NRCS CONSERVATION INNOVATION GRANT

Final Report

Grantee Entity Name: Minnesota Agricultural Water Resource Center
Project Title: Developing Diagnostics to Improve Water Quality and Soil Health on Tile Drained Lands in Minnesota and Wisconsin
Agreement Number: 69-3A75-17-11
Project Director: Tim Radatz
Contact Information Phone Number: 608-443-6587
E-Mail: radatz@mawrc.org

Background

Many farmers in the Upper Midwest use agricultural tile drainage to produce crops. Farmers in Minnesota and Wisconsin have been using agricultural tile drainage for decades. Tile drainage is used to achieve moisture conditions that improve field access, promote crop growth and yield, and decrease surface runoff. Tile drainage can also serve as a conduit for sediment and nutrient transport to surface waters and more information and education is needed to reduce this potential pathway for transport.

Most of the farmland that contains tile drainage in Wisconsin is in the Lake Michigan Basin, and in Minnesota, most is in the Mississippi River Basin. Delivery of nutrients to the Gulf of Mexico through the Mississippi River results in a hypoxic zone that affects aquatic life and the industries that depend on it. Delivery of nutrients to the Great Lakes or other freshwater sources in Wisconsin and Minnesota results in algal blooms and eutrophic conditions that are harmful to aquatic life and interfere with intended uses. Water quality impairment in both states is largely attributed to intensive agricultural land use.

Recently there has been an increased emphasis on soil health, led by the NRCS which launched a national soil health initiative in 2012. The initiative is “meant to highlight the benefits of improving and maintaining America’s soil.” Healthy soils are more than just fertile soils with adequate nutrient levels, they also have high soil quality including, physical structure and biology. The key principles are plant diversity, minimal soil disturbance, and substantial vegetative and soil cover. Increases in soil health have the potential to improve water quality by increasing infiltration and water holding capacity, protecting soil from erosion by providing adequate soil cover, and increasing nutrient retention. However, there is a lack of documentation on the impact of soil health improvements on water quality, in particular, tile water quality.

Discovery Farms is an edge-of-field water quality research and outreach program focusing on farmer leadership, credible research design and implementation, and effective communication of results. The Discovery Farms programs in Wisconsin and Minnesota have been collecting edge-of-field surface runoff and tile flow data for 15-20 years. Many relationships between farming practices, sediment, and nutrients of surface runoff and tile flow have been quantified through the program’s extensive monitoring network. However, this type of intensive edge-of-field water quality monitoring is expensive to operate and difficult to site, which limits the number of farmers able to participate.

This project significantly added to the existing tile water quality monitoring efforts and soil health monitoring and knowledge, specifically:

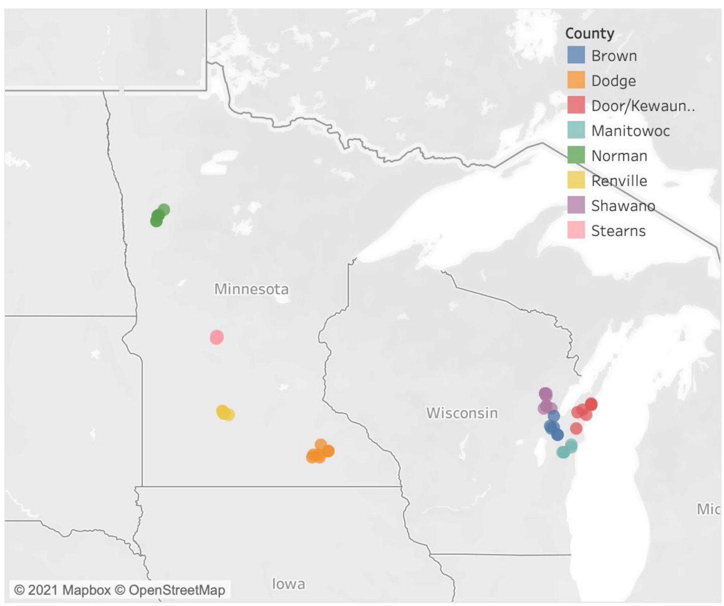
- Demonstrated the potential add-on or alternative to current edge-of-field NRCS practice standards making edge-of-field monitoring a more accessible diagnostic for farmers and farm advisors.
- Identified agricultural practices and field conditions where the potential for loss from tile drainage is high and assessed available practices to reduce losses.

