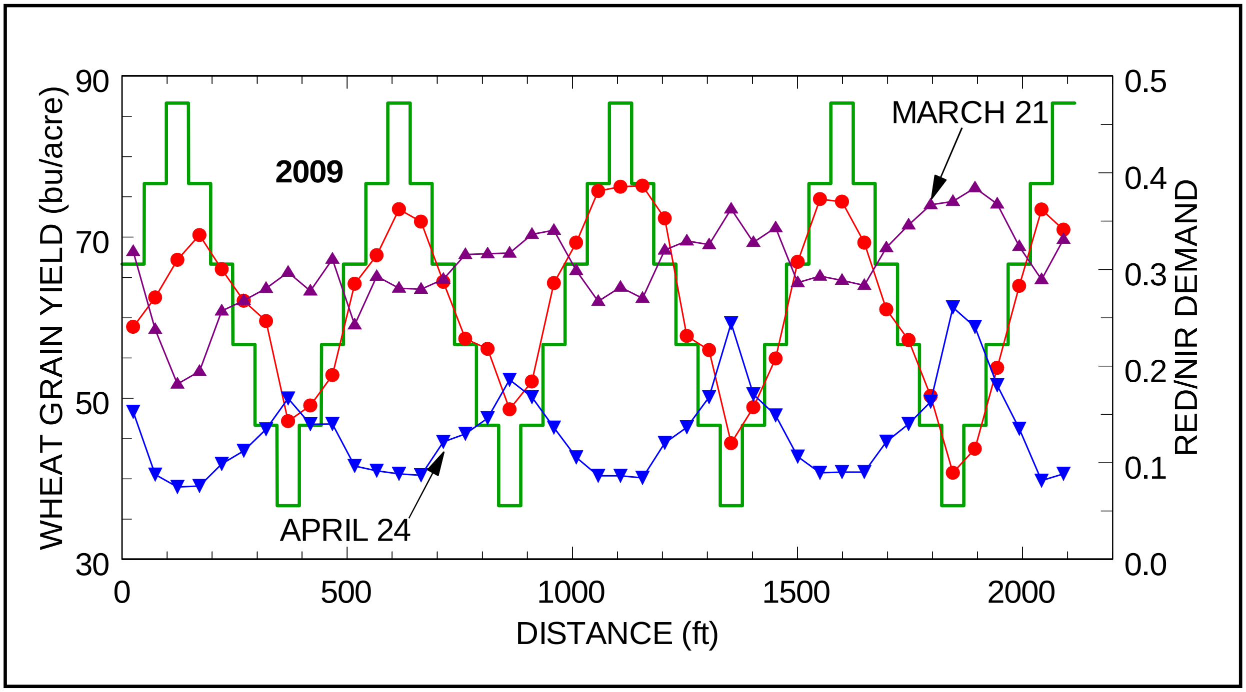

Figure 3. Wheat grain yield, nitrogen application rate and spatial pattern of nitrogen demand, reflected by the RIRR measurement at two different times.

In Figure 4, spatial patterns of biomass measured with the ALS are given for two different times in spring 2009. The results reflect the nitrogen application pattern and are consistent with the grain yield measured later. Spatial differences as well as the overall difference in biomass between the two different times are noticeable. Even the larger growth rate in those plots that received higher fertilization rates can be observed. The biomass measured with the ALS on April 24 was compared to hand-harvest measurements of aboveground biomass. Those hand-harvested were noisier than sensor measurements but overall are strongly related with each other (Figure 5).

What happened to the mineral soil nitrogen? In Figure 6, spatial distribution of mineral soil nitrogen is depicted for three different times, i.e., two days before planting, once in January, and three weeks after the second nitrogen application. The variance of mineral nitrogen along the field was similar for the three different times. In general, nitrogen contents were highest in January. Interestingly, the spatial pattern at three weeks after the second nitrogen fertilizer application, the spatial pattern did not reflect at all the pattern of fertilizer application.

Apparently, it had been mostly taken up by plants. In other words, plants took most of what was there and depleted soil nitrogen down to a relatively uniform level.

