Final Report For: Michigan Wheat Checkoff Program

Title: High-Intensity Management of Nitrogen (N) in Wheat: How Soil Water Forecast Modeling Improves Fertilizer Efficiency

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Objectives

The overall objective of this proposal is to integrate high-intensive management into previously studied prescription N methodology using forecasted weather scenarios and precision agriculture technologies. Variable rate nitrogen (VRN) prescriptions are important for delivering N at the right time and in the right amount at crucial stages during the plants' development.

Specific Research Objectives

Task 1: Data Collection and Analytics
Task 2: Field Experimentation and Design

Methodology

Task 1: Historical data drives strategic planning for N management decisions. Field data from local Michigan farms were collected and cataloged as part of this project (Table 1 and Figure 1). Yield history for many fields consisted of up to 15 years of data. These data led to the creation of yield stability maps that reveal patterns of historical yielding productivity (Table 2). Additionally, these historical datasets were examined further by calculating the average yields per yield stability zone for the wheat years available for each field.

Task 2: The development of VRN maps is an important aspect of this project. The VRN procedure uses historical data, crop simulation modeling, and remotely sensed imagery to create N prescriptions that best manage temporal and spatial variability for each field. Historical data provides a context for the production levels of each field over a variety of years. Output from the Systems Approach for Land Use Sustainability (SALUS) model were used to develop scenarios for rates applied at each field. The yields for each stability zone were simulated using weather data from the North American Land Data Assimilation (NLDAS) system from 1979 through April 8th, 2021. Weather categories considered were different for each locale of fields (Table 3). Soil water forecasts were simulated for the current growing season to determine the ability of each zone to use additional N fertilizer applied as a top-dress. Remotely sensed imagery taken with an unmanned aerial vehicle (UAV) were used to categorize plant health in the field using the normalized difference red edge (NDRE) vegetation index (Figure 2).
A new component of research for this project was to maximize the output of wheat yields in the high and stable zones. Additional fertilizer was given to plants in these zones if adequate amounts of water soil water were forecasted.

Results

<u>Yield Stability</u>

Yield stability maps for one field in Portland and three fields in Springport were created from historical yields. The maps show distinct patterns of spatial variability with medium stable encompassing most of the fields and high-, low- and stable zones accumulating in smaller portions. The unstable zones are separated into three topographic classes: unstable depression, unstable slopes, and unstable hilltops (Figure 3).

Crop Simulation Modeling, Remote Sensing, and VRN Creation

Simulations of soil water content by zone revealed varying patterns for each field (Figure 4). These patterns were considered when developing the rates that attributed more N to the high- and medium-stable zones. These zones saw a positive yield response to additional N in the cold and wet and normal weather scenarios. The yield values were much lower and yield only responded to additional N under the cold and wet scenario in the low and stable, unstable slope, and unstable hilltops zones. The high yield values along with the lack of yield response in the unstable depression zone indicated sufficient soil water for N uptake across all weather scenarios. Through an image analysis of the NDRE index, similar pixels are grouped together into classes using a cluster algorithm (Figure 5). The areas of highest NDRE are candidates for the highest N rate considering their spatial position in the field. Rates assigned to the VRN map considered the total amount of N applied in all prior applications (Table 4). Nitrogen at planting and an early top-dress (green up) provide enough N if conditions are not optimal for additional growth after April.

Validation of VRN

An analysis of the yield data coming from the combine grain yield monitor revealed the impact of the top-dress treatment along with total N (Table 5). Top-dress rates were determined to be 0, 11.9 and 22.9 lb N ac^{-1} based on the results of SALUS simulations. Final yields by zones and N rates are grouped in 3 categories: high/medium/low. The highest yields (greater than 120 bu ac^{-1}) were at the 22.9 lb N rate found in the high and stable and unstable high stability zones. The medium yield grouping was high and medium stable zones around 100 bu ac^{-1} with both the 22.9 lb N and 11.9 lb N ac^{-1} rates. The lower yield zones were in the low and stable and unstable medium stability zones. Two of these zones had the higher N rate revealing that the plants were showing high growth potential from imagery analysis.

Conclusions

Additional N applications are beneficial to wheat in the spring if it is placed in a spatially variable manner. Uniform applications across the field fail to adapt to the differences in wheat growth over space and time.

Field	City	Size (acres)	Previous Crop
304	Springport	80.76	Soybeans
306	Springport	29.66	Soybeans
307	Springport	33.67	Soybeans
SJ1	Portland	57.53	Soybeans

Table 1. Field location, size, and previous crop for 2021 fields of study.