- Completed soil health assessments and compared to tile water quality measurements building on the soil health knowledge base.
- Provided multiple approaches to information transfer, allowing information from the project to reach many farmers and stakeholders.

This project was funded through NRCS Conservation Innovation Grants (CIG). CIG is a competitive grant program that stimulates the development and adoption of innovative approaches and technologies for conservation on agricultural lands. Through CIG, NRCS partners with public and private entities to accelerate technology transfer and adopt promising technologies.

Methods

Three tiers of water quality monitoring were assessed; intensive, intermediate, and basic. Intensive tile flow and water quality data was collected from 8 locations, one in each specified county area. Intensive sites utilized automated sampling equipment and a flow based sampling approach, including dataloggers, ISCO water samplers, and remote communications. Water samples from intensive sites were analyzed for suspended sediment, total Kjeldahl nitrogen, ammonium, nitrate, total phosphorus, dissolved phosphorus, chloride, total organic carbon, and dissolved organic carbon. Bi-weekly grab samples were also taken at these sites to assess the lower cost monitoring approach.



There were 20 intermediate sites and 20 basic sites in the project. Intermediate sites included continuous flow monitoring and bi-weekly water sampling. Basic sites included bi-weekly flow monitoring and water sampling. Water samples from the intermediate and basic sites were analyzed for suspended sediment, dissolved phosphorus, total phosphorus, and nitrate.

Agronomic information and a soil health assessment was collected for each location. The link between tile water quality and soil health was assessed using total organic carbon, particulate organic matter, and active carbon. Soil samples were also taken for a complete chemical soil health analysis.

Field days, meetings, print materials, webinars, and an online farmer network were all utilized for information transfer. Agronomic, water quality, and soil health information were presented and discussed in all of these formats.

