Groundwater Research Report
WR18R001

IMPROVING WATER AND NITROGEN USE EFFICIENCY UNDER CHANGING WEATHER VARIABILITY IN THE CENTRAL SAND

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Improving water and nitrogen use efficiency under changing weather variability in the Central Sand

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Project Summary

Title: Improving water and nitrogen use efficiency under changing weather variability in the Central Sands

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Background/Need: The Wisconsin Central Sands (WCS), a region characterized by its sandy soils, is a major vegetable producer in Wisconsin. Due to the sandy soil, shallow water table, and agricultural practices, the groundwater in the region is highly susceptible to nitrate (N) pollution. As many members of the community receive their drinking water from wells, groundwater contamination is a serious issue generating national attention. High levels of nitrate, well above the EPA 10 ppm threshold, have been documented in groundwater across the WCS (Kraft and Stites 2003, Groundwater Coordinating Council 2020), as well as the resulting human health impacts. In addition to water quality concerns, growers in the WCS also must manage water quantity challenges. Growers in the region regularly irrigate their crops due to water demands of crops and high evapotranspiration (ET), the low water holding capacity of the soil, and the sometimes infrequent rainfall. To irrigate, groundwater is pumped from the water table using high capacity wells, where it is then applied to crops through a center pivot irrigation system. Considering the high levels of N in the groundwater, which is reapplied to the landscape as irrigation water, it has been proposed that growers should account for the N in irrigation water when determining their fertilizer rate. However, it is unclear how N levels vary across the region and within season and year to year. By measuring N levels in irrigation water consistently throughout the growing season, and for multiple growing seasons, we aim to provide growers with the information needed to accurately account for the N in irrigation water. By accounting for the N in irrigation water, growers can reduce their overall fertilizer application, thereby limiting continued groundwater contamination. Using the data collected from irrigation samples, in combination with additional plant eco-physiological data we worked towards improving the representation of varied agricultural management in the agroecosystem model, Agro-IBIS for the WCS region. Ecosystem modeling allows us to assess large scale impacts of different management practices that would be impractical or impossible to conduct at a field-scale. Our modeling scenarios focus on determining which nitrogen and irrigation management strategies may promote water and nitrogen use efficiency while maintaining crop yields.

Objectives: (1) Quantify spatiotemporal variability of nitrate in precipitation and irrigation water applied to potato and maize in the WCS; (2) Utilize field measurements in the WCS to parameterize and improve simulation of N cycling, water balance, and productivity of potato and maize in the Agro-IBIS agroecosystem model to link irrigation and N fertilizer management choices to water use and NO_3-N leaching; (3) Use Agro-IBIS to identify irrigation and fertilizer management strategies that maximize water use efficiency (WUE) and N use efficiency (NUE) for potato and maize under more challenging growing conditions (e.g., weather) in the future

Methods: To quantify N found in irrigation water, we collected both irrigation and rainwater samples from on-farm irrigation wells located across the WCS during the 2018, 2019, and 2020 growing seasons. For each farm, three replicated funnel systems were installed per field with three additional funnels placed in unirrigated areas per farm for precipitation collection. Each funnel system consisted of one, 10 in. diameter funnel mounted on the top of a 4 ft. metal fence post connected to a 3-gallon container to store irrigation and rainwater. The collection system was both inexpensive and easily reproducible. Water volume and samples were collected weekly throughout the growing season and measured for nitrate, chloride, and Total Kjeldahl Nitrogen (TKN). Additional data on potato ecophysiology was collected in order to better understand how photosynthetic rate varies in response to environmental changes. Additionally, to evaluate the implications of large scale management changes on corn yield and nitrogen leaching, ecosystem modeling was used.

Results and Discussion: Preliminary results indicate that N levels in irrigation water have large spatial variability, but limited within season variability. Across all years, not only do N levels vary widely between farms, but also between wells on the same farm. Our results indicate that on some farms, the range can span 4 mg/L - 45 mg/L. When comparing N concentrations across fields that were sampled for multiple years of our study, for some fields the year to year variability was less than 1 mg/L. Considering all three summers of our study, the average N concentration in irrigation water was approximately 20 mg/L, or twice the EPA standard for safe drinking water. Preliminary ecophysiology data on potato production systems indicate a lack of a relationship between N rate and photosynthetic rate per leaf area, which will be useful information when improving agroecosystem modeling of potato cropping systems. When evaluating the impact of timing and rate of N fertilizer through ecosystem modeling, our preliminary results indicate that splitting fertilizer application does not impact corn yield, but does reduce N leaching by about 10%.

