Report on Michigan Wheat Checkoff Program Proposal

Strategic and Tactical Nitrogen (N) Management Using Drone Images and Crop Modeling to Increase Protein Content and Grain Quality in Wheat

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Objectives

The main objective of this study was to develop a protocol that can assist farmers using precision agriculture (PA) technologies to increase their nitrogen use efficiency and enhance profitability.

Specific research objectives:

- **Task 1.** Historical Yield Analysis – Develop yield stability maps by using combine yield monitor data that delineates zones of high, medium, low, and unstable productivity by spatial and temporal variability.
- **Task 2.** Image Analysis of Spatial and Temporal Change – Use remotely sensed imagery from satellite, airplane, and unmanned aerial vehicle (UAV) to discern patterns of spatial variability related to the particular growing season of interest.
- **Task 3.** In-season Crop Modeling – Utilize the crop model SALUS to simulate multiple managements and diverse weather scenarios to determine yield potential of the field.
- **Task 4.** Variable Rate N Experiment – Apply the knowledge gained from remote sensing, crop modeling, and early in-season field sampling to apply N fertilizer in the most productive parts of the field.
- **Task 5.** Field Observation – Collect plant and soil data during the growing season and at harvest to validate the protocol.

Methodology

A field trial was established in 2017 at a field with multiple years of yield history data. Plant and soil samples were collected in conjunction with remotely sensed imagery from a UAV. There were two side-dress applications of N applied variably (Table 1) by the Ag-retailer Wilbur-Ellis. The applicator data from each fertilization was used in order to relate N applications with additional data collected. Application of N was intended to be varied in two distinctly dissimilar parts of the field related to their yield stability. Unfortunately, the direction was not followed by Wilbur-Ellis and the tactical treatment was applied in differing strips at the second application than the first. The varying strips placed across the field provided the unique opportunity to study the field as an N rate trial with slightly differing total N amounts and application timings (Figure 1).

Table 1. N management for wheat field.

Management Zone	Planting Date	N at Planting (lb N/ac)	N at first side-dress (lb N/ac) (3/26/18)	N at second side-dress (lb N/ac) (4/28/2018)	Total N Applied (lb N/ac)
Conventional	9/26/2017	20	55.4	49.8	125.2
Tactical West	9/26/2017	20	98.9	0	119.9
Tactical Middle	9/26/2017	20	98.9	49.8	168.7
Tactical East	9/26/2017	20	55.4	0	75.4

Management information for the field was input into the SALUS crop simulation model to create side-dress recommendations based on historical weather scenarios. Weather input including maximum temperature, minimum temperature, solar radiation, and daily precipitation for 39 years was used for individual model runs. SALUS estimates crop yield for multiple management schemes and weather scenarios, generating a different grain yield response for each change in weather and/or management. Yield data was collected on July 11 with a grain yield monitor in a John Deere 9770 STS. Analysis from these data validated the hypothesized response of grain yield, effected by location in the field (yield stability zone), total N applied (N Rate), and the timing (tactical vs. conventional).

Results

Task 1. Historical yield analysis provided additional knowledge of the field's spatial patterns of variability. A yield stability map for the field was built from 8 years of yield data (Figure 2). Field sampling locations for soil and plants were chosen to establish equal sampling point replicates in each yield stability type. Samples taken from these zones further validated the use of the yield stability method to characterize spatial variability. Yield results taken directly from the combine yield monitor in each zone reflected the trend of higher yields in the high and stable zone and decreased yields in the low yielding zone (Figure 3).

Task 2. Remotely sensed imagery included 8 images from UAV and 12 from an airborne plane service. Early season imagery collected in conjunction with field samples of wheat at the early vegetative stages facilitates the creation of the Canopy Chlorophyll Concentration Index (CCCI), a vegetation index used in assessment of canopy nitrogen status. As the growing season continues, the concentration of N in the plant is reduced as it is distributed to the head for making grain (Figure 4). This relationship is critical to relating remotely sensed imagery to plant N uptake.

