Final Report For: Michigan Wheat Checkoff Program

Title: Understanding and Managing Factors Affecting Wheat Yields in Michigan: A Modeling Framework to Help Farmers Make Better Decisions

MWP Tracking Number: 21-08-01-AS

MSU Number (Optional): RC114635

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Date: 08/01/2022

Objectives

Yield gaps, defined as the difference from yield potential (YP) and average farm yield (YA) are realized by farmers every year (Figure 1). These differences come from the variability in weather, planting date, cultivar maturity, fertilization, and other factors year after year. The **overall objective** of this proposal is to calculate theoretical and potential wheat yields and define these yields gaps with realistic and tangible results. The knowledge gained from this project benefits Michigan wheat farmers to better understand their yield variability and help them plan for more productive and profitable subsequent growing seasons.

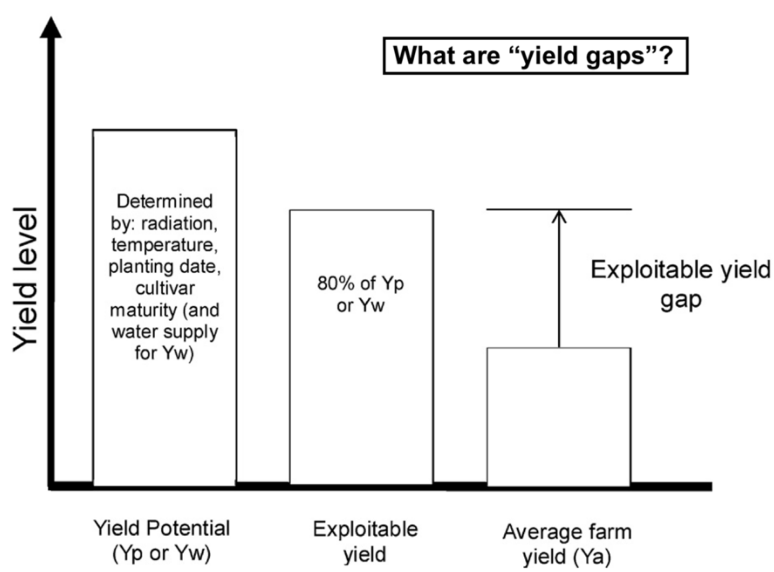

Figure 1. Yield gaps as described by the difference between the maximum yield potential and the actual observed average yields on-farm.

Specific Research Tasks:

Task 1: Understand YEN farms observed data in comparison to results obtained from the SALUS crop simulation model

Task 2: Continue to develop high resolution maps of wheat potential and actual yield across the MI wheat growing areas

Task 3: Continue to calculate yield gaps and map the impact of the contributing factors to the yield gaps

Task 4: Evaluate the risk associated with the management decision to implement in relation to climate and soil variability by using results from over a long-time period of climate data and historical satellite images.

Task 5: Introduce the concept of climate-smart commodities with farmers that have opportunity to adopt regenerative agriculture practices or digital agriculture

Methodology
Observed data collected as part of the Yield Enhancement Network (YEN) is used as a baseline of model calibration (Figure 2). The Systems Approach for Land Use Sustainability (SALUS) (Basso et al. 2006) crop simulation model integrates management, soil, and plant processes into a digital structure to reproduce physical real-world scenarios. Integrating the baseline observation data from YEN into SALUS provides important validation for various management practices that test obtaining greater observable yields.