Conclusions and Implications: If growers were to begin accounting for the N-credits that can be attributed to irrigation water for each field, they could reduce fertilizer use (and the costs associated), and limit further groundwater contamination that occurs as the result of excess nitrogen application. However, our results indicate wide spatial variability in N levels, suggesting that blanket recommendations on N crediting will likely be inaccurate. However, as temporal variability was low – growers likely only need to measure their wells annually. Additionally, altering the timing of fertilizer application may aid in reducing N leaching, but will likely not be enough if substantial groundwater quality improvements are desired.

Related Publications:

Key Words: groundwater quality, nitrate leaching, ecosystem modeling, water use, ecophysiology

Funding:

Introduction

The Wisconsin Central Sands (WCS) exemplifies many of the current challenges facing communities across the world when it comes to maintaining crop yields while simultaneously preventing water quality degradation and over use. Located in the center of Wisconsin, the WCS is comprised of large-scale agricultural production, forests, wetlands, trout streams and lakes. The region is characterized by its sandy soil, high water table, and use of high capacity wells. The sandy soil lends itself to be extensively drained with low water holding capacity and low cation exchange capacity. Common crops grown in the area include potato, corn, soybean, and a variety of other vegetables. As a result of a combination of the geology, hydrology, and land use, the eastern portion of the region is highly susceptible to groundwater contamination and nonpoint source pollution (Wisconsin Department of Natural Resources 2015).

Groundwater contamination due to N leaching has been heavily documented across the state (Groundwater Coordinating Council 2020). High levels of N in water are linked to methemoglobinemia in infants, birth defects, and various forms of cancer. Ecologically, high levels of N may decrease biodiversity in both terrestrial and aquatic systems. As 25% of the state's residents receive their drinking water from private wells, this is particularly concerning from a human health standpoint. Recently, ~9% of private wells in Wisconsin tested above the EPA's threshold of 10 ppm N for safe drinking water (Groundwater Coordinating Council 2020). Furthermore, a recent study conducted in Portage county, which falls within the boundaries of the WCS, found that 24% of private wells tested above 10 ppm, about 2.5 times higher than the state average (Masarik et al. 2018).

Ongoing groundwater contamination is further compounded by climate change, which is creating warmer and wetter conditions across the area. Climate change is already apparent in the region, with rising nighttime temperatures and an increase in extreme rainfall events. Since 1948, average annual temperature has increased between 1-2ºC, and the growing season has lengthened by 15-20 days (Kniffin et al. 2014). Precipitation has increased by about 10 cm during the same time period. Moving forward, temperatures are expected to rise and precipitation is expected to continue to increase, but there is greater uncertainty surrounding the timing of precipitation (Wisconsin Initiative on Climate Change Impacts 2011). Increased temperatures will lengthen the growing season in the WCS, increasing overall crop water demand during the growing season. Additionally, with rising air temperatures, evapotranspiration (ET) is likely to also increase, contributing to greater water loss and increased water demand. Increases in overall rainfall and extreme rainfall events will increase the chance of N leaching, while rising temperatures may also increase crop stress and reduce nutrient uptake. To exacerbate water quantity challenges, depending on timing of rainfall and degree of temperature rise, irrigation demand and overall water use in the region may rise.

Growers in the WCS regularly irrigate their crops due to water demands of crops and high evapotranspiration (ET), the low water holding capacity of the soil, and the sometimes infrequent rainfall. To irrigate, groundwater is pumped from the water table using high capacity wells, where it is then applied to crops through a center pivot irrigation system. Considering the high levels of N in the groundwater, which is reapplied to the landscape as irrigation water, it has been proposed that growers should account for the N in irrigation water when determining their fertilizer rate. However, while high N levels in groundwater are heavily documented, it is unclear how N levels vary spatially and temporally across the region. By measuring N levels in irrigation water consistently throughout the growing season, and for multiple growing seasons, we hope to provide growers with the information needed to accurately account for the N in irrigation water. By accounting for the N in irrigation water, growers could reduce their overall fertilizer application, thereby limiting continued groundwater contamination. As rainfall becomes more variable and temperatures rise with a changing climate, improved nitrogen and irrigation management strategies will both be more crucial, and likely more challenging.

While crediting N in irrigation water has been proposed for at least the last 30 years (Point 1994, Keeney and Follett 2015), few studies have measured the N in irrigation water directly, and to the best of our knowledge, no one has measured N in irrigation water across this spatial scale and at this frequency. Additionally, while a few past studies have measured N in wells, some conducted over 50 years ago, when paired together - our study emphasizes the growing contamination of groundwater as N concentration continues to rise. Specifically, a study conducted in the 1970's across the region found an average N concentration of 9 mg/L (Saffigna and Keeney 1977), substantially lower than today's levels.