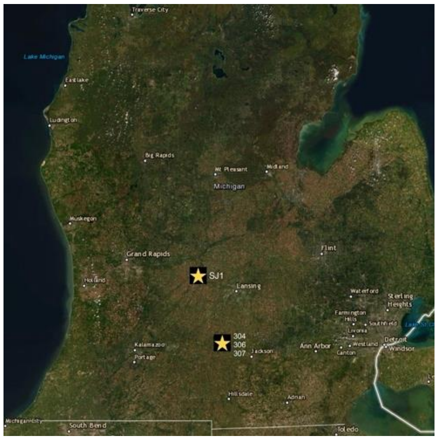

Figure 1. Locations of wheat fields for 2021 VRN.

Year	Yield Stability Zone	304	306	307	SJ1
2003	Unstable	83.6	79.8	67.1	N/A
	Low and Stable	77.2	70.1	61.9	N/A
	Med. and Stable	82.3	80.6	72.0	N/A
	High and Stable	88.3	90.3	80.3	N/A
2010	Unstable	77.4	73.0	64.0	N/A
	Low and Stable	65.4	65.7	66.4	N/A
	Med. and Stable	83.3	75.9	75.9	N/A
	High and Stable	88.7	77.4	80.1	N/A
2014	Unstable	90.2	82.5	71.8	N/A
	Low and Stable	75.7	72.5	62.4	N/A
	Med. and Stable	91.7	91.3	87.5	N/A
	High and Stable	100.7	98.8	97.2	N/A
2018	Unstable	N/A	N/A	N/A	93.5
	Low and Stable	N/A	N/A	N/A	84.0
	Med. and Stable	N/A	N/A	N/A	97.2
	High and Stable	N/A	N/A	N/A	103.4

Table 2. Average yields in bushels per acre of each stability zone for years where wheat was in the rotation for 4 farmer fields in Michigan.

Farms	Hot and Dry	Cold and Wet	Normal Temperature and Normal Precipitation
Portland	1987, 1998	1993	1990, 1986, 2002, 2008
Springport	1987, 2012	1981, 1983, 1996	1986, 1990, 1994, 2008

Table 3. Weather scenarios used to SALUS simulations.

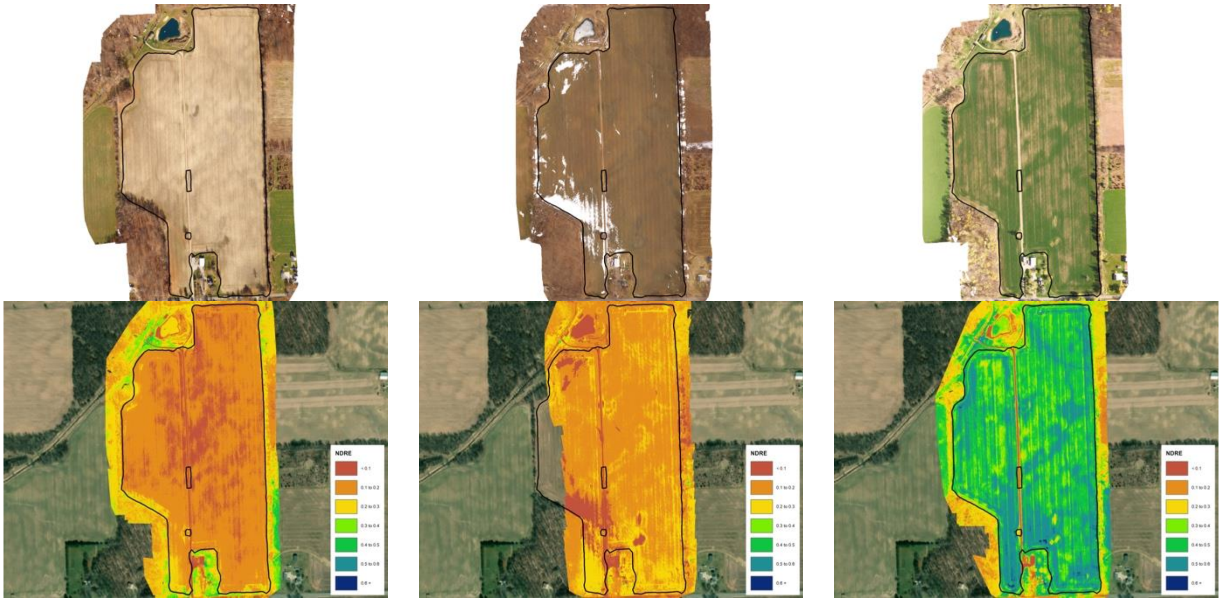

Figure 2. Remotely sensed imagery in visible (top) and NDRE (bottom). Imagery from Nov. 9, 2020 (left), March 10, 2021 (center), and April 13, 2021 (right).

Figure 3. Yield stability maps for the 4 fields of study.