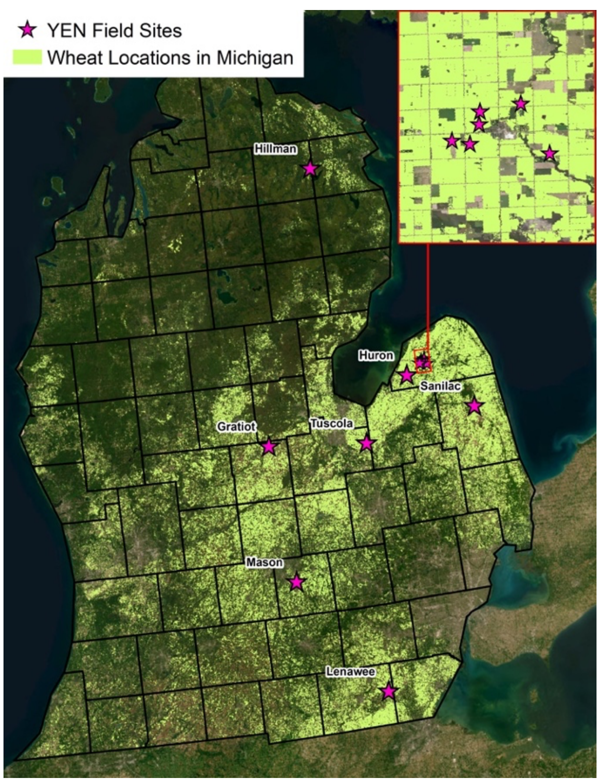

Figure 2. Yield Enhancement Network (YEN) field sites available and locations of wheat grown in Michigan.

Wheat is grown statewide across Michigan, with most of the production in the lower peninsula. This report focuses on the lower peninsula of Michigan. Input data that are necessary for SALUS simulations include: The Soil Survey Geographic Database (SSURGO) at a 10m resolution and the gridded surface meteorological dataset (GRIDMET) which has daily temperature, precipitation, and solar radiation available from 1979 to the present at a 4km resolution (Figure 3).

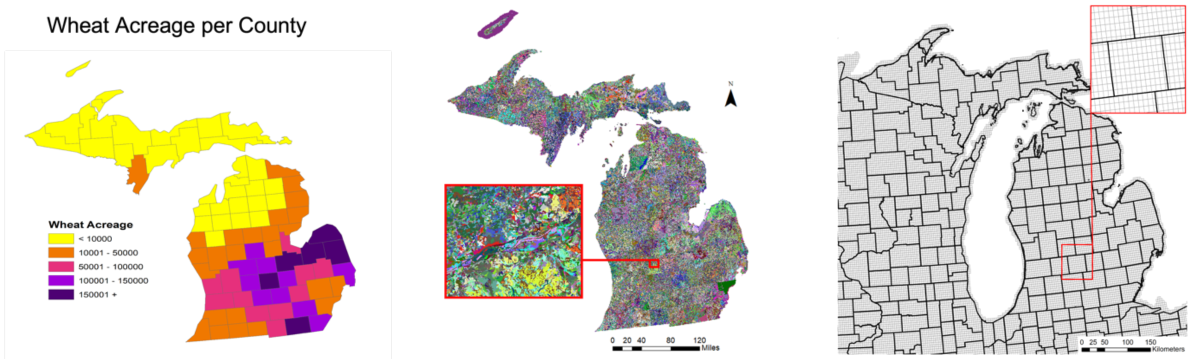

Figure 3. Wheat acreage in Michigan (left), soil input from USDA SSURGO dataset (center), and the gridded weather input GRIDMET (right).

To investigate the yield gaps from reality to potential, SALUS was used to quantify water and nitrogen (N) stresses. For this goal, 4 stress scenarios were simulated:

- No Stress (represents yield potential)
- Water Stress Only (no N stress)
- N Stress Only (no water stress)
- Water and N Stress (represents reality)

In these simulations, typical N management was assumed, with a total of 89.2 lb N acre^{-1} applied with split application (17.8 lb N acre^{-1} at planting and 71.4 lb N acre^{-1} at top-dress in mid-March). Both no-till and conventional tillage management scenarios were implemented. Wheat planting dates for Michigan varied by year, ranging from Sept 30th to Oct 16th, downloaded from USDA NASS. The past 30 years were simulated with continuous winter wheat to examine the yield gaps caused by N or water stress each year and to quantify the risk potential (Figure 4).

