MANAGING WITHIN-FIELD VARIABILITY OF WINTER WHEAT – UPSCALING FROM TRANSECT TO FIELD

Ole Wendroth, Lloyd Murdock, Chad Lee, and Dennis Egli – in cooperation with Adam Hendricks (Wheat Tec)
Department of Plant & Soil Sciences, University of Kentucky,
College of Agriculture, Food and the Environment.
Ph: (859) 257-4768; Email: owendroth@uky.edu

WHAT WE LEARN FROM OUR EXPERIMENTS:

1. Our experiments on site-specific nitrogen fertilizer application based on crop sensor measurements in winter wheat were conducted for the first time on a whole field. NDVI-based nitrogen application resulted in about 4 bu/acre advantage over the uniform N application (93.4 bu/acre compared to 89.5 bu/acre). On the average, the total amount of nitrogen applied was 9 lb N/acre higher for variable rate than in the uniform management. The results are certainly influenced by the favorable weather development during the spring of 2013.
2. The NDVI was measured with 5 sensors spread across the boom of a 120-ft wide farmer's sprayer. The magnitude of NDVI systematically varied between the individual sensors. A scaling procedure was applied to adjust the sensors to the same mean and standard deviation.
3. Interestingly, a difference in average NDVI between the different sprayer passes was observed, depending on the driving direction. We do not know, to what extent the sun angle or the wind direction caused this result, or what other reasons caused this behavior.
4. Four zero-nitrogen plots were laid out across the field that received no nitrogen during the first split. Their NDVI averages differed depending on the location in the field. Based on the NDVI level in the N-zero plots and the average NDVI in each pass, a pass-specific fertilizer application function was computed in order to account for spatial soil variability. To develop an application map, some time for data processing between scanning and fertilizer application is required.

INTRODUCTION

Crop sensors have become very useful tools for quantifying the crop growth status with various indices based on canopy light reflectance. A very common index for deriving the crop nitrogen status and fertilizer needs is the NDVI (Normalized Difference Vegetation Index). In order to use sensor results to recommend the rate of nitrogen to apply, the crop's response to nitrogen deficiency has to be known. For this purpose, a small fraction of the field can be left unfertilized during the first N split, which is usually applied at a uniform rate in the early beginning of the main growing season. Such zones can be called zero-N plots. A special advantage of basing the N recommendation on sensor measurements is the opportunity to consider soil spatial variability, and the fact that the crop response to N or the crop N needs differ across the field depending on soil properties. Therefore, the objectives of this project were

- to collect and process crop sensor measurements taken prior to the second N split, and
- to derive a flexible nitrogen application rate computation for the second split, and compare it with uniform N application.

A third objective, i.e., to process past years' yield maps and weather data to quantify temporal stability and instability of crop yields in the same field to identify relationships to landscape topography and relate yield patterns to the weather is still in process and will be reported at the end of the project.

APPROACH AND RESULTS

On February 7, the winter wheat grown in the Hartigan field (Hillview Farms, Princeton, KY) received 39 lb N/acre as UAN (28% N). At this time, four 120 by 120 ft. plots were left out during the fertilizer application. Symptoms of lighter green color reflecting lower crop N status were not visible before March 14.

Figure 1. Hartigan field and scheme of the experiment consisting of uniform and variable rate strips during the 2nd split. The first split was applied uniformly, except for four plots (Zero-N 1st split) that did not receive any N fertilizer during the 1st split.