Currently the N in irrigation is treated as a constant background value that is indirectly accounted for in N management recommendations. However, N management recommendations for the central sands were primarily developed from trials at Hancock Agricultural Station, and do not reflect the large variability in N levels in irrigation water across the region which are evident in our results. Additionally, the inches of irrigation applied, or estimated values, must be considered in order to accurately reflect the N that is being applied to crops through the irrigation water. As a result, indirectly accounting for N in irrigation water based on field trials conducted at Hancock Agricultural Station likely underestimate the current levels of N in irrigation water and does not accurately credit the N in irrigation water.

In addition to accounting for the N in irrigation water, growers in the area may need to alter their nitrogen management practices if groundwater quality is going to be improved by a large magnitude. To determine which management practices are likely to produce more efficient use of water and nutrients, ecosystem modeling can be used. Ecosystem modeling allows us to better understand the biophysical changes that may occur as a result of large-scale changes, while still providing meaningful data to growers and policy makers.

The purpose of this project is to propose water and nitrogen use efficiency under changing weather variability across the WCS. To do so, we proposed three separate objectives. The first focused on evaluating the spatiotemporal variability of N in irrigation water through regular sampling. The second utilizes the collection of more field data to better parameterize the agroecosystem model, Agro-IBIS for the improved modeling of potato and maize cropping systems. Specific field measurements that were collected as part of this objective include potato ecophysiological data, N leaching lysimeter data, and biophysical data such as soil moisture, crop biomass, and leaf area index. And lastly, the third objective uses Agro-IBIS to assess the impact of varied management strategies that could promote improved water and nitrogen use efficiency across the WCS.

Procedures and Methods

Sampling and analysis of N in irrigation water

To determine the spatial and temporal variability of N levels in irrigation water, water samples were collected and analyzed weekly during the growing seasons in 2018, 2019, and 2020 for nitrate and chloride concentration. To collect samples from the fields, we installed funnel systems on farms spanning a North-South gradient across the WCS. Funnel systems were simple, portable, and cost-effective, consisting of a funnel at canopy height, and using PVC pipe and a fence post to route water to a 3-gallon storage container on the ground. During the 2018 growing season, samples were taken from four farms, with five to six fields (each field serviced by a different well) sampled at each farm. We expanded the number of farms involved during the 2019 field season, for a total of six farms, with five to seven fields sampled at each farm. Due to the selling of one farm, only five farms were included in our sampling during the 2020 growing season. In order to balance both the temporal and spatial aspects of the research, roughly half the fields were repeated each year of the study. To allow for replication, three funnels were placed in each field, and each funnel was placed at a different point along the center pivot irrigation system. To account for precipitation, three funnels were placed at each farm in an area free of irrigation. In general, this approach allowed for the passive collection of irrigation water. While sampling from fields, rather than wells directly, meant that our water samples often included both irrigation and precipitation water, we were able to collect roughly ~90 samples a week, which would not have been possible otherwise. As a result of the passive system of sampling, back calculations were performed for each sample to account for any dilution that may have occurred due to precipitation. This study was not crop specific, and any field receiving regular irrigation was included. Throughout the three years of the study, a wide array of crops were grown on the fields sampled, including soybean, potato, sweet corn, field corn, cabbage, hemp, pea, carrot, and strawberry.

Samples were analyzed for both nitrate and chloride using a liquid membrane, combination ion selective electrode. Nitrate and chloride concentration was determined by adding an ionic strength adjuster to each sample, and then measuring the voltage that occurs as a result of the ion exchange between the solution and membrane. To assess the accuracy of our lab analysis (with electrode probes) and determine whether any biases existed, 10% of samples were sent to the UW Stevens Point Water and Environmental Analysis lab and analyzed for N content using a Lachat Instruments Flow Injected Analyzer. Additionally, a subset of samples were also measured for Total Kjeldahl Nitrogen (TKN), which will allow us to determine how much N is being added during fertigation events (e.g. additional N is mixed with the irrigation water and applied to fields) and provide an additional component of the N budget.

Measurements of potato ecophysiology

In collaboration with ongoing field trials conducted by Prof. Yi Wang in the Dept. of Horticulture at UW-Madison, the ecophysiological response of potato to N rate and irrigation management was measured. Field trials were carried out at Hancock Agricultural Research Station on research plots for both the 2019 and 2020 growing season. The irrigation experiment, conducted only in 2019, involved four treatments: Deficit 1 (75% of Standard practice), Deficit 2 (50% of Standard practice), Standard, and Over (125% of Standard practice) irrigation. Nitrogen rate trials, which were conducted in both 2019 and 2020 included the following N rates: 40, 180, 240, 300, and 360. Due to time limitations in 2020, only plots with N rates of 40, 240, and 360 were sampled. For both the 2019 and 2020 growing season, data was collected across at least two potato varieties.

