An Analysis of Sensor-Based Fertigation Management Determined by Unmanned Aerial Vehicles in Corn Production

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Abstract

Sensor-based fertigation management (SBFM) is an emerging practice which utilizes multispectral sensors to make fertigation decisions (i.e., the application of nitrogen (N) fertilizer through irrigation systems) to improve N management. Unmanned aerial vehicles (UAVs) equipped with multispectral sensors collected normalized difference red edge (NDRE) index imagery to detect N deficiency in randomized control block designed sectors (**Figure 1**) in corn. With N needs varying across soil types and from year to year, the use of sensors and variable rate technology can aid in making more profitable and efficient N application decisions. Treatment variations were tested each week by collecting images, processing, and analyzing images for N deficient areas that would influence fertigation decisions and applications. At completion of the growing season, response variables, such as yield and N applied, are analyzed in comparison to that specific grower's best N management sectors' performance. SBFM showed to be more efficient per lb-grain produced per lb-N applied at 96% of sites. Future implementation variations that optimize both N and yield savings will continue to improve the profitability and efficiency in corn production.

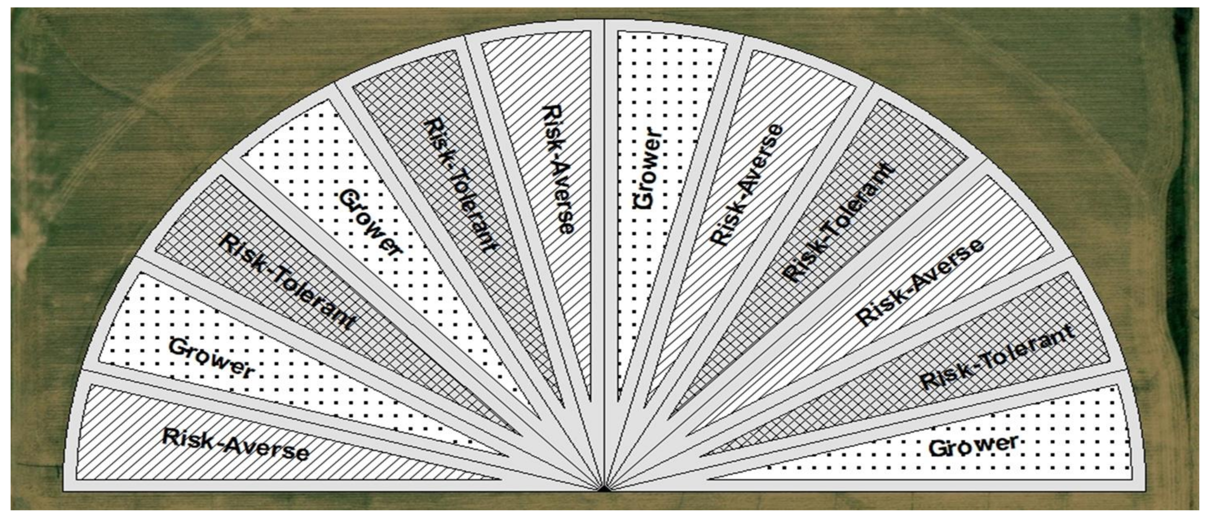

Figure 1. Randomized control block design implementation variation layout.

Introduction

In Nebraska and other states with shallow water tables, nitrate contamination of groundwater and other surface waterways from excessive N, is a major concern which can contribute to human health risks. Over application of N can lead to nitrate leaching through the soil profile, causing agriculture to be a leading contributor to the high concentration of groundwater nitrates. Many farmers still use conventional N management techniques and only apply N once at the beginning of the year (or the prior fall). By splitting applications and distributing them throughout the growing season, N may be more readily available for plant uptake during critical growth periods and lead to a decreased risk of leaching.

Fertigation (application of N through a center pivot during irrigation events) can improve N use efficiency (NUE) by reducing the risk of losing N applied early in the growing season. More recently, the practice of sensor-based fertigation management (SBFM) has introduced a data-driven approach to manage weekly fertigation decisions based on remote-sensed imagery using a patent-pending methodology. After establishment of indicator blocks (showing different N stress levels also seen in **Figure 2**), an automated software, *N-time*, progresses through logic to determine if corn in a particular zone (or sector) require N or could wait an additional week for application.