Task 3. Crop modeling results simulated the best, worst, and most representative of our sampling year for grain yield using a gradient of N applied (Figure 5). Using average temperature, precipitation, and solar radiation values don't account for the variability in seasonal weather events, in which case utilizing historical annual weather and yield response is valuable. The best curve (red) was simulated using daily weather observations from 1992. The worst curve (green) occurred using 1988, where a miniscule amount of precipitation accumulated during the late-spring and early summer.

Task 4. The variable rate N experiment was intended to apply reduced rates of N fertilizer in areas of high yield stability where productivity was expected to be higher. Precision application of N was not followed completely and therefore the results of the study can only be analyzed as a simple rate trial. The high rates 168.7, 125.2, and 119.9 lb N/ac respectively, did not show yield responses significantly different from one another, averaging 103 bu/ac across the field (Figure 6). This matches the model simulation that the higher rates would show no response to any additional N applied over 80 lb N/ac. The intention was the supply N in a varying pattern according to the crop's demand monitored by remotely sensed imagery. Unfortunately, the tactical N applications were placed in different locations within the field by the Ag retailer Wilbur Ellis.

Task 5. Plant samples of wheat were collected in coordination with yield stability zones throughout the fields. Samples were collected, dried, and weighed. They were processed for total N content. Early season samples showed higher N concentrations (Figure 4).

Conclusions

Precision application of N fertilizers is an important tool in providing the desired rates of product to areas of the field where it is needed most. Implementing these strategies can lead to increasing profitability through decreased rates of fertilization and maximizing nitrogen use efficiency. It is imperative that the implications of applying N with tactical management be considered and discussed with the ag-retailer, or custom applicator before implementation. Important details like applicator width, tip size, tank capacity, GPS module, monitor model, coordinate system, and others are critical to making sure the N gets applied correctly. Incorrect N application, although very useful in research terms, can decrease NUE and profit while leading to more N leached or lost in the system.

Figure 1. Application of varying strips of N in the field varied.

