IN-SEASON OBSERVATION OF WHEAT GROWTH STATUS IN A FARMER'S FIELD: CONTINUOUS CHANGE OF NITROGEN APPLICATION RATE ACROSS THE LANDSCAPE AS AN ALTERNATIVE TO SMALL PLOT RESEARCH

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Introduction:

When studying the yield response to fertilizer application rate or other managed impacts on yield, the enigma of underlying soil heterogeneity caused by soil formation or a spatially diverging management history make interpretation of results very complicated. Often, spatial variability of soil conditions in the field are ignored, and assumptions of homogeneous soil conditions not valid. Therefore the impact of an imposed treatment cannot be completely separated from soil spatial variability.

Objective:

The objective of this study is to measure and analyse biomass development and grain yield of winter wheat with on-the-go crop sensors in a farmer's field and determine the impact of spatially continuously varying nitrogen application rates on growth and yield while considering underlying soil heterogeneity. This procedure is evaluated in order to demonstrate an alternative method of on-farm research with considering the inherent soil variability 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 2007/2008 growing season. The experimental strip is 90 feet wide and approximately 1480 ft long. This strip and the two neighboring strips managed by the farmer were monitored at two different growth stages using the GreenSeeker, the HydroN sensor, a new active laser scanner for identifying biomass, and a leaf area index meter. Leaf area index (LAI) is the green leaf area per area of ground, e.g., LAI = 3 stands for an area of 3 ft^2 of green leaves growing per 1 ft^2 of ground. Along the main strip, six rates of nitrogen between 0 and 150 lb/acre were applied. These varying amounts of nitrogen were applied to plots being 30 feet long by 90 feet wide. Plots receiving different amounts of nitrogen were spatially arranged in a sine-oidal pattern (Figure 1). Along this track, measurements of NDVI were taken using the GreenSeeker, and the HydroN sensor, as well as for the two neighboring paths which received a homogeneous nitrogen application rate by the farmer.

The site specific nitrogen applications and the sensor measurements were undertaken with a high-clearance platform remote sensing vehicle. This vehicle has adjustable wheel width between 6 and 10 feet and height above the canopy of up to 7 feet.

Measurements in the neighboring paths and in the sine-oidal application strip were analyzed with spatial statistical tools, and special focus was directed upon the spatial representatitivity of measurements, hence, how valid a sensor measurement is and what area in the field it represents. Another focus was to find out, how far apart from each other different properties can be measured while they are still correlated with each other. The spatial models being used for analysis and yield prediction are described in Nielsen and Wendroth (2003).

Soil information was obtained using a motor driven soil sampler for soil textural analysis and soil surface water content. The latter was used as an indicator variable for processes occurring in the profile which are manifested at certain times at the land surface.

What we learn from our experiments:

1. Continuously varying amounts of added nitrogen fertilizer caused a pronounced spatial pattern in wheat yield across the landscape.
2. The response to the cyclic nitrogen application pattern was clearly identifiable with our remote sensors, and can be used for predicting yield distribution patterns.
3. Crop response to fertilizer nitrogen varies across the landscape and our experimental design is capable of demonstrating the impact of underlying landscape variables.
4. The four crop sensors we are using produce reliable results. Our own software package for data aggregation analysis works well for yield monitor and crop sensor data.

<u>Results</u>:

Overall, yield variation of winter wheat in 2007 reflected the wave-like pattern of nitrogen fertilizer application (Figure 1). However, across the entire field, a decreasing yield trend was obvious, especially for the higher nitrogen levels.

Due to the spatially changing results, we concluded that mineral soil nitrogen had no statistically significant effect on wheat yield (see Table 1). However, this result was caused by underlying soil differences, and therefore by a response of wheat yields to fertilizer nitrogen application rate that varies throughout the field.

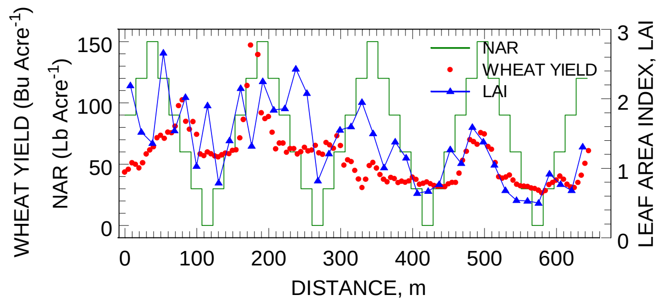

Figure 1. Experimental design of nitrogen application rate (NAR) and resulting wheat grain yield, 2007. Raw yield data were aggregated over 15 ft distance and the resulting averages are presented here.

Table 1: Analysis of variance of wheat grain yield and fertilizer nitrogen rate applied.

ANOVA

Variation	DF	SS	MQ	F_{calc}*	F_{tab}*
Total	41	38296611			
Treatment	5	9793334	1958667	2.47	2.45
Error	36	28503276	791758		

* 5 % level

The experiment in the 2007/2008 season in a different field showed an obvious response to nitrogen fertilizer (Figure 2). Surprisingly, the yields in the zone displayed in the right hand side of Figure 2 were very low, unlike the previous year when this part of the field had the highest corn yields.