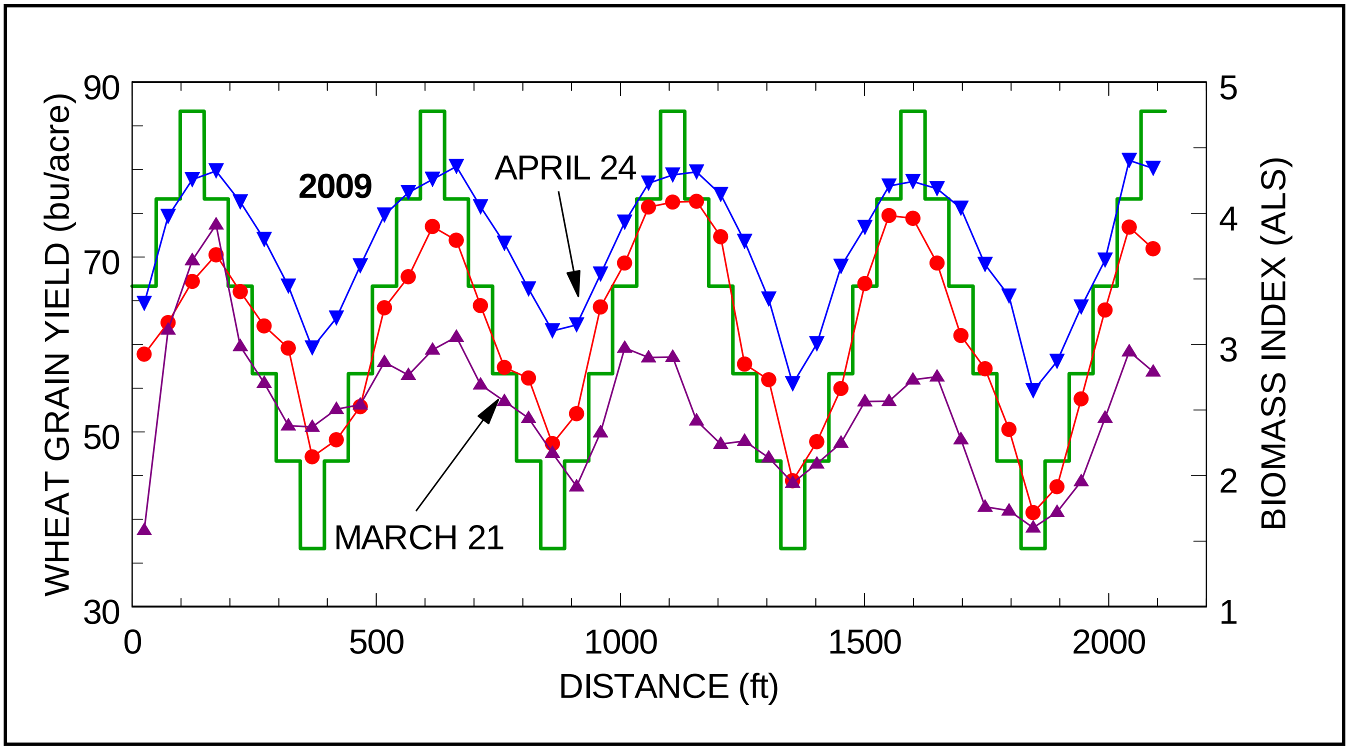

Figure 4. Wheat grain yield, nitrogen application rate and spatial pattern of biomass measured with the ALS at two different times.

In the following, first results of the computer simulation are analyzed and discussed. The model underestimates the aboveground biomass development for the 30 lb/ac N, estimates relatively close to the 90 lb/ac N, and overestimates the 150 lb/ac N scenario. Simulation of grain yield is comparable to measured grain yield for the 30 and 90 lb/ac scenario but is much higher than the measured grain yields in the 150 lb/ac N case (Figure 7).

Probably, the soil nitrogen dynamics are not completely captured by the model as can be seen in Figure 8. Especially during the early growing season mineral nitrogen development in time deviates from measured values from January 21, 2009. The simulation indicates how fast the nitrogen peaks caused by application of fertilizer disappear, probably due to nitrogen uptake. Only the measured mineral nitrogen for the 150 lb/ac N scenario is captured by the model, not the other two cases. If the model were correct, the leaching of nitrogen did not differ much between the different fertilizer rates. Interestingly, the majority of leaching even occurs before any fertilizer is applied as indicated by the nitrate leaching series in Figure 8.