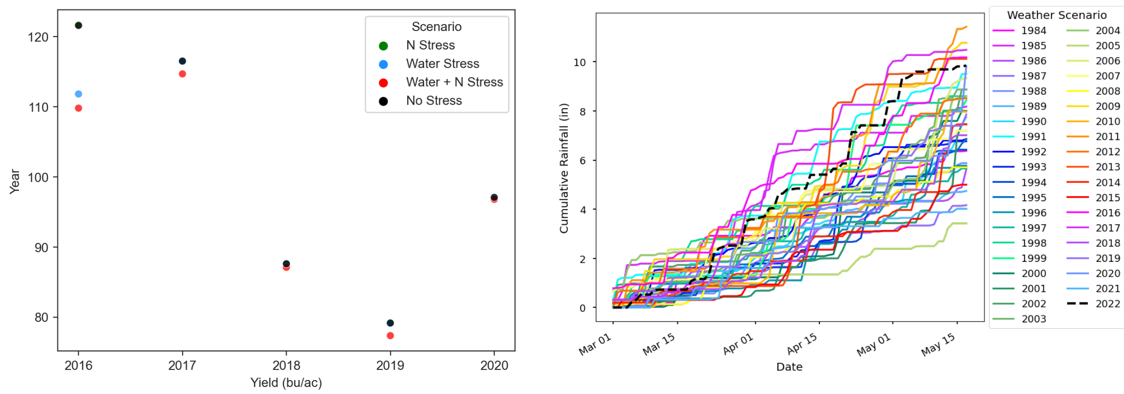

Figure 4. SALUS simulates various stress scenarios for individual fields and years to determine the cause of the yield gaps in each year (left). Precipitation accumulation during the growing season is accounted for and compared with historical years (right).

The same scenarios were simulated for the YEN fields. An additional pre-processing step for these fields was to create stability maps to capture the spatial variability within each field. This spatial variability was represented in the model simulations to capture an individual field's responses more accurately regarding water and N stress. Since the historical yield monitor data was lacking for these fields, satellite images of NDVI from Planet Labs® were used to create the stability maps. These satellite images were cleaned of clouds and shadows before being used in the algorithm to create the stability maps (Figure 5).

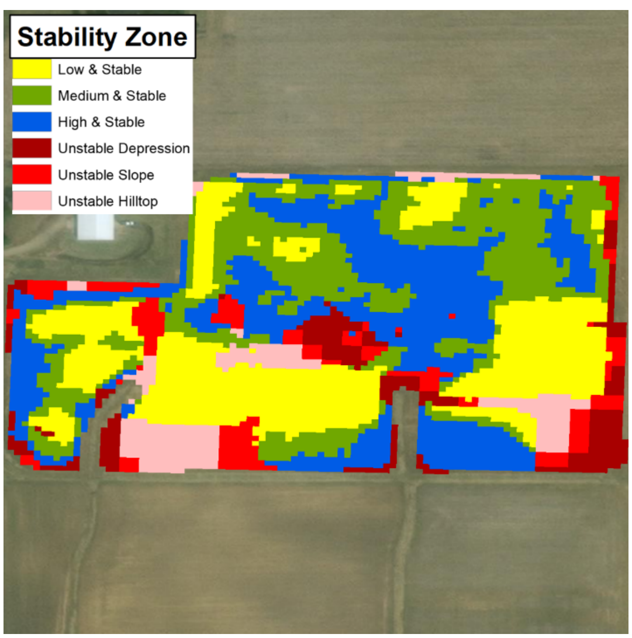

Figure 5. Stability map created from remotely sensed NDVI from Planet Labs for YEN field in Mason, Michigan.

Field implementation of results were output through a variable rate nitrogen (VRN) prescription map sent to various farmers participating in research trials in Michigan (Figure 6). Simulation results of different N scenarios are run for over 40 years of recorded weather data to provide wheat yield response curves. In combination with the stability maps, the optimal N rate was selected for application in zones based on the significant positive yield responses to varying simulated N application amounts. To analyze the VRN maps, the as-applied data (post N application) and the yield map were used to compare the amount of N applied and the nitrogen use efficiency (NUE) over each yield stability zone.

Figure 6. Example of the variable rate prescription map.

Results

SALUS Simulations

Mean yields from 30-year simulations using SALUS are presented for the 4 stress scenarios: no stress, water stress only, N stress only, and water + N stress (Figure 7). The mean yields for the no stress scenario were the highest, all locations producing above 100 bu acre^{-1}. The water stress scenario showed slightly lower yields than the N stress scenario but were similarly low. The combined water + N stress, representing real conditions, has the lowest yields. The annual simulated yields under the real-world conditions with combined water + N stress shows the temporal fluctuations of yield (Figure 8).