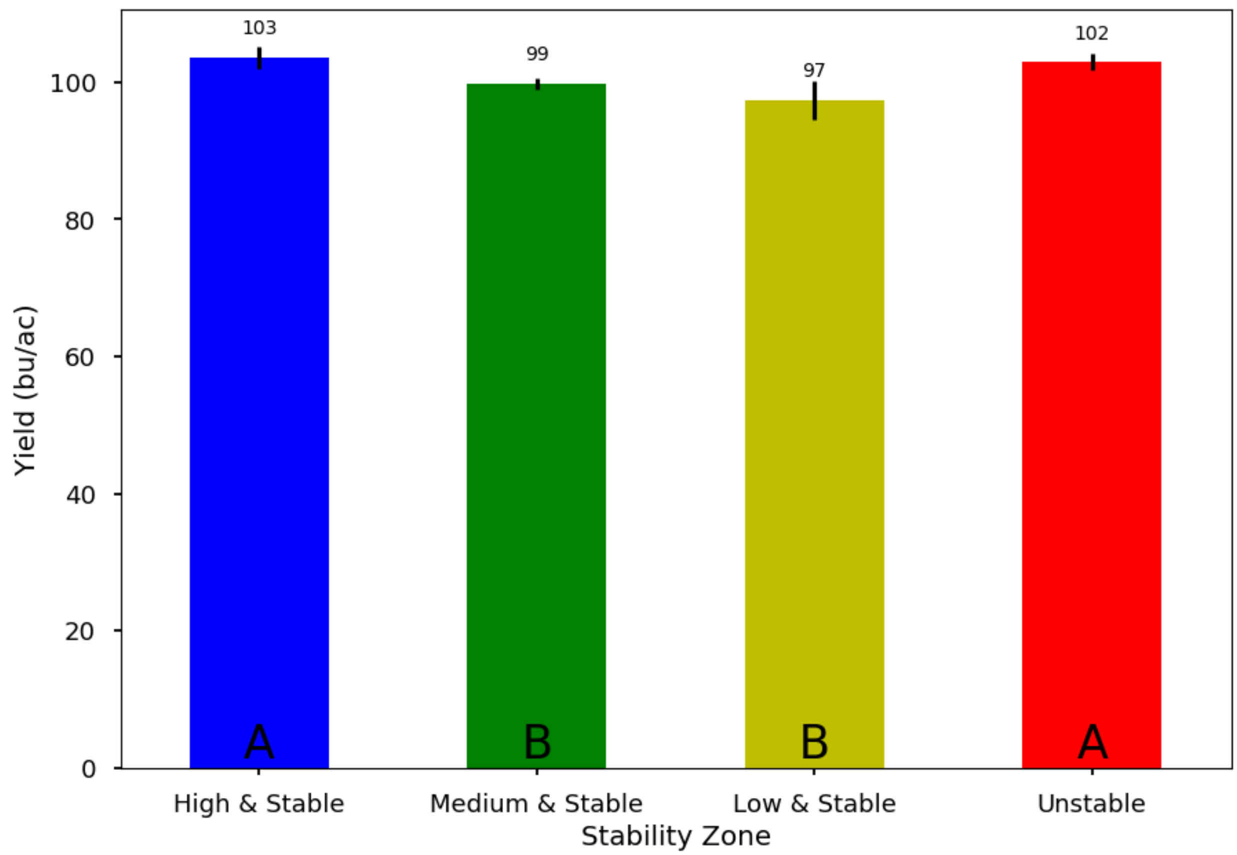

Figure 2. Wheat grain yields exported from the yield monitor at each yield stability zone.

Figure 3. Yield stability map including 10 years of yield monitor data from corn, soybean, and wheat.