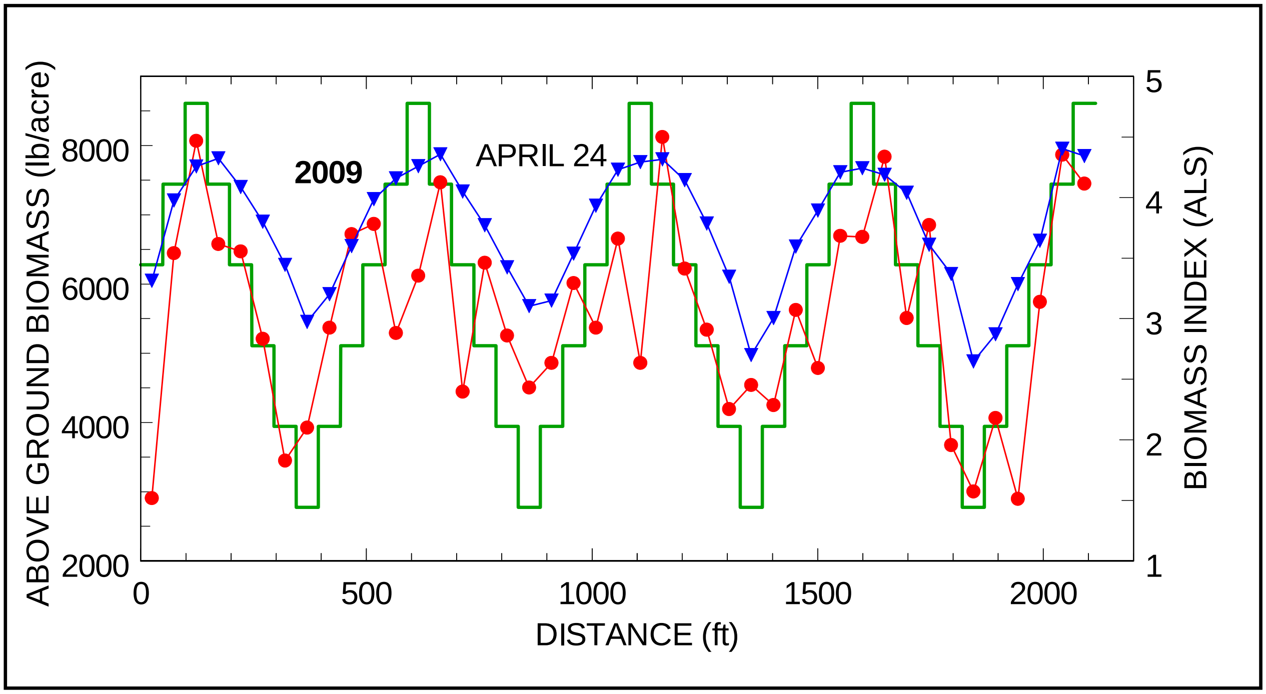

Figure 5. Biomass index measurements obtained with the ALS in comparison to hand-harvested aboveground biomass.