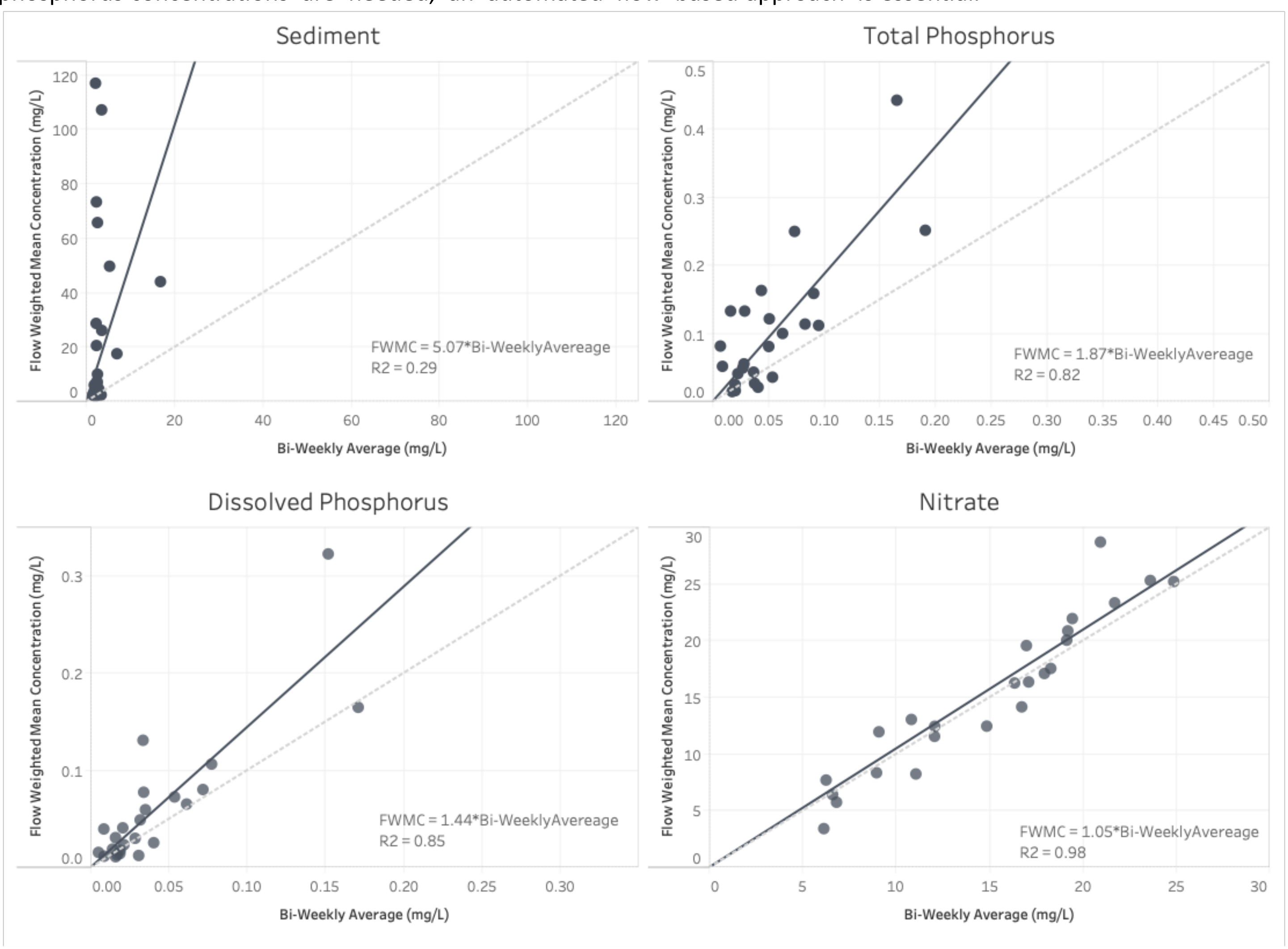
Results

Comparison of Tile Flow Monitoring Approaches - Intensive, Intermediate, and Basic

If measuring flow is a necessity, the intensive and intermediate approaches in this project would produce reliable results.

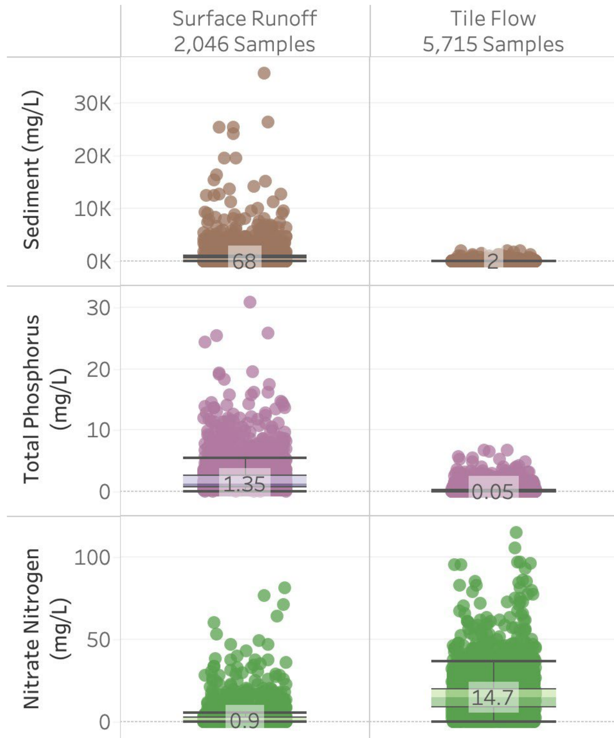
Flow measurement of the intensive approach was reliable under all conditions. The only flow measurement limitation of the intermediate approach is during pressurized flow conditions where water levels don't necessarily correspond to flow rates. This happened at different sites throughout the project, although these pressurized flow periods had limited impact on annual runoff totals. The basic approach is insufficient for annual flow measurements as there is too much variability to only measure once every two weeks.