Introduction (continued)

While preliminary testing indicated the potential for significant improvements in NUE, further studies are necessary to test different implementation approaches and N treatment scenarios to further optimize the process.

The objectives of this study were to 1) conduct additional field trials using different N treatment and implementation approaches and 2) compare the profitability and NUE metrics versus the cooperating producers' current approach.

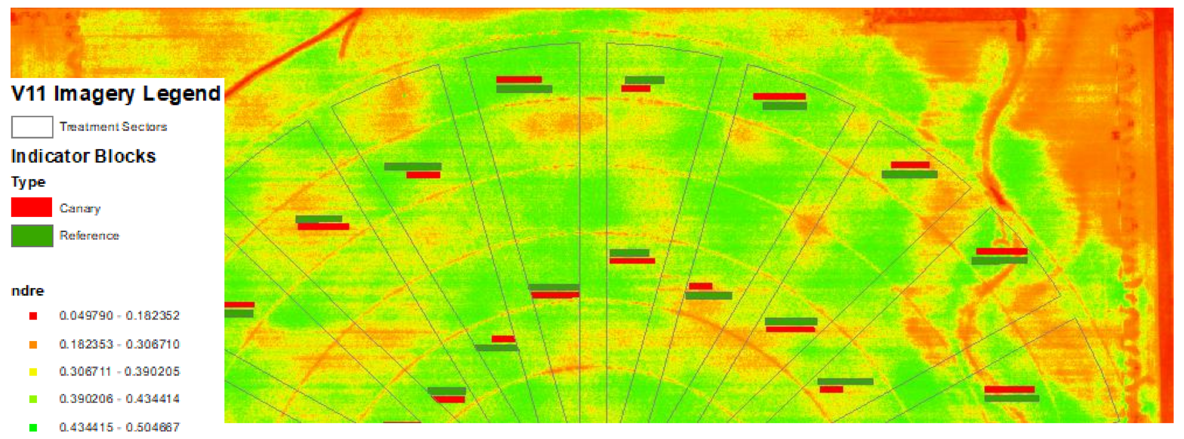

Figure 2. NDRE image collected via UAV at the V11 growth stage displaying buffered sectors overlayed with indicator blocks.

Methods

Over the three-year study, five SBFM implementation approach variations were created, analyzed, and compared to grower's best N management at nine sites. The *N-time* software relied on indicator blocks containing short strips of higher N (+30 lb-N/ac) adjacent to lower N (-30 lb-N/ac) compared to the bulk base N rate. Each sector contained at least one set of indicator blocks. Indicator blocks were used by *N-time* to calculate the Sufficiency Index (SI) for a particular sector and if the sector SI dropped below 0.95, a fertigation application was triggered for that sector at a rate of 30 lb-N/ac.

Once the initiation conditions listed in **Figure 4** for each implementation approach were reached, the processing cycle via *N-time* in **Figure 3** was repeated weekly until the termination of that specific approach occurred. At the end of the growing season, each sector was buffered and yield monitor data was collected and averaged. A partial accounting of NUE was calculated based on total N used for each sector and the respective yield. In addition, partial profit (based on $5.20/bu of corn and $0.40/lb-N) was also calculated for comparison between the respective implementation approach and the growers' approach, noting the difference between SBFM techniques and grower management.