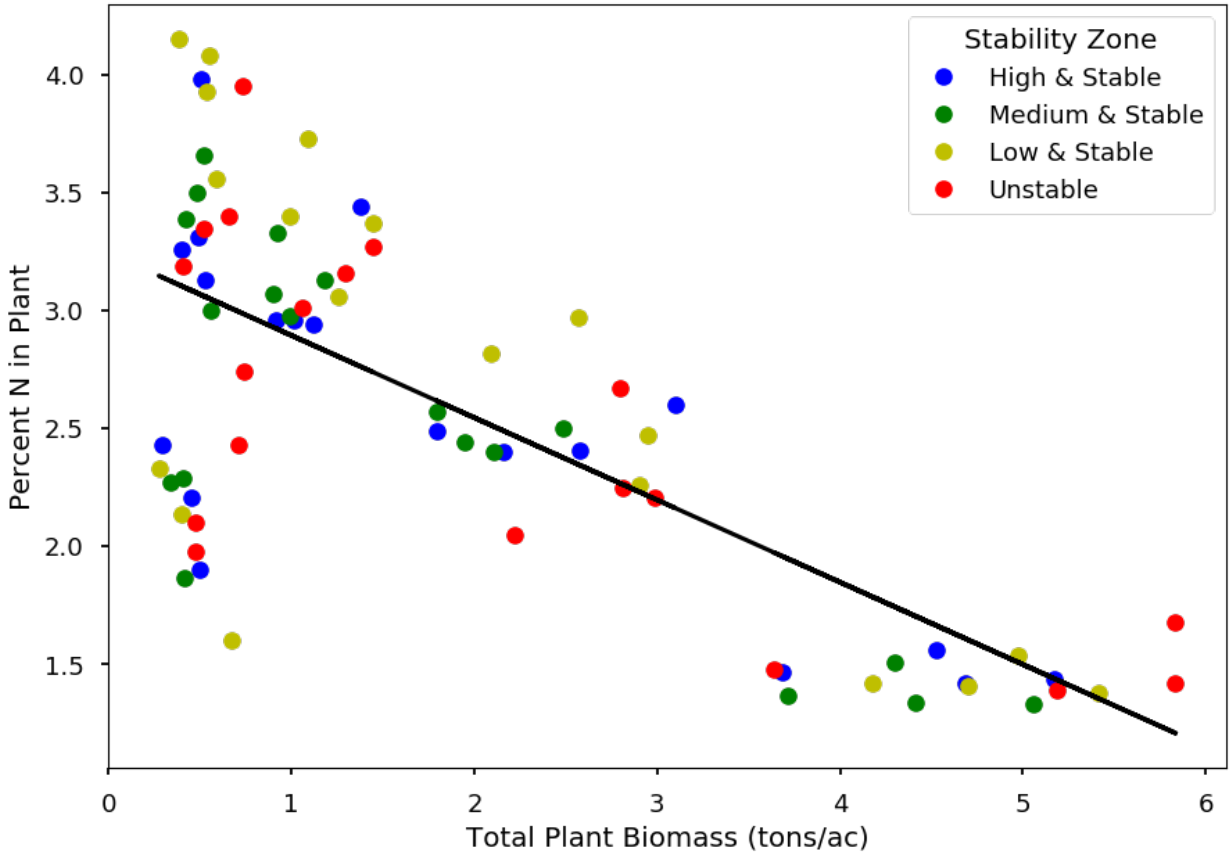

Figure 4. Canopy Chlorophyll Content Index values for MG1 in 2018. Samples collected early in the growing season (0-1 tons/acre) have higher concentrations of N.

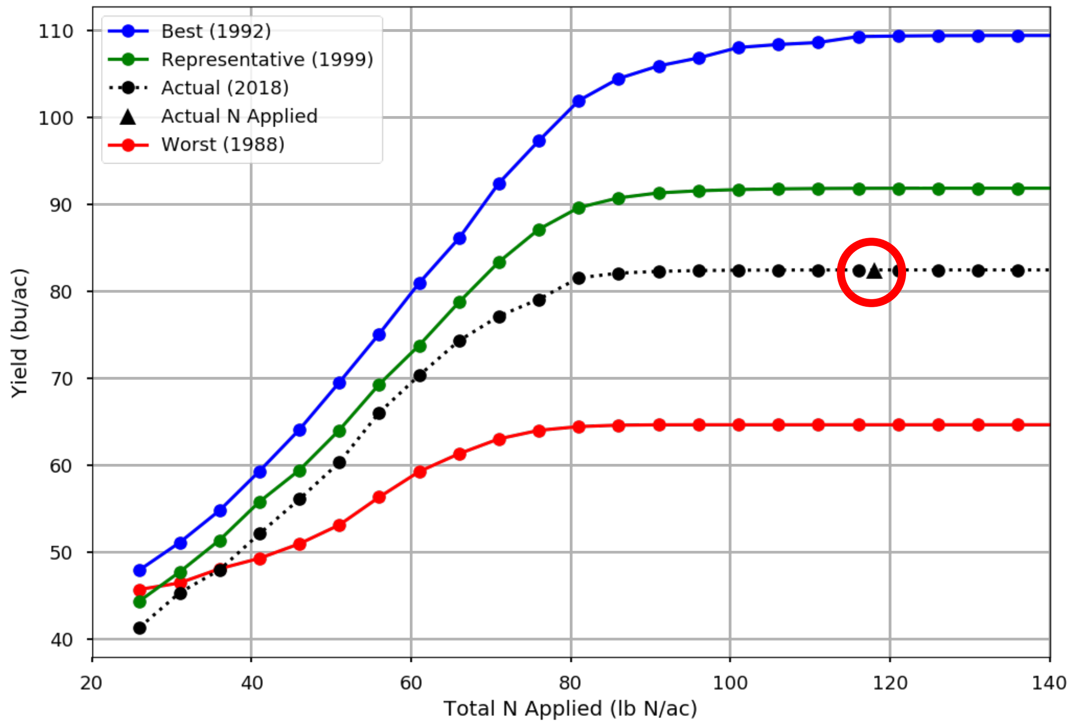

Figure 5. SALUS results for the field using the same management, but different daily weather observations for multiple years. Weather observations for 2018 appear in black with observed average yield highlighted with a red circle.

