DISCOVERY FARMS MINNESOTA

Lessons Learned from

GORANS FARM & LAKE WAKANDA PROJECT

WORKING TOGETHER TO IMPROVE WATER QUALITY

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Water resources can be impacted by nutrient runoff from both agricultural and urban landscapes. This long-term study began in 2007 with the main objective of quantifying and comparing contaminant transport from agricultural drainage water and urban stormwater runoff. After several years of monitoring both landscapes the urban portion was discontinued, while the agricultural monitoring continues to shed light on the importance of good nutrient practices. Information from the study has been published in a peer-reviewed journal.[1] This report, containing excerpts and data from the article, will walk you through its discoveries.

2019

[1]Ghane E, Ranaivoson AZ, Feyereisen GW, Rosen CJ, Moncrief JF (2016) Comparison of Contaminant Transport in Agricultural Drainage Water and Urban Stormwater Runoff. PLOS ONE 11(12): e0167834. doi.org/10.1371/journal.pone.0167834

WHAT IS DISCOVERY FARMS?

Discovery Farms Minnesota is a farmer-led effort to gather field scale water quality information from different types of farming systems, in landscapes across Minnesota. The mission of the Discovery Farms program is to gather water quality information under real-world conditions. The goal is to provide practical, credible, site-specific information to enable better farm management.

The program is designed to collect accurate measurements of sediment, nitrogen and phosphorus movement over the soil surface and through subsurface drainage tiles. This work leads to a better understanding of the relationship between agricultural management and water quality.

DISCOVERIES AT THE GORANS FARM AND LAKE WAKANDA PROJECT

Management of both urban and agricultural areas is important to protect water quality. Water quality risks from agricultural areas are minimized with appropriate use of conservation practices and careful nutrient management. Water quality risks from urban areas are minimized with the use of conventional stormwater control measures as well as innovative ways to reduce peak flows and contaminant concentrations in stormwater.

- **Proper nutrient management** is essential for crop production.
- **Impervious surfaces of urban areas** contribute to a higher. percentage of rainfall leaving as runoff from urban areas compared to agricultural areas.
- **Sediment and phosphorus losses were lower from the agricultural fields** on a lb/ac basis compared to the urban storm water.
- **The form of nitrogen matters**. In the nitrate form, losses are higher from agricultural fields. In the ammonium form, losses were higher from urban storm water.
- **Urban and agriculture areas both contribute** to water quality challenges in the watershed. Each must employ a different set of management practices to reduce impairments.

Management of both urban and agricultural areas is important to protect water quality

PROJECT BACKGROUND AND STUDY DESIGN

Agriculture is part of the fabric of Minnesota, contributing significantly to the economy and communities around Minnesota. Lakes and water quality are also part of Minnesota's identity and are vital to farmers, communities, and the environment. It is vital to keep both healthy and strong.

Lake Wakanda is located just south of Willmar in Kandiyohi County. The lake has a history of challenges due to periods of high and low water levels, accentuated by algal blooms dating back to 1968. Agricultural and urban development, water management via ditching and drainage, and discharge from wastewater treatment plants (WWTP) have all been identified as contributors to Lake Wakanda's water quality challenges.

Just south of Lake Wakanda, is the Gorans farm. The Gorans raise turkeys and grow corn and soybeans on tile-drained fields. With their help, John Moncrief of the University of Minnesota started a long-term research project in 2007 to assess nutrient and sediment losses from the landscape that drains to Lake Wakanda.

PROJECT BACKGROUND AND STUDY DESIGN

The goal of this research is to identify sources of sediment and nutrients from urban and agricultural areas

Site	Type	Drainage Area (acres)
Fertilized Field	Tile drainage with surface intakes	123.6
Unfertilized Field	Tile drainage with surface intakes	3.2
City Stormwater	Urban stormwater runoff (54% impervious)	1403.6

Table 1: Site details

Three sites were chosen to identify where runoff or tile flow, sediment, and nutrients were entering Lake Wakanda (**Figure and Table 1**). Two of the sites were located on agricultural fields where tile drainage with surface inlets were used to remove excess water. The Fertilized Field was in a corn-soybean rotation where nitrogen and phosphorus were supplied primarily with turkey manure and supplemented by commercial fertilizer. The Unfertilized Field was in a corn-soybean rotation, but no nutrients were applied. The City Stormwater was the third site included in the study where runoff from a portion of the city of Willmar was monitored.

