WINTER WHEAT DEVELOPMENT, GRAIN YIELD AND SOIL WATER AND NITROGEN DYNAMICS IN A FARMER'S FIELD IN WESTERN KENTUCKY

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What we learn from our experiments:

1. Upon the first split of nitrogen applied uniformly, canopy reflectance measurements show the inherent variability of nitrogen deficiency of the crop which is related to soil properties and landscape topography.
2. Upon the second variable rate nitrogen application, spatial reflectance measurements taken at different times are temporally very stable and consistent.
3. The same levels of nitrogen applied over a variable landscape causes grain yield and crop indices to respond differently, depending on the site-specific landscape position with its specific soil characteristics.

INTRODUCTION

Results from previous years have shown that with our optical sensors we are able to detect zones in which the mineral nitrogen supply had been kept short intentionally. The spatial pattern of different nitrogen fertilizer rates could clearly be identified. It was surprising, to see spatial differences in the response to various Nitrogen application rates. The response of the wheat to nitrogen fertilizer is not unique across the landscape.

OBJECTIVE

The objectives of this study were:

- to investigate the nitrogen fertilizer response across a field and find out whether it is uniform or differs,
- to find out to what extent soil information (textural variability and mineral soil nitrogen) is related to crop growth and yield,
- to study how various crop indices measured with the Greenseeker, HydroN Sensor, and the Yara ALS sensor reflect different crop growth and to what extent they reflect crop differences being related to nitrogen application rate.

MATERIALS AND METHODS

The experiment was performed in the wheat field Hartigan of the farmer Trevor Gilkey, Princeton (Hillview Farms). The experimental strip investigated in this study was 90 feet wide and approximately 1500 ft long. The strip was divided into 45 cells, each being 90 ft wide and approximately 33 ft long. At three times (once in fall, once during winter, once in spring) mineral soil nitrogen was sampled in each of these 45 cells at four depth increments between 0 and 3 ft depth. In spring the strip was monitored at three different growth stages using the GreenSeeker, the HydroN sensor, an active laser scanner for identifying biomass (ALS sensor), and hand harvest of above ground biomass at different vegetation stages. The scanning dates were once before the second nitrogen fertilization, and twice after the second application. The first nitrogen was applied uniformly at a rate of approximately 75 lbs per acre. The second nitrogen application was varied at six rates between 0 and 75 lb ac^{-1} and occurred in a sine-oidal fashion along the landscape (Figure 1).

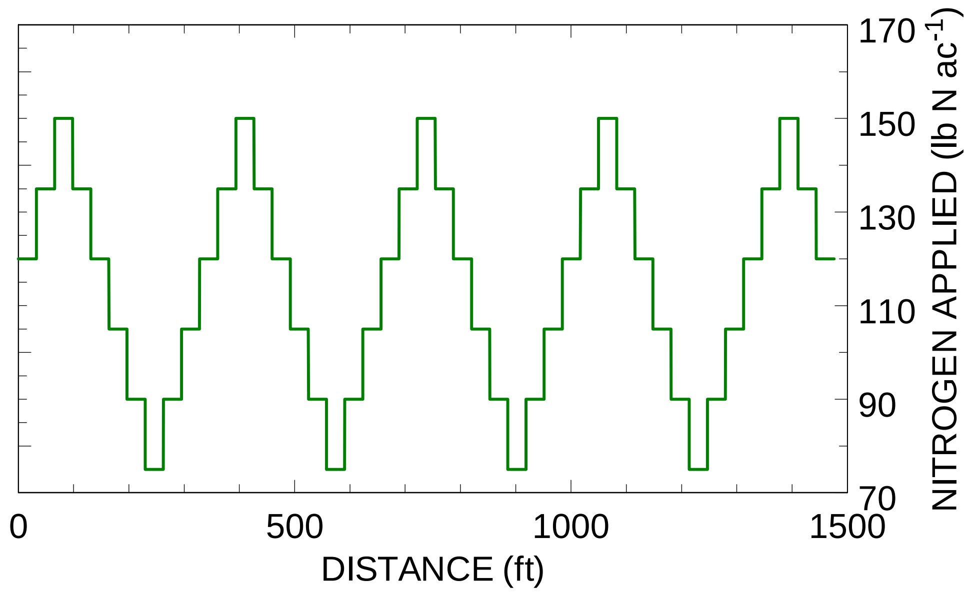

Figure 1. Spatial distribution of different total nitrogen application rates along the 90ft wide and 1500 ft long strip.