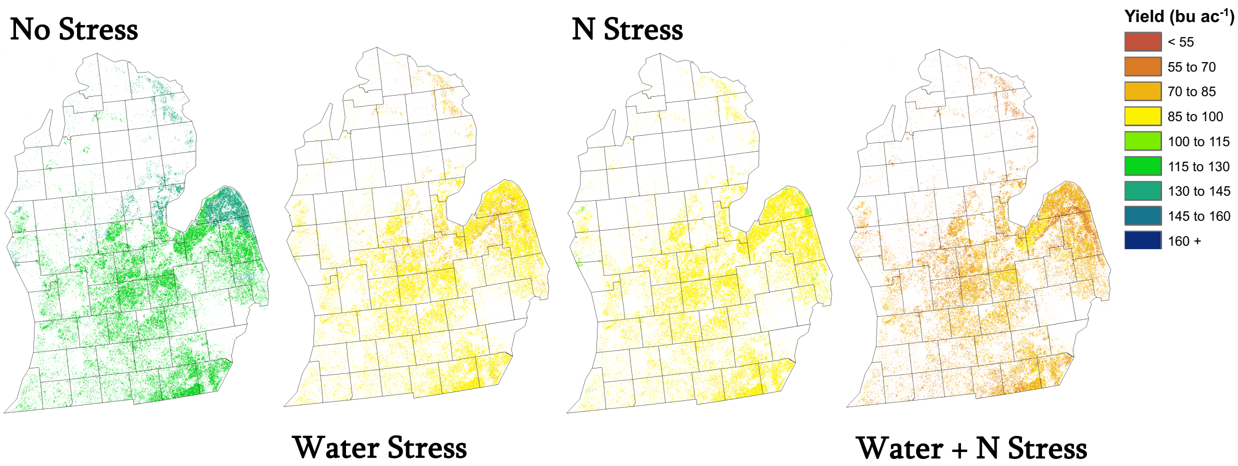

Figure 7. Simulated average yields over 30 years under various stress scenarios: No stress, water stress only, N stress only, and water + N stress.

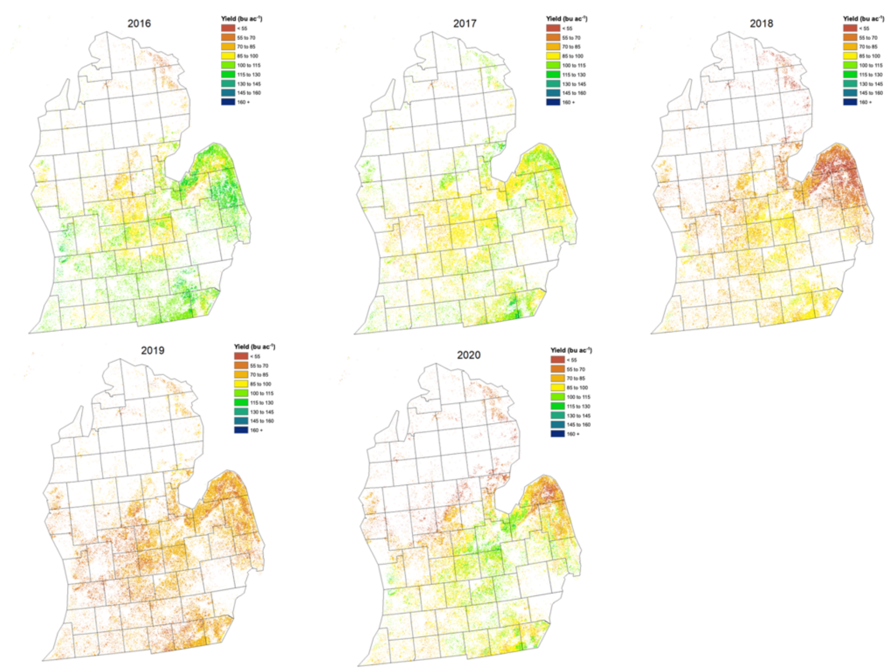

Figure 88. Simulated annual wheat yields under real-world conditions for 2016-2020.