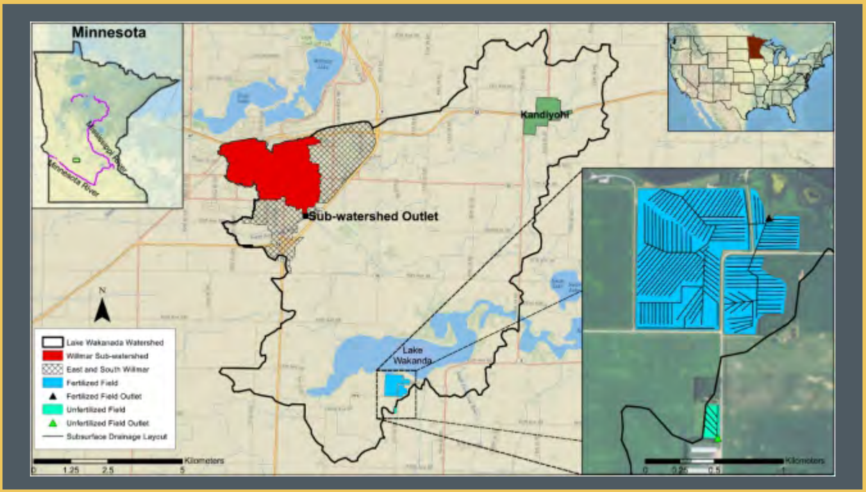

Figure 1: Location of monitoring sites at the Gorans Farm and Lake Wakanda Project

Once the monitoring sites were identified, automated sampling equipment was installed. Samples were collected at Gorans Farms and the stormwater ditch from spring thaw (usually April) all the way until freeze up (usually November). Phosphorus, nitrogen, and total suspended solids (sediment) levels were measured in each sample. The volume of water moving through each site was also measured so that calculations of the total amount of phosphorus, nitrogen, and sediment could be made.

FINDINGS

For the Fertilized and Unfertilized Fields, the crop planting sequence started with soybean in 2007 followed by two years of corn. Soybean was planted again in 2010 followed by three years of corn. The Unfertilized Field did not have any soil amendments applied since the fall of 2005. For the Fertilized Field for the corn crop following soybean, turkey manure was applied based on manure N content and supplemented with commercial fertilizer. For all the other corn years in the Fertilized Field, commercial fertilizer was used. On average 149.4 lbs N/A, 66.6 lbs P_2O_5/A, and 68.0 lbs K_2O/A were applied yearly to the corn crop. No amendments were added during the soybean rotation.

Tillage practices varied depending on the crop. For the Fertilized Field following soybeans, manure was incorporated with a chisel plow. After first year corn, a moldboard plow was used to incorporate fertilizer in the fall. After second year corn, fields were fall chisel plowed. All fields were tilled in the spring with a field cultivator to break up soil clods prior to planting.

Corn was planted at a planting density of 33,500 seeds per acre with 22-inch row spacing on both fields. As expected, corn yields were significantly lower each year on the Unfertilized Field, due to insufficient nitrogen supply. On average, 69.4 fewer bushels of corn per acre were harvested from the Unfertilized Field compared to the Fertilized Field.

Soybeans were planted at a planting density of 133,450 seeds per acre with 22-inch row spacing. Soybean yields were slightly higher (≈6 bushels per acre) on the Unfertilized Field. For soybean, a lack of nitrogen in the soil is not an issue, because soybean converts atmospheric nitrogen into a form usable by the plant. These results provide further support that nitrogen is the limiting factor in the Unfertilized Field for corn.

Impervious Surfaces of Urban Areas Result in More Runoff

Precipitation was measured daily using rain gauges at both the Fertilized Field plot and at the City Stormwater site. The two sites were not significantly different, so any difference in the city runoff and agricultural drainage was not because of the amount of rainfall.

In the City of Willmar, 94.9 inches of rain fell during 5 growing seasons, resulting in 43.7 inches of runoff (cumulative flow depth). That means 46% of the total rainfall in Willmar found its way to the City Stormwater monitoring site.

In comparison, 97.1 inches of rain fell on the Fertilized Field plot during 5 growing seasons, resulting in 26.6 inches of drainage water. For the field site, 30.5% of the total rainfall ended up in the tile drains and was pumped into a wetland bordering Lake Wakanda. The Fertilized and

Unfertilized Fields had similar amounts of drainage throughout the study.

A significantly higher percentage of the precipitation becomes runoff in the City of Willmar because more of the Willmar watershed is covered by impervious surfaces, such as streets, sidewalks, buildings, and parking lots (an estimated 54%). In contrast, the agricultural fields allow more water to soak into the soil and be used by the plants.

Sediment and Phosphorus Were Lower from the Agricultural Fields

The Fertilized Field was compared to the City Stormwater to assess the levels of sediment and phosphorus that these two land uses were contributing to the Lake Wakanda watershed.

At the City Stormwater site, the concentrations of TSS, TP, and the volume of water per acre were all greater than for the Fertilized Field. These measurements show that urban areas can transport high amounts of TSS and TP **(Table 2)**.