Leaf level gas exchange measurements were taken using a LI-COR 6400xt portable gas exchange analyzer (LICOR Inc., Lincoln, Nebraska, USA). The portable system consists of an infrared gas analyzer, leaf chamber, and computer console, allowing for the control of light intensity, temperature, flow rate, relative humidity, and CO_2 concentration. To measure photosynthesis and transpiration, an open system approach is taken, calculating photosynthesis and transpiration based on the differences in CO_2 and H_2O concentrations in in-chamber and pre-chamber air streams. Conceptually, rate of photosynthesis is measured as the difference between photosynthetic carbon assimilation and the CO_2 that is lost during mitochondrial respiration.

Data collection focused on three ecophysiological components: light response curves, CO_2 response curves, and survey measurements. Light response curves were taken in increments from 0 to 2000 micromoles quanta m^{-2} s^{-1} PAR and CO_2 response curves ranged from 0 to 1200 ppm CO_2, allowing us to gain insight on how the plant responds to a wide range of environmental conditions. Following photosynthesis measurements of response curves, each leaf was collected for future N content analysis and dried at 80ºC for 24h. In the spring of 2021, samples of at least 8-10 mg of leaf dry matter will be ground and analyzed for total C and N via combustion at 900 degrees Celsius using a Flash EA 1112 CN Automatic Elemental Analyzer (Thermo Finnigan, Milan, Italy).

On two to three clear days during the growing season, survey photosynthesis measurements were taken to provide an instantaneous measurement of the current rate of photosynthesis under ambient environmental conditions. In our experiment, survey measurements were collected from sunrise (~5:45 am) to sunset (~8:45 pm) on clear days. In 2019, measurements were repeated every three hours, and in 2020 survey measurements were conducted hourly. Photosynthesis measurements were taken on the second fully expanded leaf at the top of the canopy.

Moving forward, data collected during the 2019 and 2020 field season will be used to improve modeling of potato and maize cropping systems. Specifically, we will calibrate potato canopy physiology modeling (photosynthesis, conductance, and respiration) with field data in order to incorporate potatoes' response to stress and the wider range of environmental conditions captured in the field. Additionally, data on N levels in irrigation water will be incorporated into the model to more accurately reflect the actual N budget of the WCS. To do so, the crop management module will be edited to assign a value for N content in irrigation water in the WCS based on field data.

Using Agro-IBIS to evaluate NUE and WUE management scenarios

Scenarios were created using Agro-IBIS, an agroecosystem model to assess the impact of varied N fertilizer management scenarios on nitrate leaching and corn yield. Agro-IBIS simulates the coupled C, water, N, and energy exchange in the soil-plant-atmosphere system and can be paired with climate data to assess the role of a changing climate on these processes. The model requires inputs of gridded soil textural data, annual land cover and land use, annual nutrient management (manure and inorganic fertilizer), and daily weather (temperature, precipitation, specific humidity, solar radiation, and wind speed), which is interpolated to an hourly time-step using statistical and stochastic modeling (Kucharik et al. 2000, Motew et al. 2017). Each scenario is run as a point simulation for a specific coordinate location falling within three select counties in Wisconsin: Sheboygan, Dane, and Portage County. Agro-IBIS has been extensively validated and calibrated for these areas (Kucharik and Brye 2003). To improve the model's simulation of the N cycle, modifications are currently ongoing. Re-parameterization of the N cycle will feature new model calibration for N leaching in corn agroecosystems and will be based on N leaching data collected via lysimeter studies supplied by Kevin Masarik (PhD student and UWSP groundwater quality specialist) and N leaching data from a meta-analysis of Midwest studies, conducted by Dr. Debendra Shrestha (Kucharik lab postdoctoral student).