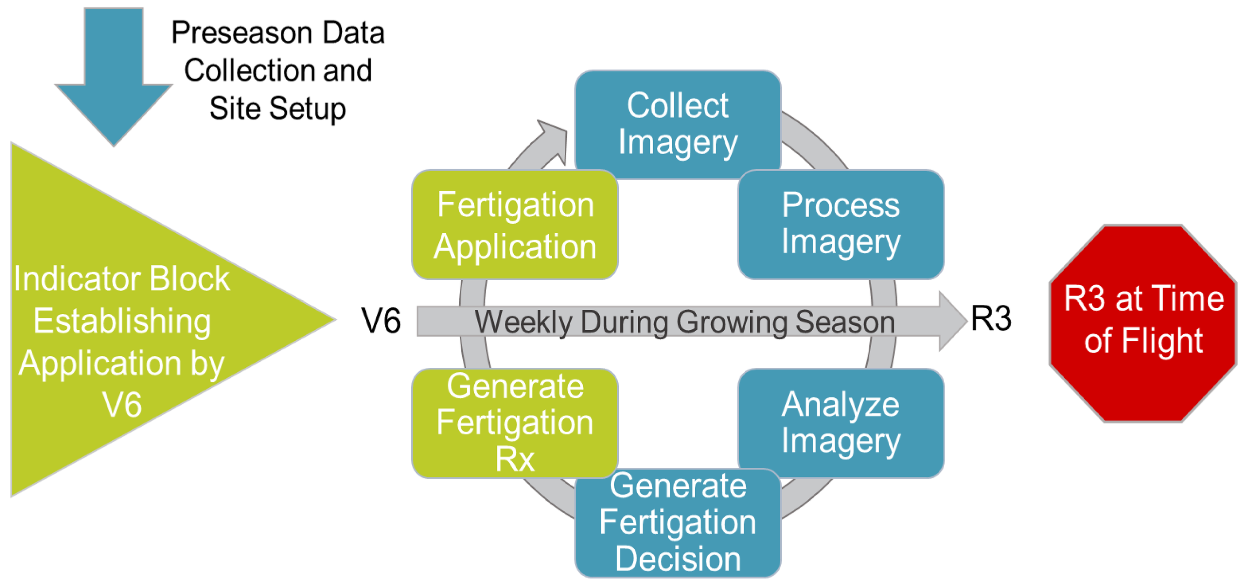

Figure 3. Weekly method process of the RAP treatment variation that *N-time* performs.

Risk-Tolerant Last 60 (RTC)
- Initiated at the last 60 lbs. of applied N.
- Terminated at R3.
- Requires more indicated deficiency to trigger fertigation event.
- Prioritize N savings.

Risk-Averse Constrained (RAC)
- Initiated at the last 60 lbs. of applied N.
- Terminated at R3.
- Requires less indicated deficiency to trigger fertigation event.
- Prioritize yield savings.

Risk-Averse Post-Establishment (RAP)
- Initiated at V6/post indicator block Est.
- Terminated at R3.
- Requires less deficiency to trigger fertigation.
- Optimize N and yield savings.

Risk-Averse Constrained R4 (RAC R4)
- Initiated at the last 60 lbs. of applied N.
- Terminated at R4.
- Requires less deficiency to trigger fertigation.
- Prioritize yield savings.

Risk-Averse Post-Establishment R4 (RAP R4)
- Initiated at V6/post indicator block Est.
- Terminated at R4.
- Requires less deficiency to trigger fertigation.
- Optimize both N and yield savings.

Risk-Averse Post-Establishment Increased Rate*
- Initiated at the V6 growth stage.
- Terminated at R3.
- From V9 to V14, application increases to 60 lb. N/ac.
- Matching N uptake during N intensive stages while optimizing N and yield savings.

Figure 4. Implementation variation descriptions including initiation conditions and treatment termination protocols. Variation colors corresponding to data points in Figure 5.
***Treatment variation currently being conducted in 2022 research study.**

Results

Overall, the SBFM showed high potential for improving current NUE while providing an opportunity for increased profitability as N prices continue to increase. A summary of NUE and profitability data (SBFM vs. grower) can be seen in **Figure 5** across all sites, years, and implementation approaches. The results from these nine fields showed SBFM to be more efficient in 96% of sector comparisons in terms of lb-grain produced per lb-N applied. Only 56% of treatments were more profitable when compared to the grower's treatment approaches.

More specific to each implementation approach:

- The RAP approach had the greatest success of all differing implementation approaches regarding both profitability and efficiency. RAP improved profitability by $4.52/ac and efficiency by 13.8 lb-grain produced per lb-N applied. This implementation variation was successfully able to perform with both high efficiency for reducing N applications and obtain high yields.
- Both the RAC and RTC approaches were less profitable. The RTC approach being one of the first implementation variations tested, showed the greatest efficiency out of all variations with 15.6 lb-grain produced per lb-N applied. Producing 7.9 lb-grain per lb-N applied, the RAC approach increased efficiency as well.
- The RAP-R4 and RAC-R4, variations that extended to the R4 growth stage, were the least efficient variations. Due to the lack of benefit shown in efficiency and profitability, continuing into R4 was proven to not show any significance and is discouraged.