Bi-weekly samples were taken at intensive sites along with the flow based automated sampling to compare results of these two methods. Flow weighted mean concentrations (total weight lost per year divided by the total volume of tile flow) of the flow based automated sampling were compared with annual averages of the bi-weekly grab samples at all intensive sites. The bi-weekly sampling approach underestimated sediment, total phosphorus, and dissolved phosphorus concentrations. This is likely because bi-weekly sampling events missed most of the high flow periods where sediment and phosphorus concentrations are typically higher. The bi-weekly sampling approach produced excellent results for nitrate concentrations, average bi-weekly concentrations were consistent with flow weighted mean concentrations. The intermediate and basic sampling approach produced reliable nitrate concentration values, but underestimated sediment and phosphorus. If reliable sediment and phosphorus concentrations are needed, an automated flow based approach is essential.



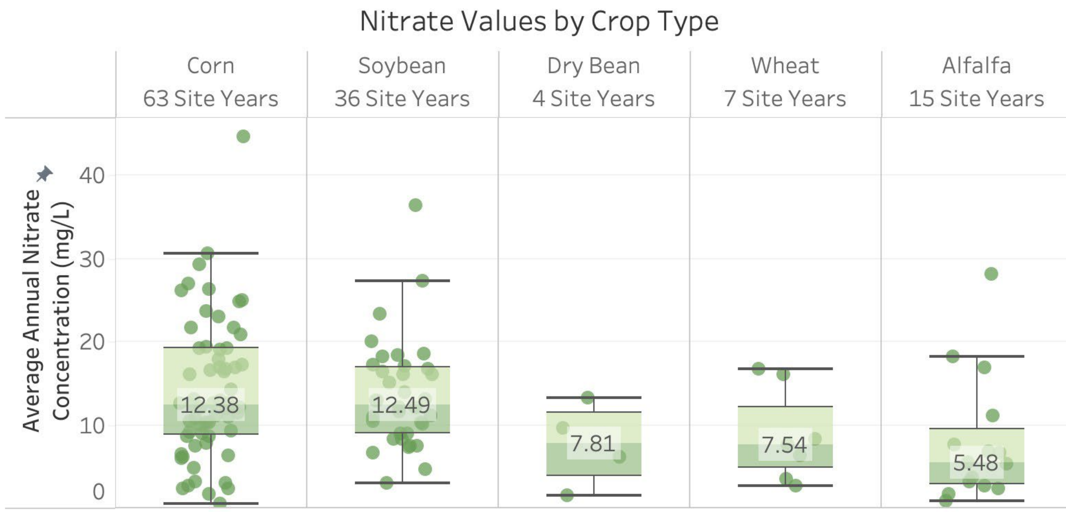
Nutrients and Sediment in Tile Flow Compared to Surface Runoff

Comparing surface runoff and tile flow samples collected throughout the history of the Discovery Farms programs in Minnesota and Wisconsin, including tile samples as part of this project, help to provide context to differences in surface runoff and tile drainage. This can also help to prioritize the source of the water when assessing water quality concerns. Sediment and phosphorus sample concentrations are generally much higher for surface runoff and more of a concern for surface runoff than tile drainage. Nitrate, on the other hand, is generally much higher for tile drainage and more of a concern for tile drainage.