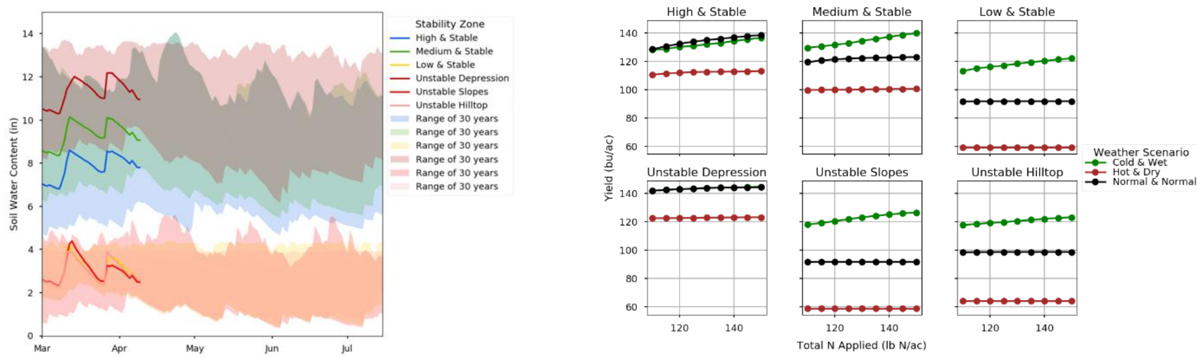

Figure 4. Forecasted soil water by zone and the range of water for 30 years (left), and yield response to additional N in 3 weather scenarios (right).

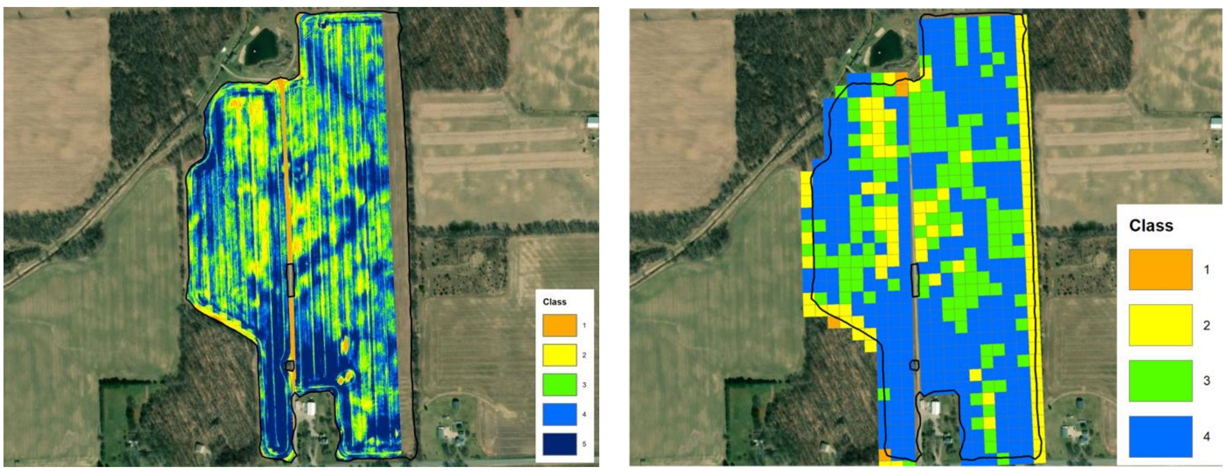

Figure 5. NDRE image is classified using a clustering algorithm for pixels and adjusted to consider yield stability zone classification (left) and the final VRN map is made that includes specific rates for each class at a specific implement size.

Classification	304, 306, 307		SJ1	
	Top-dress (lb N/ac)	Total N (lb N/ac)	Top-dress (lb N/ac)	Total N (lb N/ac)
1	0	108	0	110
2	0	108	0	110
3	15	123	11.9	121.9
4	25	133	26.8	136.8

Table 4. Top-dress rate (lb N/ac) and total N for each field according to the VRN.

Yield Stability Zone	Top-Dress N Rate	Category	Yield (bu/ac)	Std. Error
Unstable High	22.9	High	124.28	12.66
High and Stable	22.9	High	121.38	5.65
Medium and Stable	22.9	Medium	101.40	7.30
High and Stable	11.9	Medium	101.05	12.64
Medium and Stable	11.9	Medium	98.86	8.94
Unstable Low	22.9	Medium	91.42	17.87
Medium and Stable	0	Medium	90.11	12.64
Low and Stable	22.9	Low	84.90	6.75
Low and Stable	0	Low	76.61	12.64
Unstable Medium	22.9	Low	74.57	10.32
Low and Stable	11.9	Low	69.16	12.64

Table 5. Wheat grain yields at each yield stability zone and top-dress rate.