Results (continued)

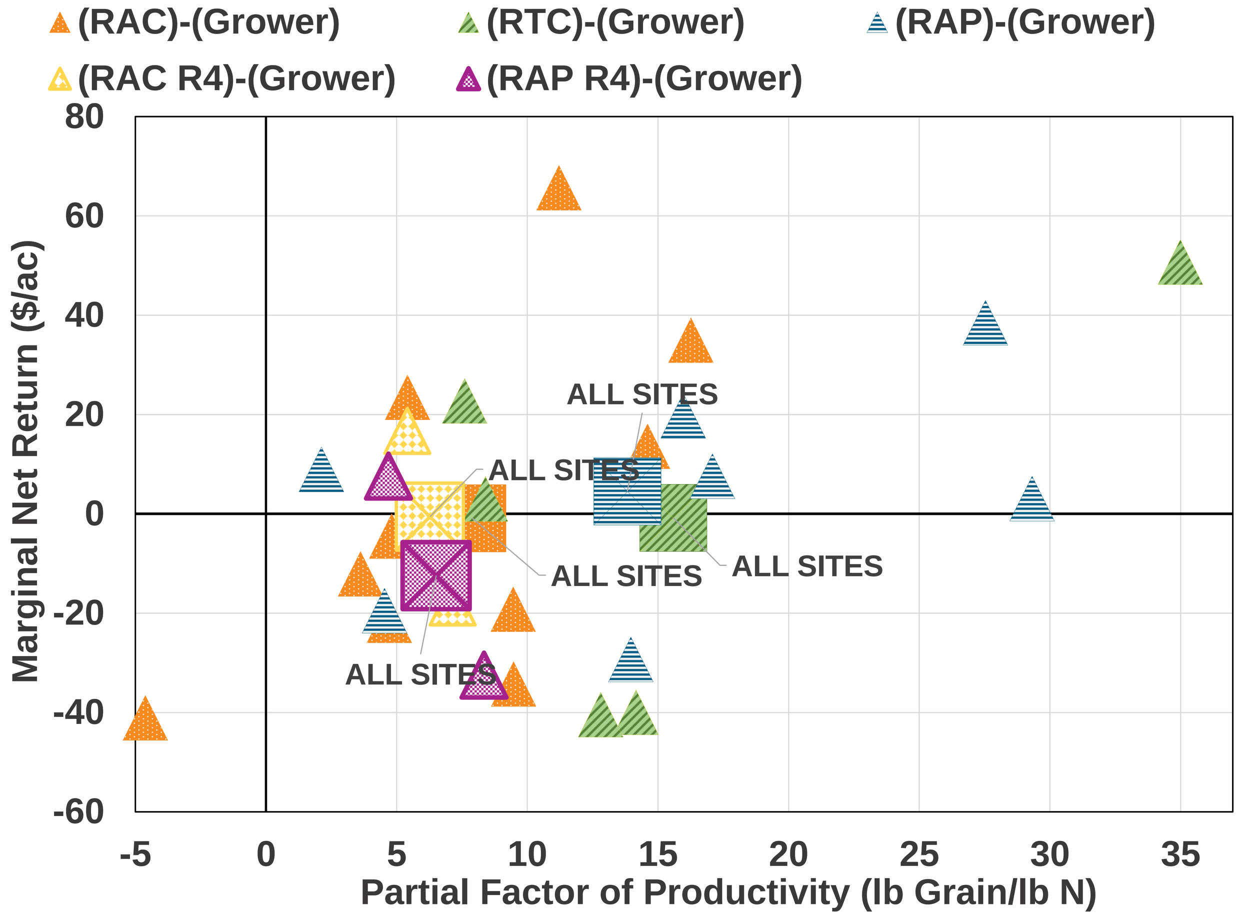

Figure 5. Aggregate results of profitability vs efficiency. Colors correspond to the treatment variations in Figure 4.

Conclusions & Future Work

The proposed SBFM practice has shown to significantly improve efficiency of corn production across all differing implementation approaches when compared to a grower's best N management practices. Although only some of the differing parameters increase profitability, it is important to note that these result are only relative to grower management and vary across sites. With increased price of N in the upcoming year's study, the opportunity for profitability to increase is greater with the efficiency this management has shown in the past years. A continuation of this study is currently taking place during the 2022 growing season and will be analyzed in the fall. The Risk-Averse Post-Establishment Increased Rate (RAP-IR) treatment variation, seen in **Figure 4,** is being implemented in the current growing season study. Continued work to adapt to environmental variation, integrating new image sourcing for ease of commercial adoption, and timing of treatment windows will contribute to the benefits of fertigation and continue to improve outcomes.

Acknowledgements

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