To determine changes in nitrate leaching and corn yield across different nitrogen management strategies, scenarios incorporating both timing of fertilizer application and amount of fertilizer applied were developed across three distinct agroclimatic regions in Wisconsin including Portage County, Sheboygan County, and Dane County representing the central, eastern, and southern regions of the state respectively. Locations are selected to represent a range of soil textures, with Portage County modeled as loamy sand, Sheboygan County as clay loam, and Dane County as silt loam. Regional differences in mean climate and weather variability were also incorporated through focus on these three locations. Timing of application included three possibilities: 1) 100% of fertilizer applied at planting. 2) ⅓ of fertilizer applied at planting, and ⅔ applied at growth stage V4. 3) ¼ of fertilizer applied at planting, growth stage V3, V8 and R1 respectively. Fertilizer was applied at the following application rates: 0, 40, 80, 120, 160, 200, 240, and 280 kg/ha. A few select scenarios were developed to focus on manure application timing. Three timing options are included as follows: 1) Fall application, 2) Spring application, and 3) Fall and Spring application. These scenarios only occur at the Sheboygan location in order to reflect typical management for the area. In total, 150 scenarios have been developed, with 75 modeling the recent past, and 75 scenarios encompassing projections of future climates. Analysis will focus on N leaching past the plant root zone at both the monthly and annual temporal scale in comparison to annual corn yield.

Past weather data was obtained from METDATA, a dataset of daily meteorological weather at a spatial resolution of 4 km (GridMET, METDATA). One general circulation model (GCM) was selected to model scenarios under climate change. Moving forward, at least two more GCMs will be included to provide a more robust analysis of the impact of future climate change. Simulated future scenarios span the years 2061-2099, and trend towards wetter and warmer conditions for the area of study.

Results and Discussion

Sampling and analysis of N in irrigation water

Preliminary results indicate that N levels in irrigation water have large spatial variability, but limited within season variability. Across all years, not only do N levels vary widely between farms, but also between wells on the same farm (Fig. 1). Our results indicate that on some farms, the range can span 4 mg/L - 45 mg/L. While generally within season variability (indicated by error bars) was lower than spatial variability, some fields and years stand out. In 2019, the variability in N levels was consistently greater than the variability in 2018 and 2020. This may be attributed to the higher rainfall received in 2019 and our method of back-calculating N concentration values. Concentrated rainfall events make it challenging to accurately account for the exact amount of rainfall received in a given field, which does influence the N concentration by altering the dilution value used. Additionally, fields with greater variability tend to be fields that are fertigated. As these results are preliminary, we are still working to ensure fertigation events are excluded from analysis. Considering all three years of our study, the average N concentration in irrigation water was approximately 20 mg/L, or 2x the EPA standard for safe drinking water.

When comparing N concentrations across fields that were sampled for multiple years of our study, very little variability exists year to year. In fact, for some fields, the year to year variability is less than 1 mg/L. While not necessarily unexpected, these results highlight that growers may not need to test each well annually in order to accurately measure the N concentration in their well and irrigation water.

While this number clearly indicates unsafe drinking water, it has less meaning when thinking about N fertilizer application. To determine how much plant available N is being applied through irrigation water, a simple calculation can be done. A grower must estimate the average amount of inches of irrigation applied during a growing season, as well as the N concentration of the specific well they are using to irrigate. Once analyzed, NO_3-N levels are typically reported in values of mg/L or ppm of nitrogen, which then can be converted to lbs. per inch of irrigation water by multiplying by 0.226. The resulting value multiplied by annual inches of irrigation estimates the nitrogen applied through irrigation water (expressed as pounds of nitrogen per acre, N lb/ac). See equation below.

$$Lbs. N\ per\ acre\ =\ NO3 - N\ (mg/L\ or\ ppm)\ *\ 0.226\ *\ inches\ of\ irrigation\ applied$$

Depending on the crop being grown and the amount of irrigation occurring in a given growing season, the amount of N in irrigation water may account for a substantial portion of the required N inputs for that crop. For instance, corn grown in the WCS typically receives in N rate application of 200 N lb/ac. If we assume a grower is irrigating 8 inches during a growing season, and the irrigation water has a concentration of 20 mg/L N, the grower is then adding approximately 36 N lb/ac through irrigation water, or about 20% of the total N inputs required by corn. Similarly, we can estimate the regional implications if every grower began accounting for the N-credit in irrigation water.