Along the path, the measurements of the red/infrared ratio (RIRR) were taken at three different times 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.

The first nitrogen application was spread by the farmer, the second with different rates, as in previous years with 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, and it was also the carrier of the remote sensors. Thousands of sensor data including automatic yield monitoring were aggregated (60ft width by 18 ft length) around the central location of each of the 45 plots using self-developed software.

RESULTS

As an example, mineral soil nitrogens content sampled in fall and shortly after the first application of Nitrogen are presented in Figure 2. At the end of winter, the magnitude of nitrogen in the soil profile and its variability was higher than during the sampling campaign in fall. Interestingly, the region at the right hand side of the transect at the lower end of the footslope has higher nitrogen contents due to a deeper soil profile caused by erosion processes in the past.

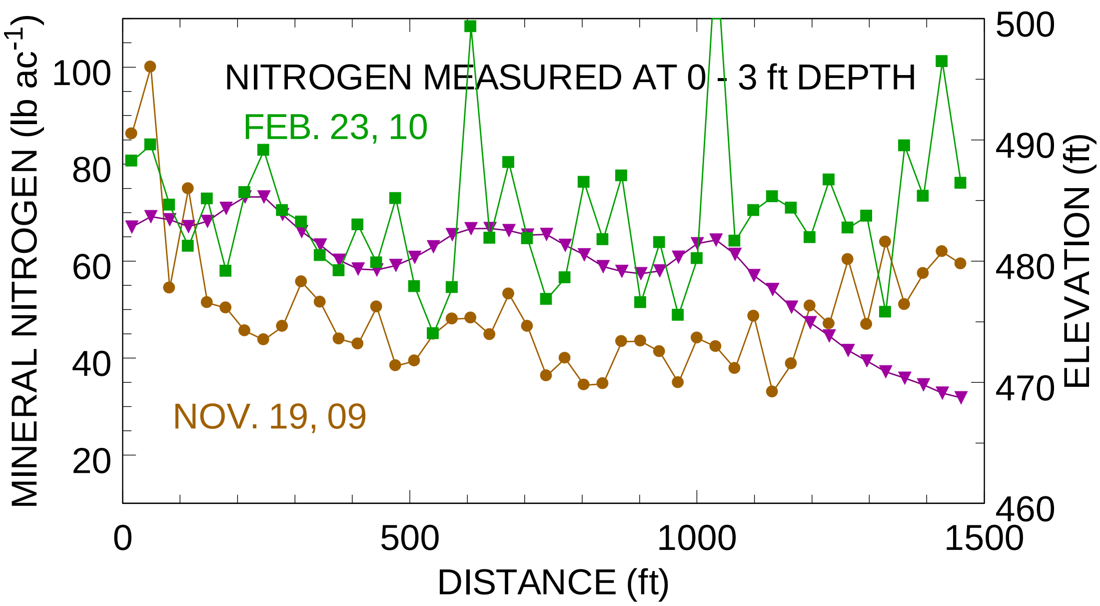

Figure 2. Spatial distribution of mineral soil nitrogen stored in the soil profile along the transect.

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 45 plots. Mineral soil nitrogen was sampled at three times, October 1, 2008, i.e., before planting, January 21, 2009, and April 23, 2009.