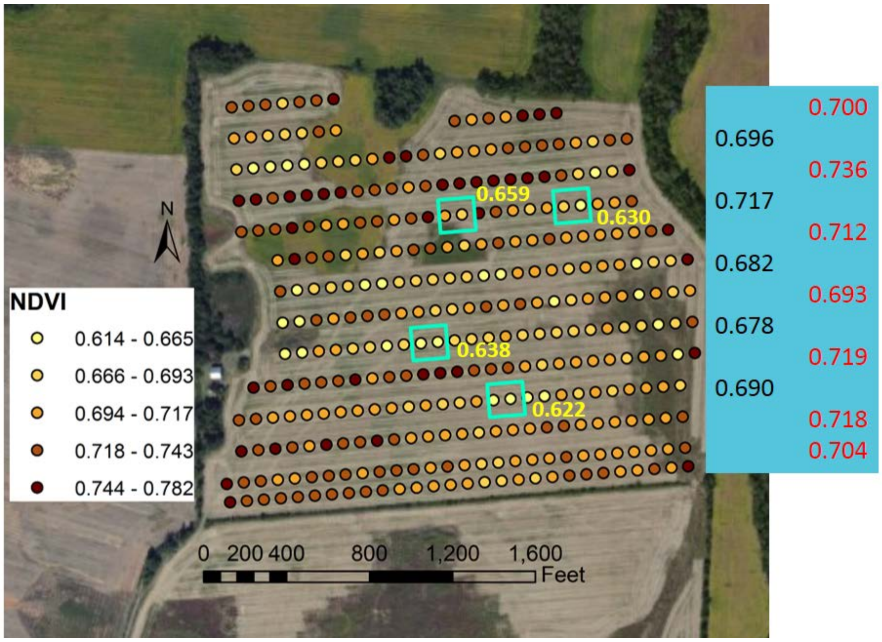


Figure 2. NDVI measured with five GreenSeeker sensors. The numbers in the blue box reflect NDVI averages computed for each pass of the sprayer.

On April 2, GreenSeeker measurements were taken at Feeke 6 (jointing). For this purpose, five GreenSeeker sensors were distributed across the 120-ft boom of a Case sprayer. The measurements were taken during a herbicide application on the wheat. For display purposes, data were aggregated (Fig. 2).

Considerable spatial variability of NDVI across the field became obvious from Figure 2. The effect of zero-N in the four respective cells was clear. However, there were other zones in the field that received the first split of nitrogen showing low NDVI values at a level similar to the zero-N plots. Interestingly, there seemed to be an effect of the machine's driving direction on NDVI. In the blue box next to the map (Fig. 2), the black numbers refer to NDVI pass averages obtained when the sprayer drove from east to west. The red numbers resulted from trips in the opposite direction and were larger than the averages in the neighboring related passes. It is not clear whether sunlight and wind or what other reasons might have caused this effect.

Another important result was found from the sensor statistics, displayed in Table 1: The left and the right hand sensors had a similar mean and standard deviation, but the other three sensors deviated. For this reason, the measurements obtained by each sensor were scaled to a common mean of 0.5 and a standard deviation of 0.25 in order to make the results of different sensors comparable among each other. In some zones in the field, the relative distribution of scaled NDVI (NDVIsc, Fig. 3) was similar to the map of NDVI (Fig. 2), but other zones exhibited a slightly different pattern. The problem of comparability among different sensors mounted to the boom has to be kept in mind for future use of different sensors across the sprayer boom.