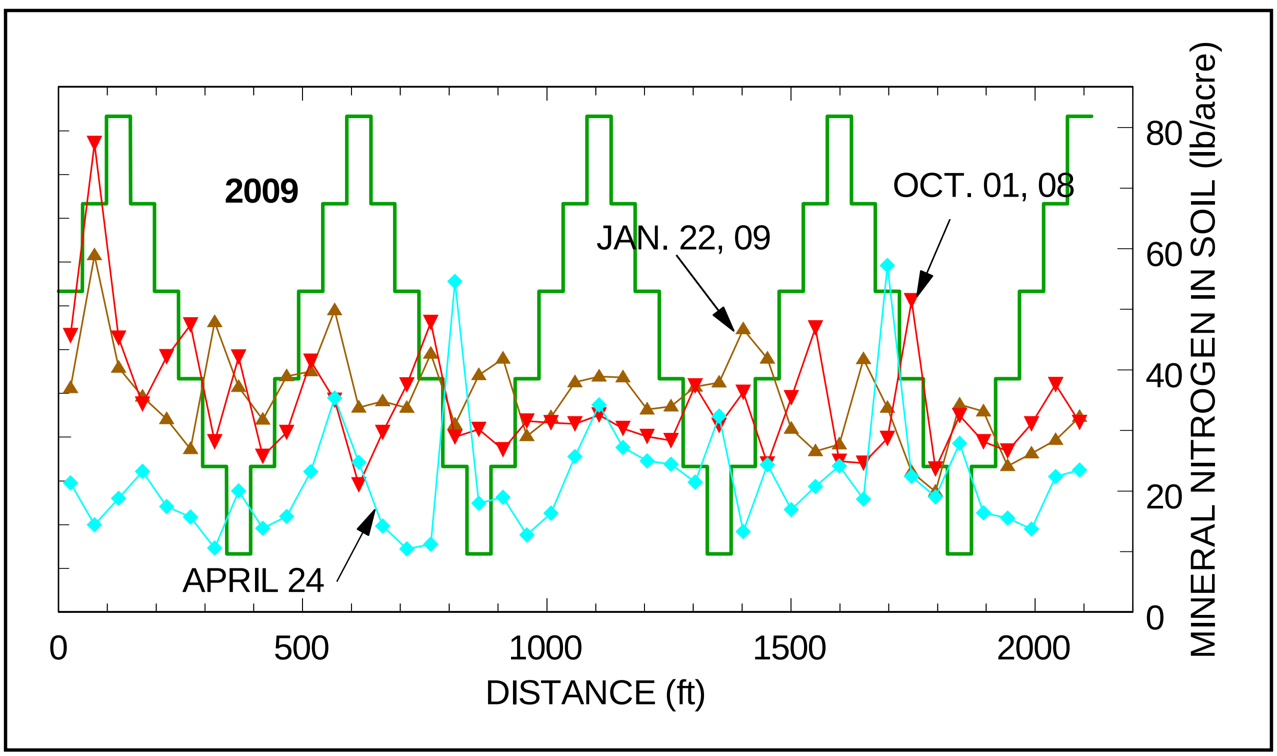

Figure 6. Mineral soil nitrogen distribution along the field, measured at three different times, i.e., shortly before planting and twice in spring of 2009.

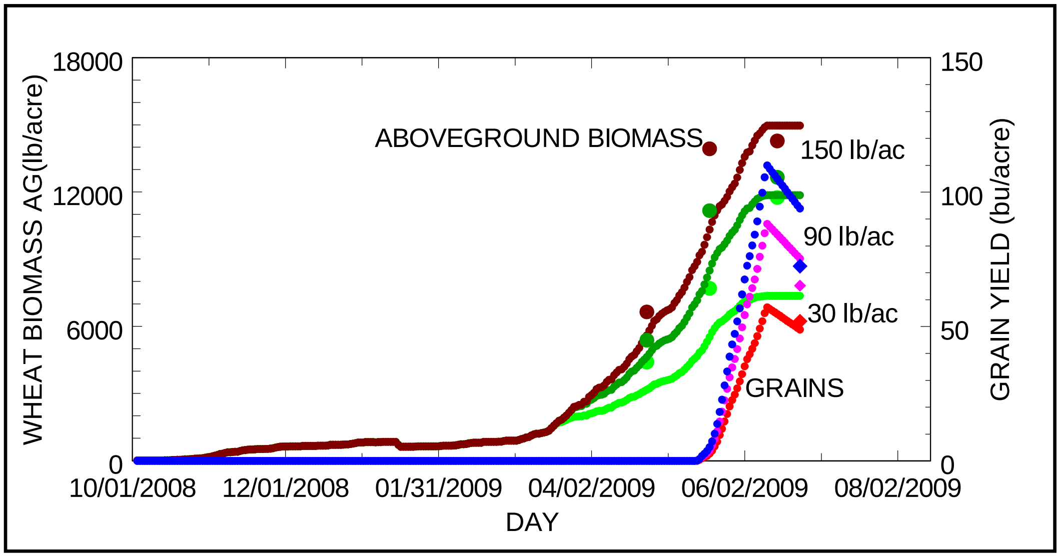

Figure 7. Time series of aboveground biomass simulated and hand measured for the fertilizer application scenarios 30, 90, and 150 lb/ac nitrogen. Simulated grain yields are shown and compared to machine harvested yield.