The median concentration of TSS for the Unfertilized Field (5 ppm) was 2.2 times higher than the Fertilized Field (2.3 ppm). Both of these numbers are very low and show that tile drainage is an effective means to remove excess water without transporting large amounts of sediment. The Fertilized Field had more crop residue present, likely reducing the among of soil movement.

The median total phosphorus concentration was 1.9 times higher in the Unfertilized Field (0.19 ppm) compared to the Fertilized Field (0.10 ppm). This is despite the fact that the soil test for phosphorus was lower in the Unfertilized Field. Because total phosphorus measurements of the drainage water include particulate phosphorus, the larger amount of sediment (TSS) in the water from the Unfertilized Field resulted in larger amounts of phosphorus. In other words, more sediment means more total phosphorus entering through the surface inlets and into the water.

Description	Cumulative load (lbs./ac)	Average daily load ± SD (lbs./ac)	One-sided p-value (for daily load)
Total Suspended Solids			
City Stormwater	**685.2**	**0.865 ± 2.348**	**<0.001**
Fertilized Field	**57.7**	**0.073 ± 0.307**	
Total Phosphorus			
City Stormwater	**2.38**	**0.003 ± 0.006**	**<0.001**
Fertilized Field	**1.09**	**0.002 ± 0.004**	

Table 2: Cumulative load from April to October of 2007 to 2012 (excluding 2008), and paired t-test comparisons of daily loads between City Stormwater and Fertilized Field after adjusting for serial correlation (n=792)

Total suspended solids (TSS) is a measure of sediment in water. The median concentration in City Stormwater (35.0 ppm) was 15.2 times higher than the Fertilized Field (2.3 ppm). This is a significant difference, but not entirely unexpected. The impervious surfaces of the city (54% of Willmar is considered an impervious surface) allow more sediments to runoff. The City of Willmar is actually slightly lower than the median sediment runoff for a city in the United States (59 ppm) as measured from 360 stormwater sites across the country.

The median amount of total phosphorus in the City Stormwater (0.22 ppm) was also higher than the Fertilized Field (0.10 ppm), 2.2 times higher. Like the Unfertilized Field, this higher amount of phosphorus can be attributed the higher sediment levels. The City of Willmar's total phosphorus concentration in the stormwater is similar to the median (0.27 ppm) from cities throughout the United States.

Loads per unit area (lbs. per acre) were significantly higher in the Unfertilized Field compared to the Fertilized Field because of the reduced crop residue **(Table 3).**

The Form of Nitrogen Matters

The Fertilized Field was compared to the City Stormwater to assess the levels of nitrogen being contributed to the Lake Wakanda watershed. Nitrate is one of the most common nutrients found in farm field drainage water, while ammonium is more prevalent in urban stormwater.

FINDINGS

Description	Cumulative load (lbs./ac)	Average daily load ± SD (lbs./ac)	One-sided p-value (for daily load)
Total Suspended Solids			
Unfertilized Field	187.4	0.175 ± 1.376	0.022
Fertilized Field	65.8	0.062 ± 0.273	
Total Phosphorus			
Unfertilized Field	2.06	0.002 ± 0.006	0.001
Fertilized Field	1.31	0.001 ± 0.004	

Table 3: Cumulative load from April to October of 2007 to 2013, and paired t-test comparisons of daily loads between Unfertilized and Fertilized Fields after adjusting for serial correlation (n=1071).

The median nitrate concentration in the water from the Fertilized Field (17.88 ppm) was 27.9 times higher than that for the City Stormwater (0.64 ppm), which can be explained by the greater inorganic and organic sources of N in the soil. Furthermore, the nitrate concentration in the City Stormwater was always below the nitrate concentration standard of 10 ppm for drinking water in the USA. Average daily nitrate load per unit area from the Fertilized Field was 12.4 times higher than from City Stormwater (Table 4), confirming that tile drains can deliver higher nitrate loads than city stormwater on a per acre basis. Subsequent research at this location seeks to identify effective nitrate mitigation strategies such as denitrifying wetlands and bioreactors.

The median ammonium concentration for the City Stormwater (0.27 ppm) was 9 times higher than for the Fertilized Field (0.03 ppm). The City of Willmar's ammonium concentration in the stormwater is similar to the median (0.44 ppm) from cities throughout the United States. Possible sources of ammonium in the city include deposition from automobiles, rainfall, and atmospheric deposition. In contrast to farm fields, the impervious surfaces in the city facilitate the transport of ammonium into the water. The ammonium average daily loads per unit area from the City Stormwater were significantly higher than from the Fertilized Field. **(Table 4)** The higher loads were the result of higher concentrations and higher flow depth for the City Stormwater. These results show that urban areas are capable of transporting higher ammonium loads than farmland on a per area basis.