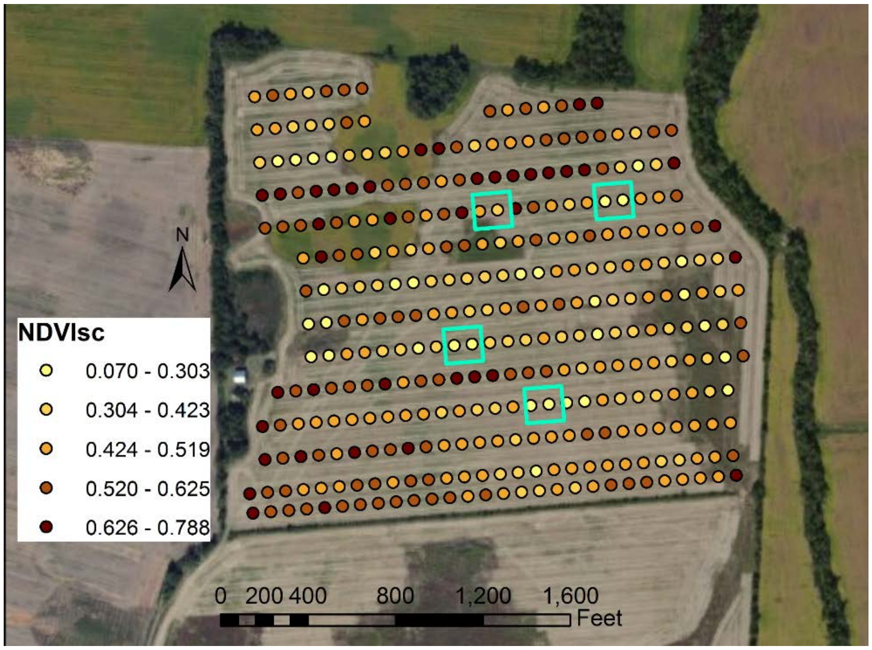
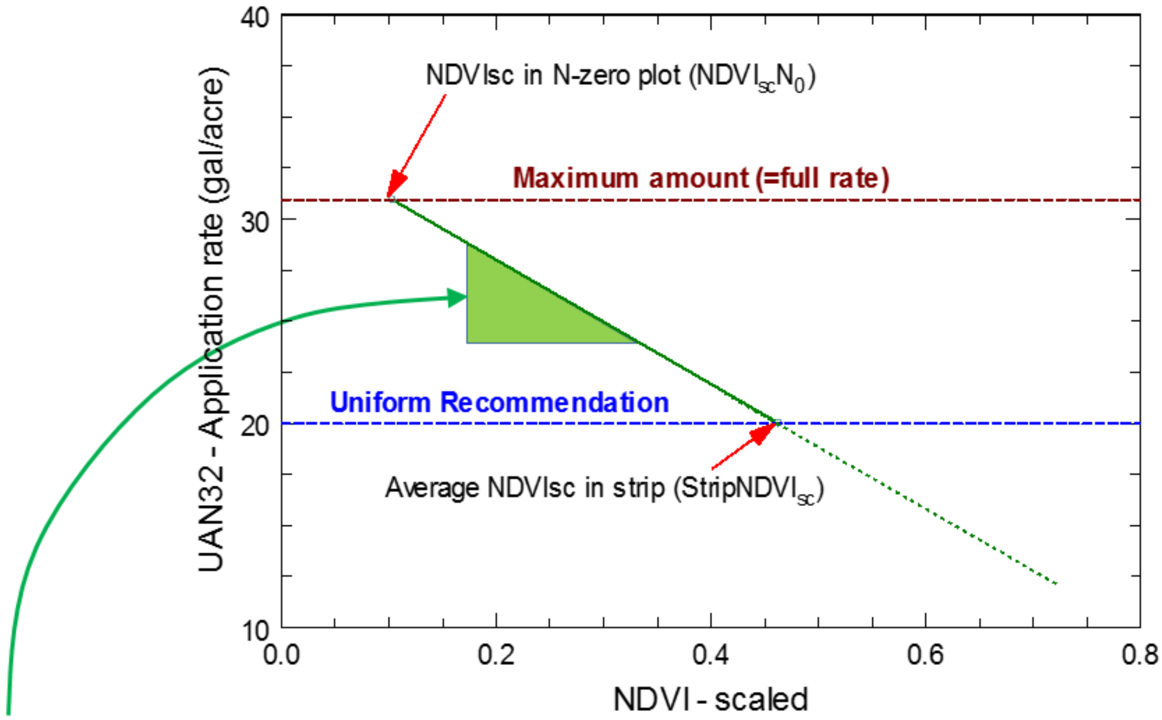


Figure 3. Scaled NDVI results (NDVIsc) for the Hartigan field. NDVIsc was derived from NDVI presented in Fig. 2.

Table 1. Statistics for the 5 GreenSeeker sensors obtained as an average of the entire field.

Sensor position:	Left	Left-Center	Center	Right-Center	Right
Mean	0.730	0.694	0.718	0.644	0.732
Std.	0.048	0.045	0.040	0.037	0.046
CV	6.541	6.543	5.615	5.795	6.286

Based on the NDVIsc results (Fig. 3), a nitrogen application map was compiled with specific rates computed as illustrated in Figure 4. For an average rate recommended for the 2nd split, we used 20 gal/acre (UAN 32% N; approximately 71 lb N/acre) as corresponding to the uniform recommendation. For the zero-N plots which had not received any N-fertilizer during the 1st split, the total amount to be applied was 30.95 gal/acre, reflected by the full rate in Figure 4. Notice, the application function (green line) is flexible with respect to zero-N response in different zones of the field and the respective pass average sensor result.



$$slope = \frac{full\ rate - uniform\ recommendation}{NDVI_{sc}N_0 - StripNDVI_{sc}}$$

$$NAR = full\ rate + \left(Meas.\ NDVI_{sc} - NDVI_{sc}N_0\right) \cdot slope$$

Figure 4. Scheme for deriving the UAN32 application map based on NDVIsc measurements, and the respective zero-N and pass average sensor results ($StripNDVI_{sc}$).