Field Experimentation

In spring, top-dress VRN prescription maps were created, sent, and implemented in multiple fields. Results indicate that wheat yields were highest in the high and stable stability zone (Figure 9). The higher N application (126 lb N acre^{-1}) applied in low and stable zones did not show a significant increase in yields over the lower N application (106 lb N acre^{-1}). Yields of over 90 bu acre^{-1} were achieved in the high and stable zones with all three N rates (106, 126, and 136 lb N acre-1). NUE was the highest in stability zones that used the least amount of fertilizer, with the values in the high and stable zones being consistently at 150%.

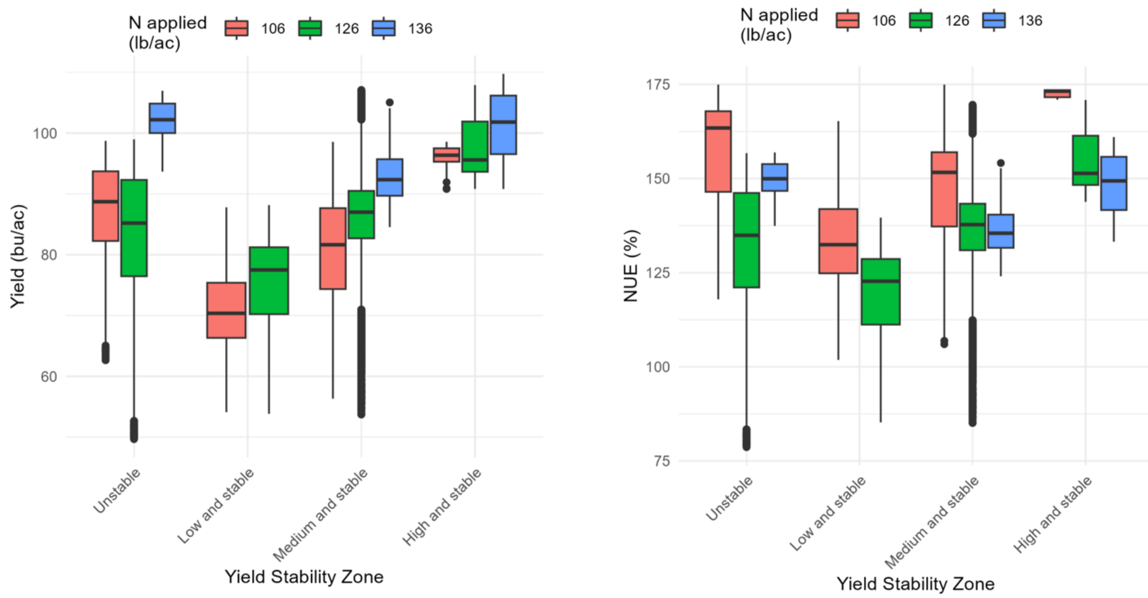

Figure 9. Yield (left) and NUE (right) analysis from a variable N rate prescription in one wheat field.

Conclusions

The concept of yield gaps is known well to wheat farmers in Michigan, yet the reasoning for the disparity between yield potential and observed yields is not well understood. **One of the goals of this study is to determine the maximum potential of wheat yields in Michigan and discover the reasons why these values are not reached.** Varying levels of productivity in the field (spatial variability), year-to-year weather variation (temporal variability), and the differing methods of tilling, planting, and fertilization (management) all contribute to these observed yield gaps. The yield stability map accurately describes productivity zones in each field and provides a basis for variable rate N prescriptions. The SALUS crop model accurately simulates these systems to ensure that nutrients are allocated efficiently for each stability zone and can determine whether water stress, N stress, or combined water + N stress are the cause for the yield gap in each growing season.

References

United States Department of Agriculture National Agricultural Statistics Service (nass.usda.gov)

United States Department of Agriculture Natural Resources Conservation Services Soil Survey Geographic Database (nrcs.usda.gov)

National Integrated Drought Information Systems (drought.gov)

Basso, B., Ritchie, J. T., Grace, P. R., & Sartori, L. (2006). Simulation of Tillage Systems Impact on Soil Biophysical Properties Using the SALUS Model. *Italian Journal of Agronomy*, 1(4), 677-688.