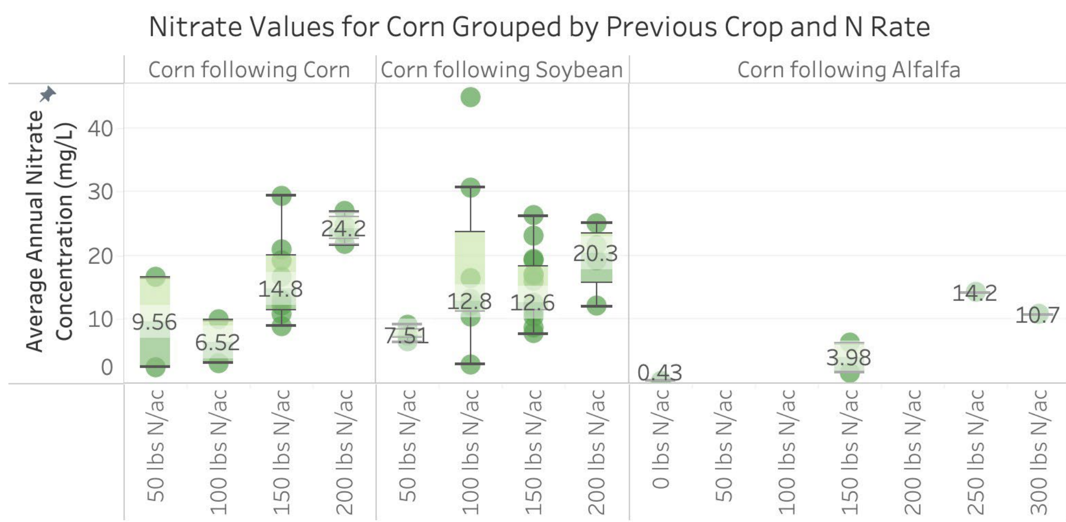


Agronomic Impacts of Tile Nitrate Levels

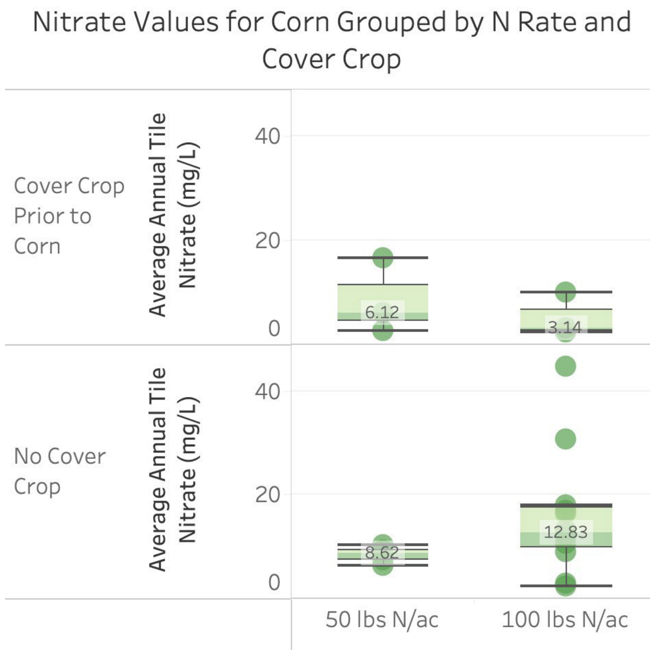
There are many weather and agronomic factors that impact tile nitrate levels, but a few factors emerged as leading impacts in this study. These factors were crop type, previous crop type, nitrogen application rate, and cover crops. Nitrate levels were higher for corn and soybean crops compared with dry bean, wheat, and alfalfa. The previous crop also impacted tile nitrate levels for corn fields with corn following corn and corn following soybean having higher tile nitrate levels than corn following alfalfa.



Nitrogen application rate was also a factor. In general, as application rate increased, so did tile nitrate concentration. This became more clear when the sites were grouped by crop and previous crop. Corn following corn and corn following soybean showed similar tile nitrate increases with nitrogen application rates. Corn following alfalfa showed an increase in tile nitrate with nitrogen application rate, but the rate of increase was smaller than corn following corn or corn following soybean.