The application rate and the yield map are presented in Figure 5. Apparently, the experimental design did not well capture the two most southern passes in the field, as the yields in this zone remained lower than in the rest of the field while the recommended N rates were not extraordinarily high. The N deficiency situation in the zero-N plots after the 1st split was compensated well with the 2nd split. The overall yield result was 93.4 bu/acre in the variable rate strips compared to 89.5 bu/acre with uniform application with an average N application of 80 and 71 lb N/acre, respectively. Assuming a price of $7 per bushel of wheat and $0.70 per pound of N, the net economic gain would have been $19/acre.

An important point to consider in this year is the fact that lodging of the wheat crop was noticeable a few weeks before harvest. This observation probably manifests a physiological crop response to excessive nitrogen, as a consequence of residual Nitrogen in the soil profile that was left over from the extremely dry previous year with no opportunity for the anteceding corn crop to take up the nitrogen at the time it would have normally done it. The NDVI readings in the wheat crop prior to the 2nd split were not excessively high. Hence, sensor readings did not necessarily reveal a high N status in the crop and in the soil at the time of sensing. Perhaps, N in the soil profile had been leached to a deeper depth and was accessible for the plant roots only at a later time during the growing season. Sampling the soil nitrogen content might reveal this “additional” N source in the soil profile that would become available to the crop later.

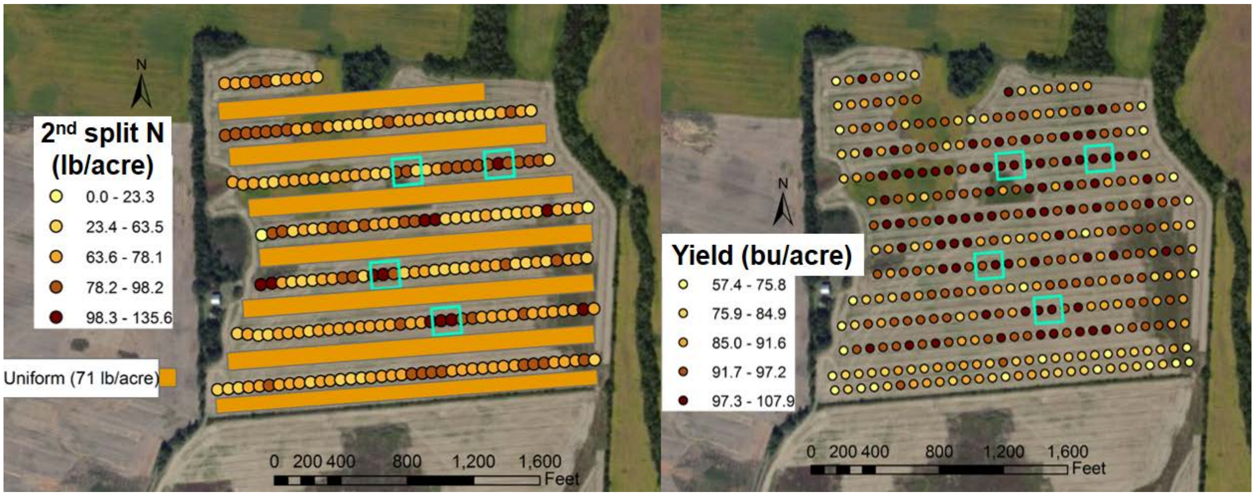


Figure 5. Nitrogen application map (left part) and wheat grain yield map (right part) for the experimental field.

ACKNOWLEDGEMENT

We thank the farmer Trevor Gilkey, Hillview Farms, Princeton KY, very much for allowing us to conduct this research in his field, for letting us mount the GreenSeeker sensors to his sprayer to obtain the sensor measurements, and for providing us his yield monitor information. The funding and support for this research by the Kentucky Small Grain Growers' Association is gratefully acknowledged.

CONCLUSION

The results of this experiment showed that in cases where different sensor heads are distributed across the sprayer's boom, an upfront calibration process against each other is required. Otherwise, deviations among sensors need to be compensated through data processing. It appeared that NDVI results differed depending on the direction in which the sprayer drove. This behavior needs to be validated and reasons for it identified. With a procedure like the one presented here the spatial soil variability is taken into account and a flexible application recommendation is provided. Data processing between scanning and N application becomes necessary. The results of this study were probably affected by residual nitrogen in the soil profile. Is spring soil sampling in place to avoid problems of residual N such as lodging.