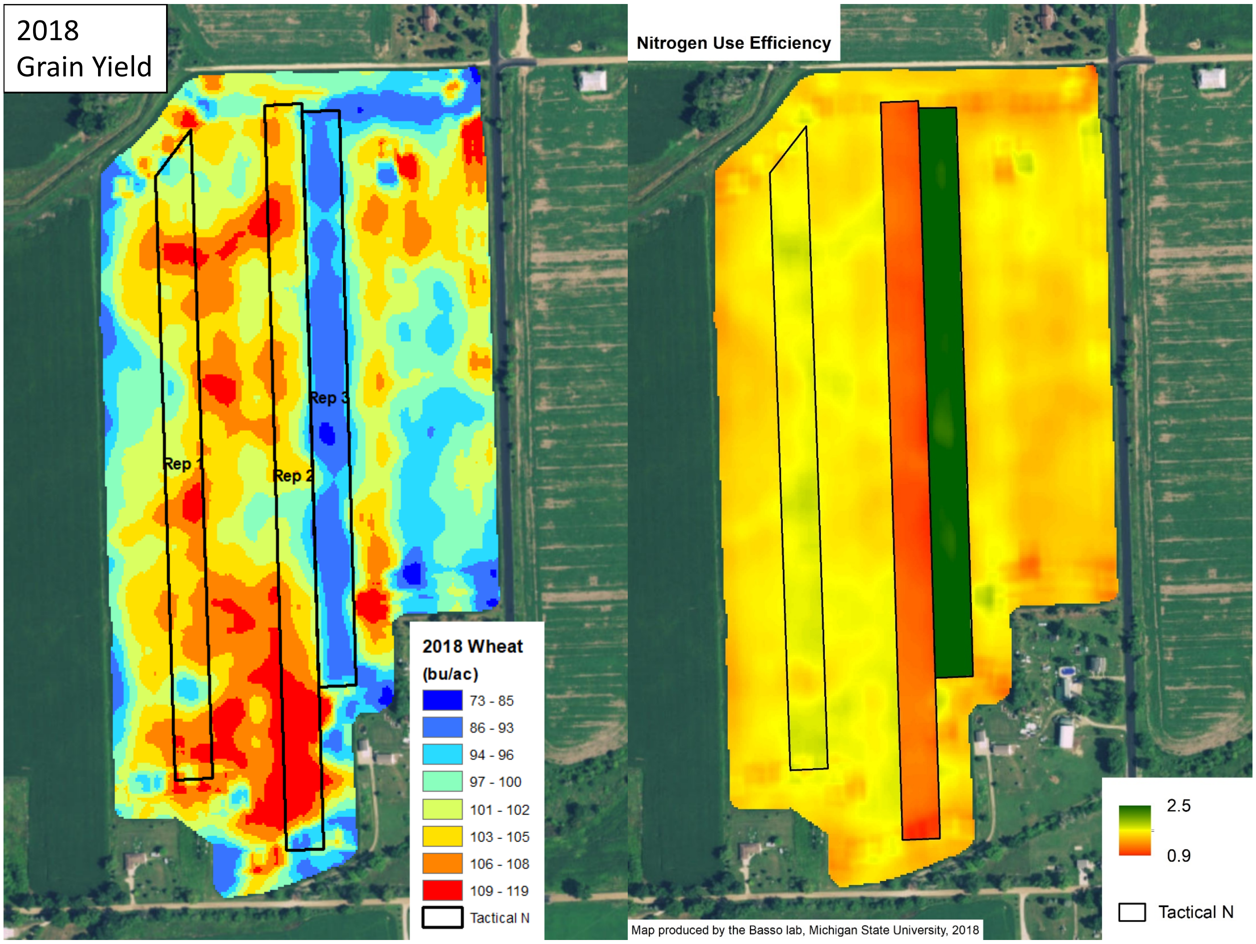

Figure 6. Grain yield response to 4 N rates. The lowest rate (75.4 lb N/ac) saw the lowest yield (91 bu/ac), however the highest NUE.