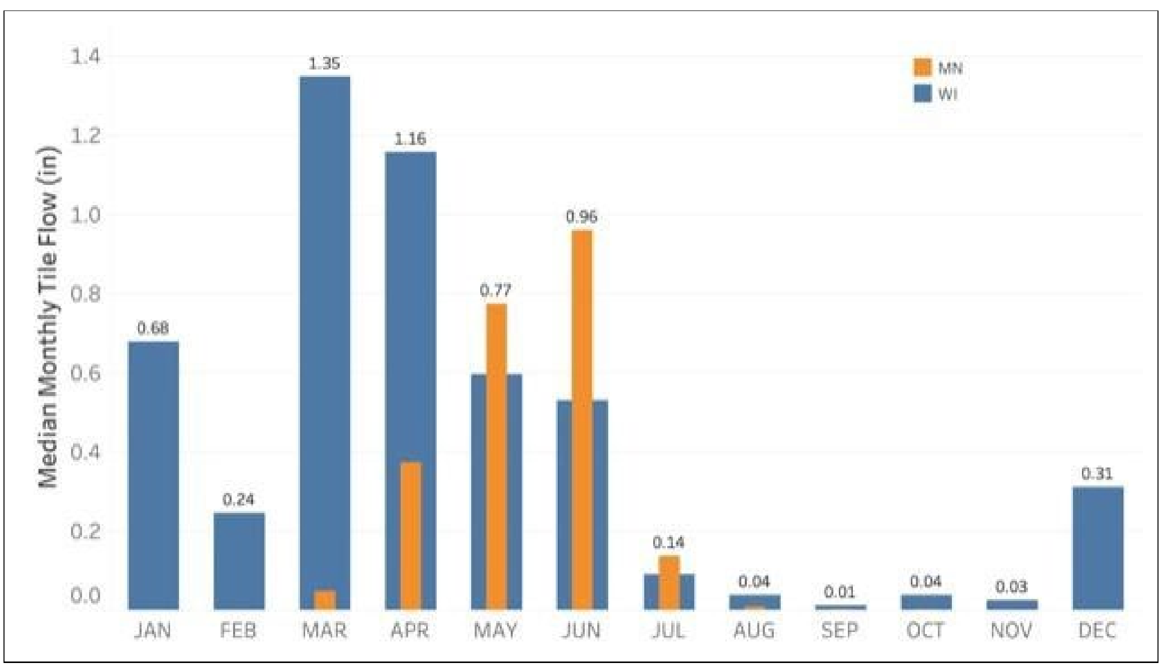


Cover crops had an impact on tile nitrate levels. Fields that had cover crops had lower median values of tile nitrate when grouped by crop type and nitrogen application rate. This demonstrates the potential of cover crops to provide nitrate reduction in tile drainage.



Tile flow dynamics in Minnesota and Wisconsin

The amount and timing of tile flow was significantly different between Minnesota and Wisconsin. Wisconsin tile sites had flowed more consistently throughout the year. The average flow frequency for Wisconsin tile sites was 82% compared with only 43% for Minnesota tile sites. Wisconsin tile sites also had a large portion of flow during frozen ground winter conditions in December through March. Minnesota tile sites had little overwinter tile flow with most of the tile flow occurring from April through June.

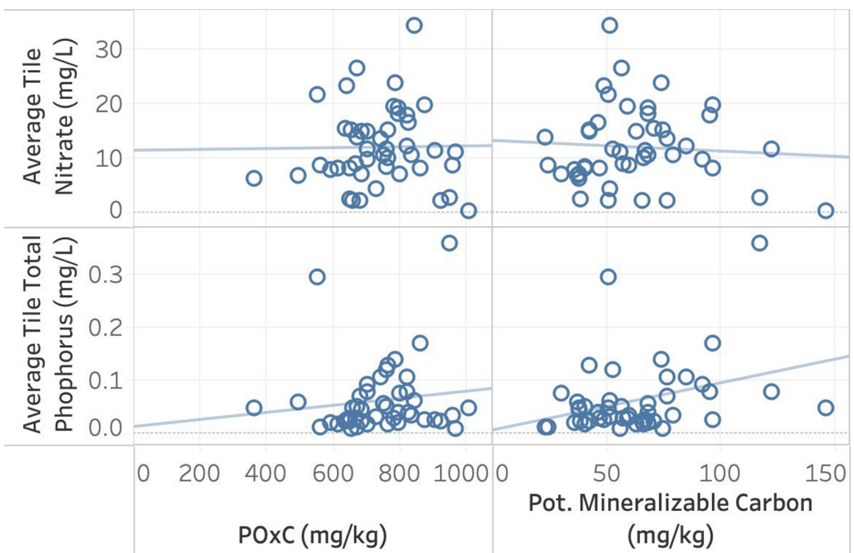


Wisconsin also had some tile sites where the amount of tile flow was greater than the amount of precipitation, meaning that the tile system was intercepting shallow groundwater from a larger regional source. For these sites, it is difficult to determine farming system impacts on tile water quality leaving the edge-of-field. Regional groundwater interception dilutes water draining from the fields, lowering nutrient and sediment concentrations and reducing the variation throughout the year.