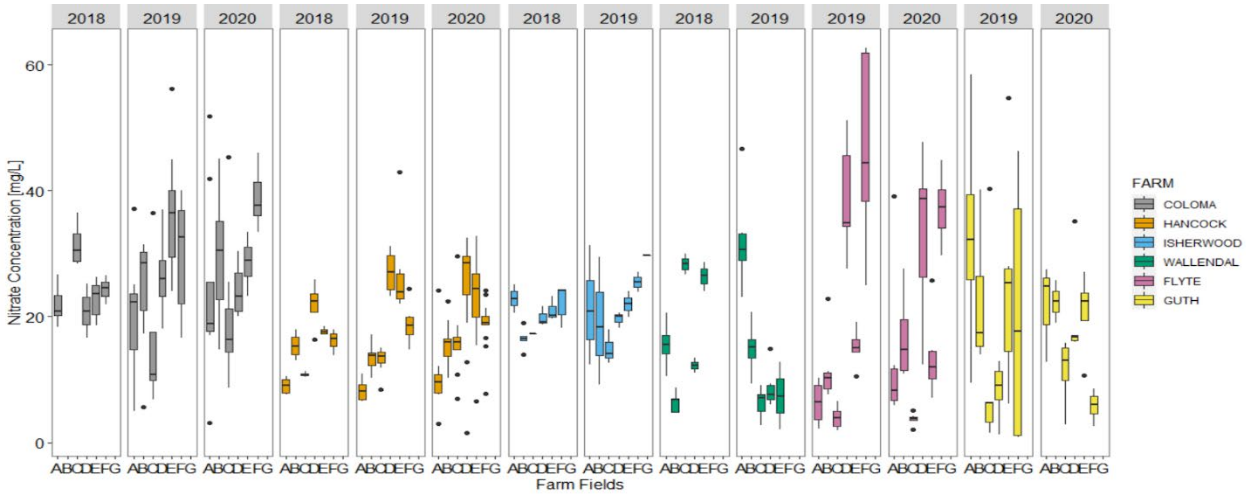

Fig. 1) N concentration [mg/L] in irrigation water across six farms located in the WCS, sampled from 2018 to 2020.

Measurements of potato ecophysiology

Survey measurements of photosynthetic rate followed similar patterns as past research (Dwelle et al. 1983, Dwelle 1985), with a peak assimilation rate observed around midday (Fig. X). Preliminary results from the N rate trials in 2019 do not necessarily indicate a relationship between N fertilization rate and photosynthetic rates, which supports previous findings (Marshall and Vos 1991, Vos and Van Der Putten 1998, Vos 2009). However, there is variability in photosynthetic rate across N management rates and potato varieties, which may be explained by different factors such as leaf temperature, soil moisture, date of measurement, and date of N application. Future analysis will include the above factors in determining any correlation to results. Additionally, analysis of leaf N content may help to elucidate our findings.

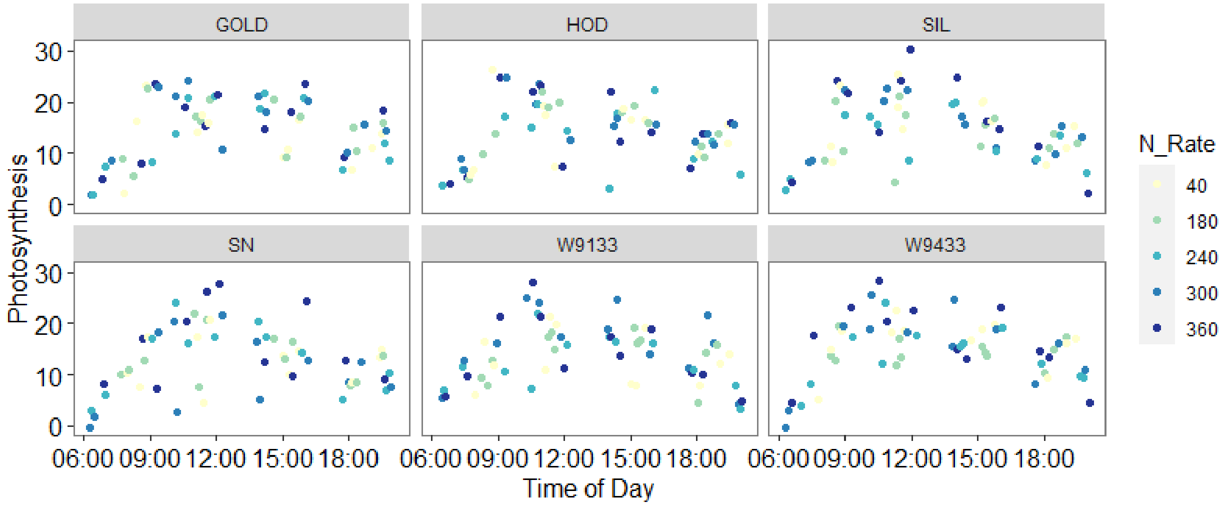

Fig. 2) Photosynthetic rate [μmol CO_2 $m^{-2}s^{-1}$] measured diurnally during peak growth across six varieties of potatoes (Goldrush, Hoag, Silverton, Snowden, W0133, and W9433) and five nitrogen rate treatments (50, 180, 240, 300, 360 lb N/ac).