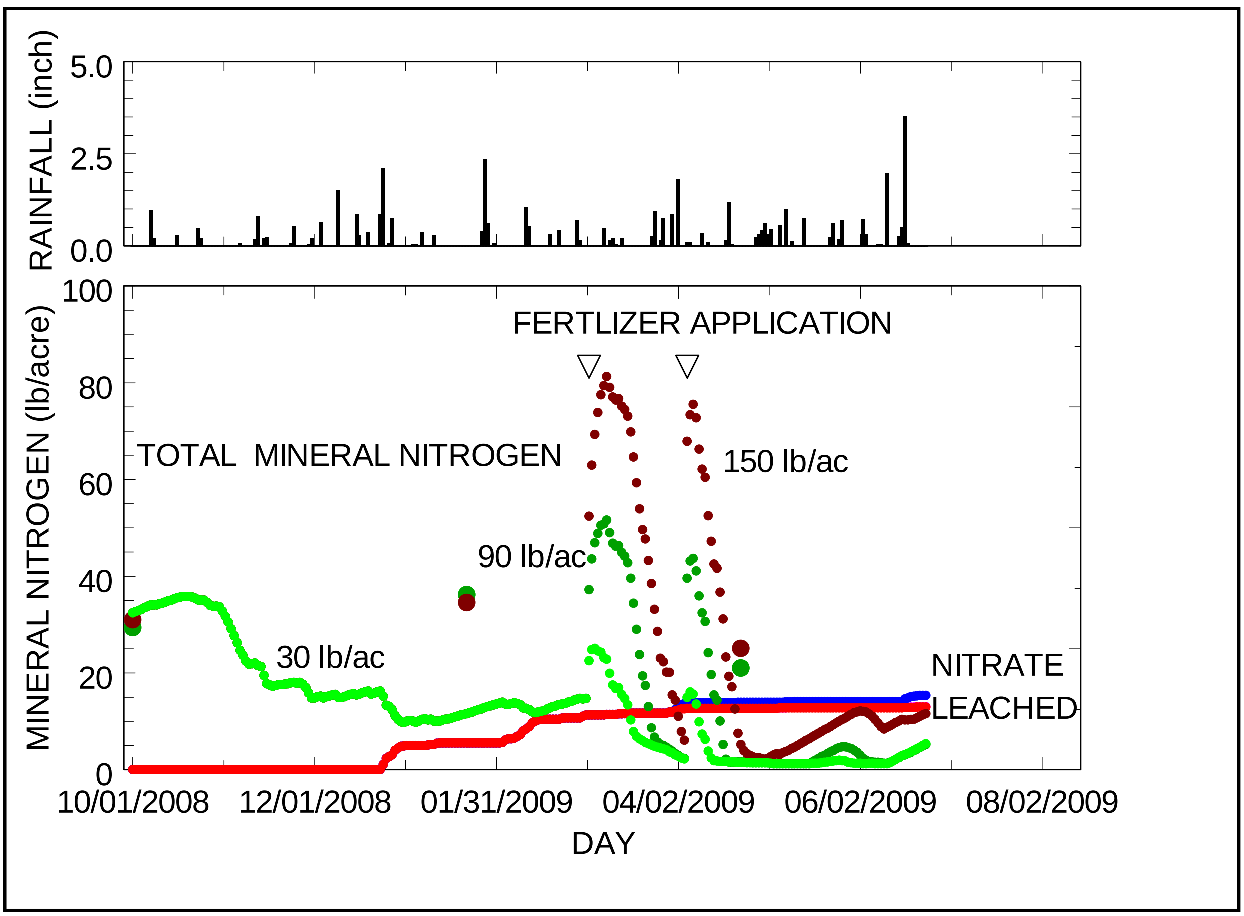

Figure 8. Mineral soil nitrogen in the entire profile and cumulative nitrate leaching during the growing season for the fertilizer scenarios 30, 90, and 150 lb/ac nitrogen.

What is next?

Can sensor measurements and the computer simulation model be usefully combined for crop yield estimation and decisions on of fertilizer application rates?

In the future, our research and field experiments are focused on:
To what extent is the computer simulation model able to capture spatial differences across the field? How detailed does the soil information need to be? How can canopy sensing be implemented in modeling?

ACKNOWLEDGEMENTS
We gratefully acknowledge the Kentucky Small Grain Growers' Association and the UK College of Agriculture for their support. We thank the farmer Trevor Gilkey for helpful cooperation, and R. Jason Walton, James Dollarhide, Ron Curd, and Krista Brown for excellent technical assistance, Tami Smith for the analysis of soil nitrogen samples, and John James for his permanent help. We also thank Dr. Charles Dougherty for providing the GreenSeeker sensors, and Tom Mueller for allowing us to use the HydroN sensor.