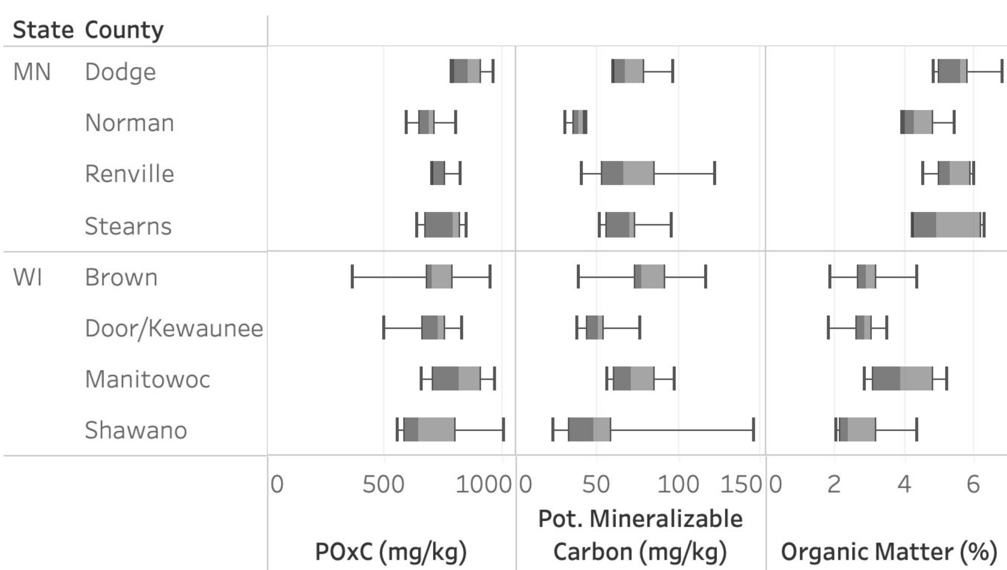
The amount of flow throughout the year at an individual tile site also impacts sediment, phosphorus, and nitrate concentrations. Typically, as tile flow increases, sediment and phosphorus concentrations also increase. For nitrate, the opposite effect occurs with concentrations decreasing with increasing tile flow.

Soil Health Measurements and Comparison to Water Quality and Agricultural Practices

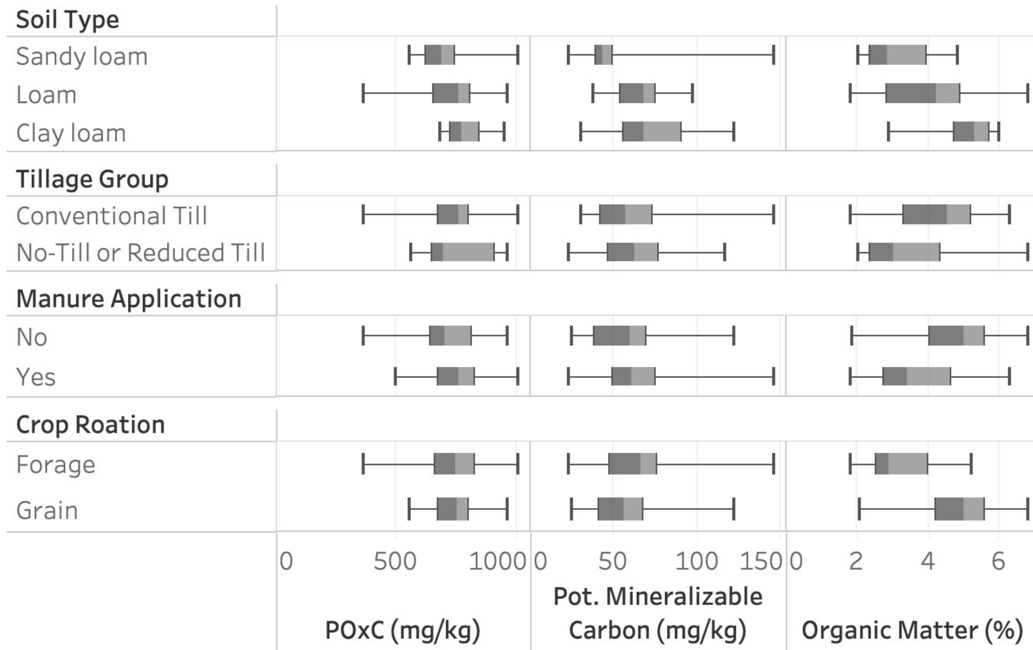
Soil health samples were taken in June during the project and to a depth of 6". A composite sample was analyzed for each field where tile water quality was being measured. No direct correlation was found between soil health
measurements and water quality metrics. There was an increasing trend of average total phosphorus concentration with permanganate oxidizable carbon (POxC) and potentially mineralizable carbon, but the trend wasn't significant. Soil health measurements have a more subtle impact on water quality compared to agronomic practices and weather conditions. It is likely that there weren't enough sites to find this subtle correlation.