Using Agro-IBIS to evaluate NUE and WUE management scenarios

Preliminary results indicate that corn yield generally increases with increased quantity of fertilizer applied. However, under the current climate, yields plateau around an N application rate of 120 kg/ha, with minimal increases in crop yield occurring at higher N rates (Fig. X). Based on model results, applying more than 120 kg/ha N does not result in substantial yield gains. Nitrate leaching past the plant root zone also increases with increasing N rates. However, splitting fertilizer applications does reduce N leaching by about 10% (Fig. 3). Scenario results indicate split fertilizer application reduces nitrate leaching with no cost to corn yield. However, if water quality improvement is a priority, these management changes alone are likely not enough.

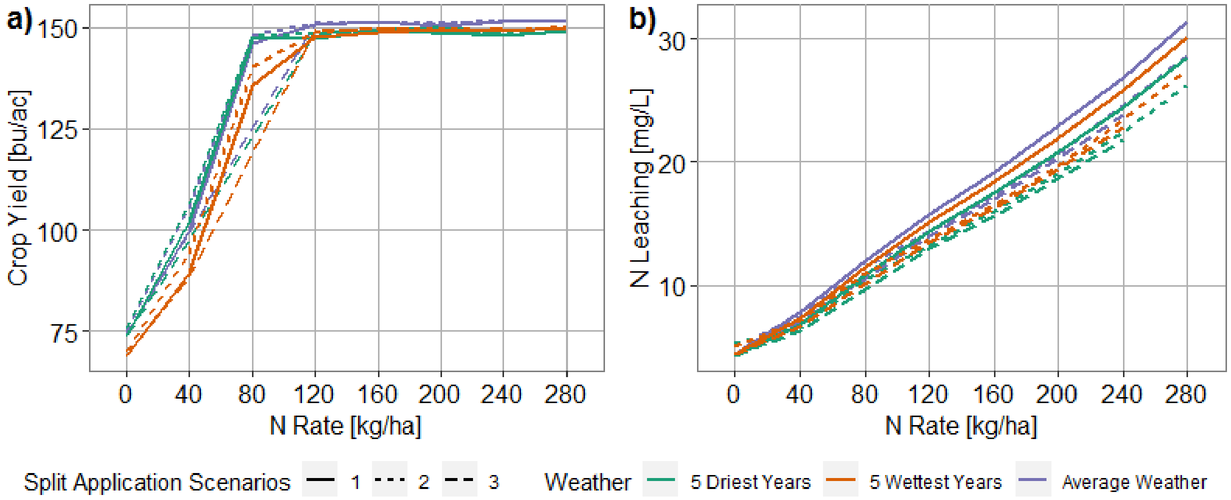

Fig. 3) (a) Modeled corn yield [bu/ac] under various N rates [kg/ha], nitrogen split application scenarios, and weather extremes for Portage County; (b) modeled N leaching [mg/L] under various N rates [kg/ha], nitrogen split application scenarios, and weather extremes for Portage County.

Conclusions and Recommendations

This study advanced our knowledge on how to potentially develop more efficient nitrogen management plans in the Wisconsin Central Sands. If growers could more accurately account for the nitrogen credits attributed to applied irrigation water for each field, they could reduce fertilizer use (and the costs associated), and help limit further groundwater contamination that occurs as the result of excess nitrogen application on crops grown in sandy soils. However, our results indicated wide spatial variability in nitrate levels, suggesting that blanket recommendations on nitrogen crediting will likely be inaccurate. However, as temporal variability was low – growers will likely only need to measure nitrate in their wells on an annual basis for nutrient management plans. Preliminary ecosystem modeling results evaluating the timing and amount of fertilizer applied indicated that while splitting nitrogen among multiple applications is a step in the right direction and can reduce nitrate leaching – this will not be a silver bullet to solve the challenging water quality issues. Therefore, growers, policy makers, and researchers must be aware of the limitations in water quality improvement associated with such management changes and be looking to make these a part of a much more comprehensive management strategy to protect water resources. Moving forward, conversations and recommendations regarding nitrogen applications must consider the potential for nitrate leaching to groundwater and move past a primary focus that has centered on yield. Much more transformative changes to nutrient management and land use will likely be required to significantly improve water quality in the long-term.

References

Dwelle, R. B. 1985. PHOTOSYNTHESIS AND PHOTOASSIMILATE PARTITIONING**This is Idaho Agricultural Experiment Station paper No. 8475. Potato Physiology. ACADEMIC PRESS, INC.

Dwelle, R. B., P. J. Hurley, and J. J. Pavek. 1983. Photosynthesis and Stomatal Conductance of Potato Clones (Solanum tuberosum L.) . Plant Physiology 72(1):172–176.