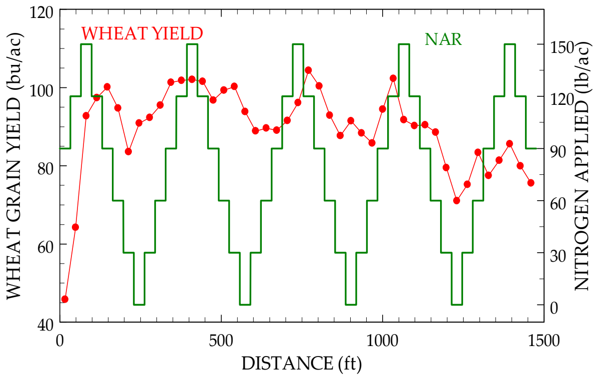

Figure 2. Wheat grain yield and nitrogen fertilizer application rate along the strip in the farmer's field (2008).

We explain this difference with the combination of the weather and the elevation in this landscape (Figure 3): The zone of low wheat yields is in a footslope region of the field with a deep and silty soil profile. In the extremely wet spring of 2008, young plants probably suffered water-logging, and although they caught up in growth later in the growing season when it was warmer and drier, they yielded less than the rest of the field. On the other hand, in the previous very dry year of 2007, the deeper soil profile allowed more water storage, causing higher yields in this area. Whereas the higher elevation locations (tops), with shallower soil profiles and higher clay content below 15 inches depth showed lower yields in 2007, due to water stress, but relatively higher yields in 2008 when water was not limiting unlike in 2007.

The measurements with the new ALS active biomass sensor revealed a good agreement between the pattern of wheat yield and biomass, as shown in Figure 4. The measurements followed the pattern of different nitrogen fertilizer application rates across the field. However, the lower yields in the footslope area were not detected by biomass index sensor measurements. We assume that, at the time of sensing (May 7), more biomass had been produced in this part of the field when growing conditions became more favorable in the late season, but this could not compensate for the stress of excessive water in the spring.

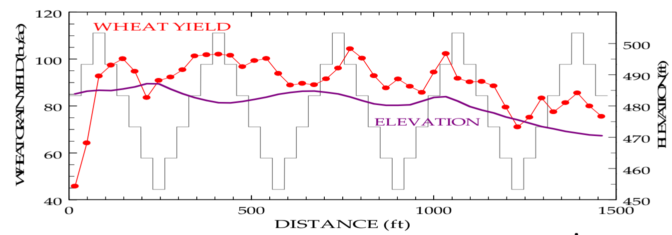

Figure 3. Landscape topography in the experimental strip in the farmer's field.

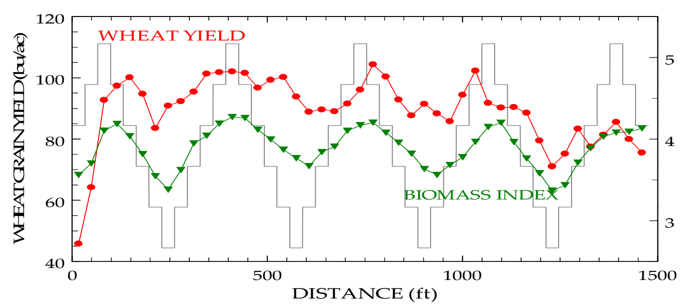

Figure 4. Wheat yield and ALS biomass sensor results along the strip in the farmer's field.

This spring season was extremely wet. We could only get on the field to apply fertilizer relatively late (March 13). In normal years this would already be the time for the second nitrogen fertilizer application. Hence, we applied all the nitrogen at once.

Prior to the nitrogen application, mineral soil nitrogen was sampled at four depth intervals down to 35” depth at all 45 sampling locations. The distribution along the strip is shown in Figure 5 for the first measurement campaign end of February with the bullet symbols. No fertilizer had been applied until that time except some poultry manure in the previous fall.

It is fairly complex to interpret the mineral nitrogen behavior. We would have expected higher nitrogen amounts in the profile in April (Figure 5, triangles). On the other hand, in the month after fertilizer application, plants took up a lot of nitrogen. It remains unclear, whether some nitrogen was lost during heavy rainfall at the end of March/early April. Interestingly, the mineral soil nitrogen increased slightly towards the right hand side of the experimental strip, which is the zone of lower yields. Eventually, the storage is higher in the footslope. There is obviously no relation between the spatial pattern of mineral soil nitrogen distribution, and fertilizer application pattern except for a zone between 600 and 900 ft distance. In general, spatial differences in mineral soil nitrogen caused by the fertilizer application were leveled out, probably by plant uptake.

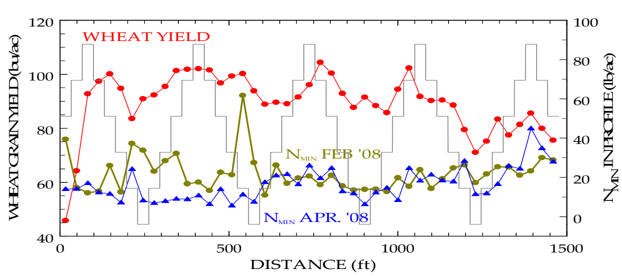

Figure 5. Soil mineral nitrogen (N_{MIN}, nitrate and ammonia) along the strip in the farmer’s field for two dates. The FEB’08 data were sampled two weeks prior to nitrogen fertilizer application, and the APR’08 data one month after nitrogen fertilizer application.

What is next?

What happens to the nitrogen in a wet spring like this? In the future, our research and field experiments or focused to give an answer to this question.

In future investigations, the experimental fertilizer application design will be maintained. We will collect soil and crop information that will allow us to run a computer simulation model as a diagnosis and prediction tool to identify the capability of computer algorithms to simulate site-specific response that we were able to monitor in the field with a high degree

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