There were regional differences observed for POxC, potentially mineralizable carbon and organic matter. This is likely due to the soils present in the area and highlights an important consideration for soil health measurements and comparisons. Site to site comparisons are difficult as not all locations and soils are going to have the soil health potential as others.



Differences of soil health metrics, POxC, potentially mineralizable carbon, and organic matter, were observed when grouping the sites by soil type. These soil health metrics increased as soil particle sizes decreased. Sands had lower measured soil health metrics than loams and clays. Differences due to tillage, manure application, and cropping rotation were not as clear, likely because of the type of soil and regional differences observed.



Challenges

Project Timeline Extension

A no-cost 12 month extension was requested and granted in 2019. Delay in grant award prevented a full year of tile monitoring in 2017 and the project was built on three full years of monitoring. With the no-cost 12 month extension, the full three years of tile monitoring (2018-2020) was completed.

Monitoring Challenges

Flooding and freezing were the biggest monitoring challenges. During these conditions, flow had to be estimated.

When measuring flow in intermediate and basic systems, the method used assumed that water was flowing unimpeded. There were issues with this assumption during the following conditions:

- High water in the drainage ditch where the tile discharged. Heavy rains and snowmelt periods would periodically flood the drainage ditches. In these cases, an outside source of water would back up into the tile.
- Snow and/or ice buildup at the outlet would impede flow from the tile and cause water inside the tile to back up. The main reasons were heavy snow and drifting at the outlet or drainage ditches freezing.

COVID-19 Pandemic

Monitoring continued during the COVID-19 pandemic, but in-person meetings and field days had to be cancelled. Web based outreach events were held in place of in-person meetings during 2020. The pandemic also created delays in sample analysis which ultimately delayed the final project analysis and reporting.

Soil Health Measurement Challenges

When this project was initiated, there was little guidance on the methods of collecting soil health samples. Specifically when to take the samples, what depth to take the soil samples, how many subsamples to include, and how to transport and store the samples. For this project, samples were taken in June as this is the time of most biological activity, at a depth of 6 inches, and one composite sample was analyzed per monitoring site. Soil health samples were kept cold for transport, but not frozen. The chosen methods may have had an impact on why there wasn't any correlation found between soil health metrics and tile water quality.

Summary of Outputs

Final project wrapup webinar - https://youtu.be/rwvEGx-souw

During the life of the project, Discovery Farms programs hosted 150 events across Minnesota and Wisconsin with over 9,000 people in attendance where the project was introduced and results were presented.

Water Quality Overview - https://drive.google.com/file/d/135SUP34BluVT75wOXJQQKTnfYdNCrwfd/view?usp=sharing

Potential Next Steps

Nitrate is the nutrient of most concern with tile drainage systems and agronomic practices can impact the level of nitrate measured in tile. Bi-weekly grab sampling of tile flow can provide a high quality measurement of average annual nitrate concentration and assessing nitrate concentration in farmers' tiles can be an excellent way to gauge the success of in-field nitrogen management practices. Increasing farmer understanding and value of tile nitrate measurement in regards to nitrogen management and farming systems would be an excellent next step in improving farming practices and protecting water quality resources.