Commercial fertilizer and manure (in this case, turkey manure) are important nitrogen sources for crop production. However, there is concern around nutrients from those sources leaving the fields in water drainage and impacting water quality. The comparison of the Unfertilized and Fertilized Fields helps increase

Description	Cumulative load (lbs./ac)	Average daily load ± SD (lbs./ac)	One-sided p-value (for daily load)
Nitrate-N			
City Stormwater	9.8	0.012 ± 0.029	<0.001
Fertilized Field	121.9	0.154 ± 0.269	
Ammonium-N			
City Stormwater	3.23	0.0041 ± 0.0099	<0.001
Fertilized Field	0.3	0.0004 ± 0.0020	

Table 4: Cumulative load from April to October of 2007 to 2012 (excluding 2008), and paired t-test comparisons of daily loads between City Stormwater and Fertilized Field after adjusting for serial correlation (n=792).

Description	Cumulative load (lbs./ac)	Average daily load ± SD (lbs./ac)	One-sided p-value (for daily load)
Nitrate-N			
Unfertilized Field	89.7	0.084 ± 0.164	<0.001
Fertilized Field	155.4	0.145 ± 0.252	
Ammonium-N			
Unfertilized Field	0.29	0.0003 ± 0.0006	0.12
Fertilized Field	0.37	0.0004 ± 0.0012	

Table 5: Cumulative load from April to October of 2007 to 2013, and paired t-test comparisons of daily loads between Unfertilized and Fertilized Fields after adjusting for serial correlation (n=1071).

understanding of the role of nutrient management in water quality.

The median concentration of nitrate in the drainage water for the Fertilized Field (17.88 ppm) was 1.7 times higher than the Unfertilized Field (10.49 ppm). The higher nitrate concentration for the Fertilized Field than the Unfertilized Field was caused by the application of manure and commercial fertilizer. The impact of manure and fertilizer applications on the soil can be seen in higher fall residual soil nitrate-N tests, approximately 2 to 3 times higher in the Fertilized Field. Although the nitrate concentration from the Unfertilized Field was lower than the Fertilized Field, it is important to note that even without fertilization there can still be significant nitrate in drainage water. The source of nitrate from the Unfertilized Field could be attributed to legacy nitrogen from previous manure applications and mineralization of soil organic matter.

Nitrate concentrations significantly decreased over the seven years of study. For the fertilized field, the reason for the decrease may be due to improved nutrient management practices implemented by the farmer. For the Unfertilized Field, the steep decline can be explained by the lack of fertilizer application.

Average daily nitrate load per unit area from the Fertilized Field was significantly higher than that from the Unfertilized Field **(Table 5)**. This is the result of the higher nitrate concentration for the Fertilized Field, since flow depths were not significantly different. Although the Unfertilized Field did not receive fertilizer nor manure since 2005, the cumulative load per area was still 58% of that of the Fertilized Field. Under management practices similar to those of this study, nitrate load in drainage water from an unfertilized field could be considerable relative to that of a fertilized field.

Ammonium concentrations were below detection limit for about 85% of the 663 and 907 sampling days for the Unfertilized and Fertilized Fields, respectively. Thus, the median concentration for each site (0.03 ppm) was very low.

Urban and Agriculture Areas Both Contribute to Water Quality

Understanding the extent of both cropland and urban land is an important factor in understanding relative contributions to water quality concerns. For the Lake Wakanda watershed, acres devoted to cropland are approximately four times the acreage in urban areas (14,730 compared to 3,180).

In order to scale up to the watershed, assumptions were made about urban and cropland areas. It was assumed that nutrient management practices for the rest of the Lake Wakanda cropland were similar to the Fertilized Field. It was assumed other urban areas would transport loads similar to the City of Willmar Stormwater Site.

Given these assumptions, the loads of contaminants on a per area basis (lbs./acre) from the 7-year study were multiplied by the total area of cropland and urban area in the Lake Wakanda watershed. The urban area, due to the greater extent of impervious surface, experiences greater runoff volumes per acre, which results in higher total suspended solid loads from the urban area (2,184,320 lbs. compared to 850,090 lbs.) at the watershed level over the monitored period. Phosphorus loads from cropland were lower than urban land on a per acre basis, but when multiplied by total watershed area result in greater loading from cropland than urban land (15,980 lbs. compared to 7,600 lbs.). Considering nitrogen, ammonium loads from the urban area were more than twice that of cropland (10,300 lbs. compared to 4,520 lbs.), while nitrate loads from cropland were much larger than from urban areas (1,796,030 lbs. compared to 31,190 lbs.). Collectively this data shows the need for both urban and agricultural to address water quality challenges.

Gorans Brothers Farm

The Discovery Farms Minnesota Program would like to thank Gorans Brothers Farms and the Gorans family for their willingness to participate in the project.

Participating in Discovery Farms helps validate what we are doing and identify ways to improve our management practices.

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Working Together to Improve Water Quality

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