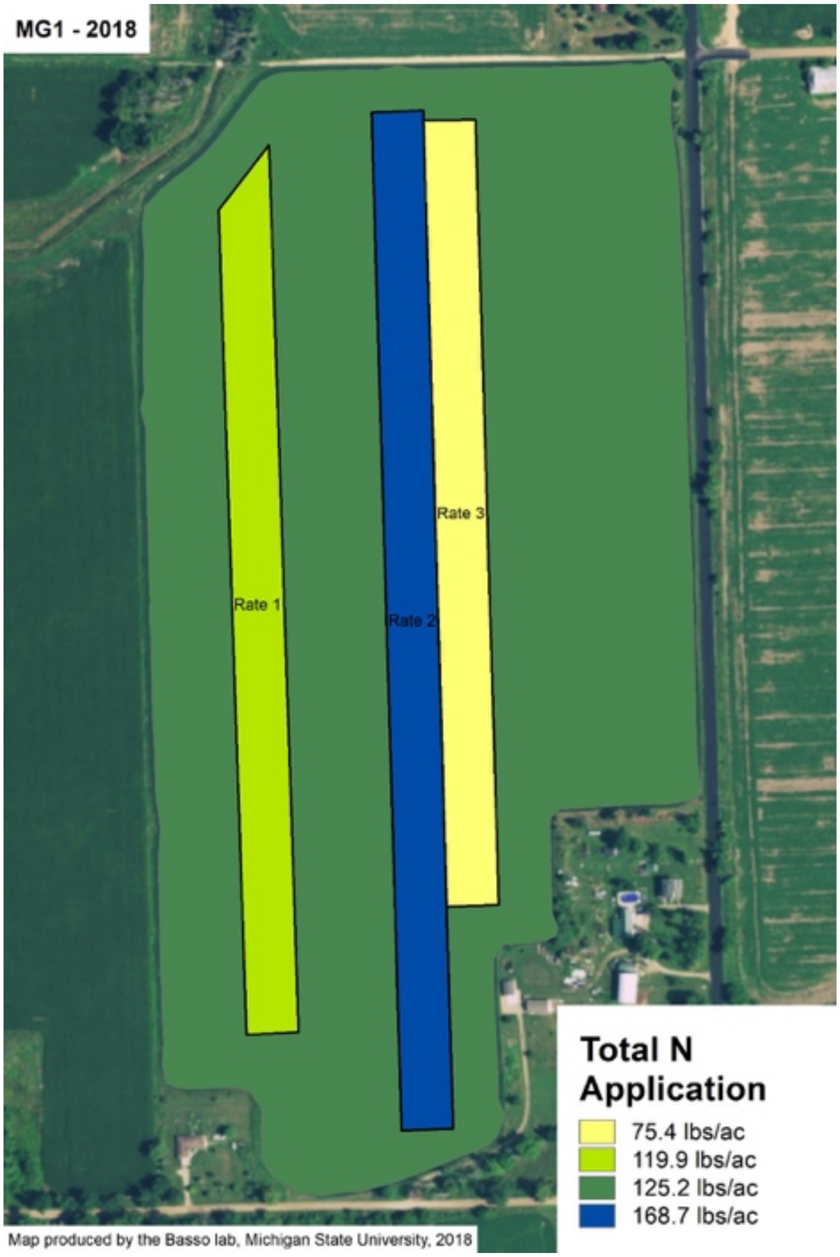

Figure 7. Rates applied in the field and their respective yield in bu/ac.