Groundwater Coordinating Council. 2020. Wisconsin Groundwater Coordinating Council Report to the Legislature.

Keeney, D. R., and R. F. Follett. 2015. Managing Nitrogen for Groundwater Quality and Farm Profitability: Overview and Introduction. Managing Nitrogen for Groundwater Quality and Farm Profitability.

Kniffin, M., K. Potter, A. Bussan, J. Colquhoun, and K. Bradbury. 2014. Sustaining Central Sands Water Resources: State of the Science (2014):1–100.

Kraft, G. J., and W. Stites. 2003. Nitrate impacts on groundwater from irrigated-vegetable systems in a humid north-central US sand plain. Agriculture, Ecosystems and Environment 100(1–3):63–74.

Marshall, B., and J. Vos. 1991. The Relation Between the Nitrogen Concentration and Photosynthetic Capacity of Potato (Solatium tuberosum L .) Leaves Author (s): B . MARSHALL and J . VOS Source : Annals of Botany , July 1991 , Vol . 68 , No . 1 (July 1991), pp . 33-39 Published by 68(1):33–39.

Masarik, K., M. Mechenich, A. Nitka, G. Kraft, and K. Masarik. 2018. Portage County Well Water Quality – 2017 Portage County Well Water Quality – 2017(January).

Point, U. 1994. Conference Proceedings Nitrate in Wisconsin ' S Groundwater : (1994).

Saffigna, P. G., and D. R. Keeney. 1977. Nitrate and Chloride in Ground Water Under Irrigated Agriculture in Central Wisconsina. Ground Water 15(2):170–177.

Vos, J. 2009. Nitrogen responses and nitrogen management in potato. Potato Research 52(4):305–317.

Vos, J., and P. E. L. Van Der Putten. 1998. Effect of nitrogen supply on leaf growth, leaf nitrogen economy and photosynthetic capacity in potato. Field Crops Research 59(1):63–72.

Wisconsin Department of Natural Resources. 2015. Central Sand Plains Ecological Landscape. The ecological landscape of Wisconsin: An assessment of ecological resources and a guide to planning sustainable management (2015):118.

Wisconsin Initiative on Climate Change Impacts. 2011. The first report of the Wisconsin Initiative on Climate Change Impacts (2011):14–33.

Appendix A

Presentations:

"Improving Nitrogen Management Strategies across Wisconsin," Agro-IBIS Annual Workshop. Virtual, April 2020

Estimated audience members: 15

"Background Nitrate Variability in Irrigation Water: How much N credit should we be giving?," Wisconsin Potato and Vegetable Growers Association Annual Meeting. Stevens Point, WI, February 2020.

Estimated audience members: 30

"Quantifying Nitrate in Irrigation Water across the Wisconsin Central Sands," American Water Resources Association – Wisconsin Chapter. Delavan, WI, March 2019.

Estimated audience members: 40

Students Funded:

Tracy Campbell: PhD Student, Department of Agronomy

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Impact of Work:

Broadly, our research focuses on evaluating management strategies to improve groundwater quality within the Wisconsin Central Sands (WCS). The WCS is a region that illustrates many challenges growers across the Corn Belt are facing as they strive to maintain crop yield while managing ongoing water quality degradation. Certain conditions in the WCS make it especially vulnerable to groundwater pollution, such as the sandy soil, high water table, and large nitrogen requirements of the crops grown in the area. As a result, the groundwater has become contaminated with high levels of nitrate, which are above the EPA threshold for safe drinking water. Considering many members of the community get their drinking water from private wells and the groundwater below, this is especially concerning. Our research helps growers work within the current agricultural system to reduce further contamination to groundwater by reducing their fertilizer use. Specifically, we measured nitrate levels in irrigation water across farms in the region to assess how nitrate levels vary from field to field, farm to farm and across time – within a growing season and year to year. By accounting for the nitrate already present in irrigation water, growers can reduce their fertilizer use, thereby reducing potential nitrate leaching to groundwater.

Throughout the three years of our study, we worked with six growers spread across the WCS region. On numerous occasions, growers expressed interest in our findings as they were unsure previously what nitrate levels were in their irrigation water. In fact, one grower went as far as to send us the email below, in which he indicates that he did indeed change his management practices as a result of our research.

hintz1_@hotmail.com
TRACY A CAMPBELL
20:18

Thank you for that and thank you for conducting this research.

That field grew excellent peas this year and I put part of that to your research making me aware of the nitrates in the water so I could credit them.

The peas stood better since I credited the N and I applied less. Higher yields and less inputs that’s a win win!

Matt

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