Results on the first scanning with the greenseeker are shown in Figure 3. This scan was obtained before the second nitrogen application. Hence the relatively large variability that can be observed is just reflecting the crop nitrogen status across a soil landscape after one uniform rate of nitrogen fertilizer several weeks before. This is a typical situation for farmers' fields and implies the need for new experimental approaches to learn how to better manage such heterogeneous environments. To some extent, the relative nitrogen deficit proceeds coherently with the soil topography.

After the second split of nitrogen had been applied at varying rates distributed in a sine-oidal pattern across the landscape, the following RIRR scanning results for two campaigns are shown in Figure 4.

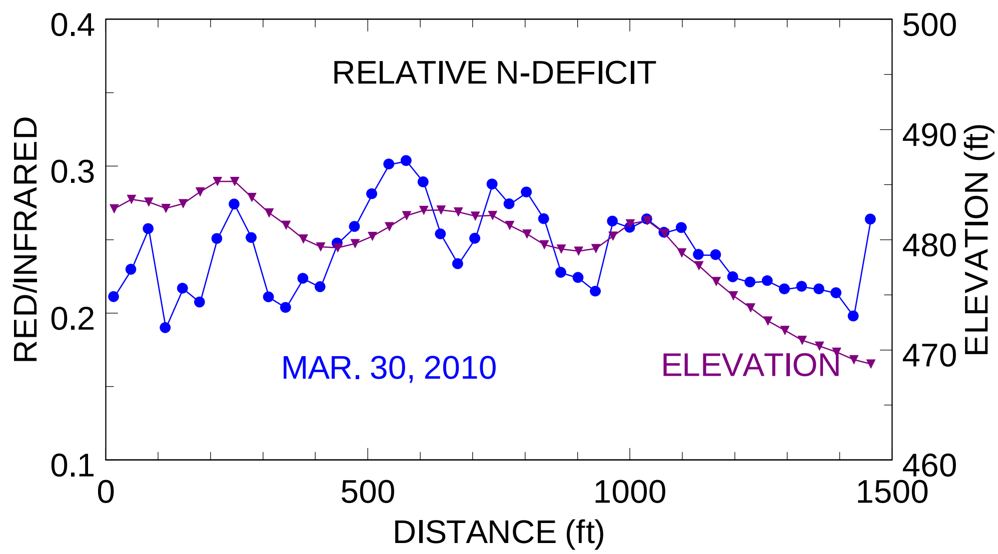

Figure 3. Relative Nitrogen deficit derived from the Red/Infrared index obtained with the greenseeker along the strip in the farmer's field after a uniform application of the first nitrogen split.

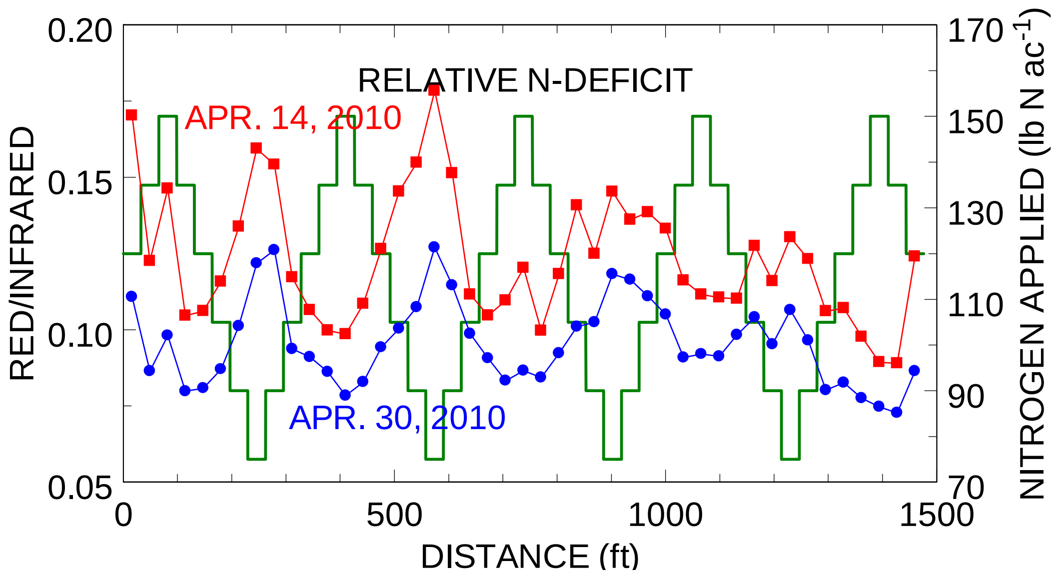

Figure 4. Relative nitrogen deficit obtained from greenseeker scannings yielding the Red/infrared ratio, after the second split of nitrogen fertilizer which was distributed at varying rates across the strip.

With the ongoing crop development, the general magnitude of N-deficit decreases. Moreover, it is obvious that the nitrogen deficit varies for the different segments of the sine waves relative to the local soil conditions. It is obvious that in the footslope region in the right hand side of the transect, nitrogen deficit is relatively low probably for the fact that the mineral nitrogen soil supply from the soil was larger here than in other parts of the field.

The final distribution of grain yield is shown in Figure 5 together with the RIRR results from end of April and the Nitrogen application rate (NAR) pattern. The inverse relationship between RIRR and grain yield is obvious. In the footslope zone of the transect where a relatively low nitrogen deficit was indicated by sensor results, the grain yield was relatively high.

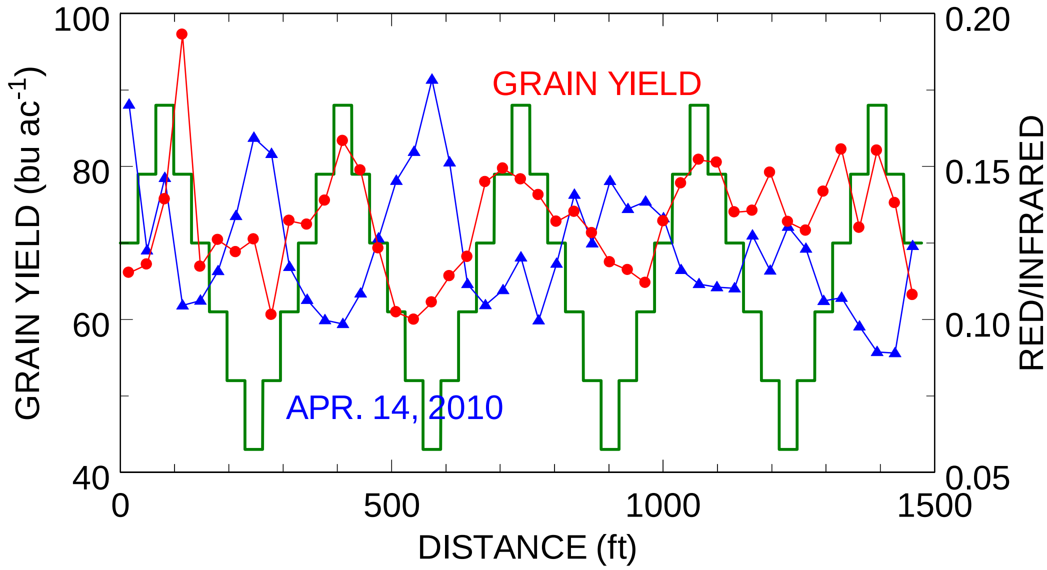

Figure 5. Grain yield, RIRR, and Nitrogen application rate along the transect.

It remains a challenge to find out how early in the season, sensor results reflect nitrogen deficiency, and whether such an image of nitrogen deficit can be used to apply nitrogen at variable rates site-specifically responding to the local needs of the crop.

What is next?

Can we put the results from sensor measurements into a practical system for site-specific nitrogen supply?

In other words, can we use RIRR measurements right before the second split of Nitrogen to create an application map? This is both a conceptual and a technological challenge. The comparison between uniform and site-specific application is the next step planned for the 2010-2011 season.

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