Understanding Nutrient & Sediment Loss at Saxon Homestead Farm

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History of the Manitowoc County Discovery Farms Project Area

How the project started

To say that environmental challenges have come to the forefront of animal agriculture is an understatement. Perhaps nowhere is that more the case than in Manitowoc County, Wisconsin. Manitowoc has been a leader in the state in terms of dairy expansion or modernization. A review of the past five to seven years indicates an average growth rate of five cows per farm. The number of truly "large" dairy farms has also increased. Manitowoc County now has about 10 permitted dairies (i.e. farms greater than 1,000 animal units) compared to three 10 years ago.

Not surprisingly, this increase in cows per farm was accompanied with an increase in requests for limits on animal expansion. Often the reasons stated for these proposed limits included concerns about the potential negative impacts on ground and surface water. With all of the turmoil and controversy and a corresponding lack of research regarding the impact of agriculture on the environment, a small group of individuals decided to investigate the possibility of obtaining funding for a Manitowoc County Discovery Farm. The leadership of the Discovery Farms Program was impressed by Manitowoc County's commitment to bring together a diverse group of stakeholders to work on identifying and solving environmental issues. The main factor in the decision to select Manitowoc County as the first Discovery Farms Project Area was the fact that several bays in Lake Michigan near the village of Cleveland were experiencing severe algae blooms. There are many factors that play a role in the development of algae blooms, including water clarity (increased light penetration), increase in nearshore concentrations of dissolved phosphorus and water temperature.

While agriculture has some affect on water clarity (the major factor being the zebra and quagga mussel filtration) or in water temperatures, it can play a significant role in the delivery of phosphorus to the lake. The questions that need to be answered by the Discovery Farms Project Area include:

- How much phosphorus is entering Lake Michigan from agricultural fields receiving manure?
- What crops or farming systems contribute the highest losses of phosphorus?
- What phosphorus form (particulate or dissolved) is leaving the fields?
- What management practices reduce these losses to acceptable levels?
- What are acceptable levels of phosphorus loss from agriculture?

It was clear that people were making tremendous assumptions about the impact of agriculture on the lake with no data to support these claims. It was also apparent that many people had already identified solutions to the issue, with little or no data to document the cause of the problem. The goal of this project area was to add an in-field water quality and quantity monitoring program that would identify the rates, timing and sources of phosphorus losses from agricultural fields and to work with county staff and producers to correct management practices that cause high losses of phosphorus.

Figure 1. Field Day at Saxon Homestead

The Manitowoc County Discovery Farms Project Area is a unique collaboration of agricultural, conservation and environmental interests. The University of Wisconsin, including UW-Extension, along with the U.S. Geological Survey (USGS) work with privately-owned farms to find the most economical and effective ways of complying with environmental regulations and protecting the environment while maintaining farm profitability. The Manitowoc County Discovery Farms Advisory Committee developed the following mission statement to assist in guiding the research and dissemination of the research results:

The Manitowoc County UW Discovery Farms Project Area will gather on-farm research data, which may be used to determine the environmental and economic effects of currently available Best Management Practices. This data will be used to evaluate and improve Best Management Practices in order to achieve a healthy and sustainable agriculture in a healthy and sustainable environment.

Research results will be used to educate and improve communication among the agricultural community, consumers, researchers and policy-makers. It is our intent that based on this research; recommendations will be developed to improve Best Management Practices and regulations.

The goals and operation of the program

The goal is to collect and utilize research data and information to educate a wide variety of audiences. By cooperating with university and agency personnel, the local conservation departments disseminate the research results to farmers, consultants, other agribusinesses, recreational and environmental interests, governmental agencies, policymakers and the general public. The research has the potential to impact farming practices in northeastern Wisconsin and on farms throughout the state. The management practices identified and developed through this program are likely to be applicable on farms that have similar farming systems and/or similar physiographic settings and soil types. The information gained through this program will not only help farmers improve their already strong environmental stewardship but will also aid in the protection of both ground and surface water, which benefits not only farmers but all the residents of Manitowoc County.

Implementing the project

After narrowing down the list of potential participants, Discovery Farms and USGS personnel visited each site to determine the viability for water quality and quantity monitoring. Two Manitowoc County farms were identified to serve as vehicles for a locally led education and outreach program. Farms that were eventually selected include Soaring Eagle Dairy and Saxon Homestead Farm.

These Discovery Farms also assist in the documentation of the effectiveness of adopting Best Management Practices to improve water quality and the affects of these practices on farm profitability. Planning for the project began in December 2003 with implementation starting in the summer of 2004. The project is slated to run through at least 2009, but the length and design of the study will depend on the data collected and the funding available to implement our recommendations.

Farm, Site and Study Design

Overview of dairy

Saxon Homestead Farm, LLC (SHF) is a spring seasonal calving, pasture based dairy farm located one mile west of the town of Cleveland in Manitowoc County, Wisconsin. SHF is a fifth-generation family partnership operated by Robert and Kathleen Block-Klessig, Karl and Elizabeth Klessig, Gerald and Elise Klessig-Heimerl, and their families.

SHF consists of approximately 425 Holstein-based, Brown Swiss-Jersey cross cows, 400 young stock, and 200 stocker and feeder steers. Cows start calving in March, and most have finished by June 30th of each year. Approximately 400 calves are housed in two hoop buildings until they are old enough to graze in nearby pastures. Older young stock are housed during winter on set stock paddocks that are rotated annually. Milking cows are housed in freestalls during the winter when rotational grazing is not feasible. In addition to milk, the farm produces and merchandises replacement dairy cattle and stocker and feeder steers.

This farm operates approximately 925 acres of owned and rented cropland and applies nutrients in accordance with an approved phosphorus-based Nutrient Management Plan. Livestock graze 600 acres managed under an intensive rotational grazing system, with excess feed grown on this land being harvested and stored in bunker silos. The remaining 325 acres are planted into crops each year with about 92 – 140 acres grown as corn and 92 – 140 acres grown as alfalfa. The cropland acreage per animal unit is approximately 2.2:1.

SHF is located in the Centerville Creek watershed, which is part of the Lake Michigan Basin (Figure 3). Centerville Creek is an intermittent stream flowing throughout SHF. Most of the surface water flows underground due to the extensive tile system which runs through the farm (a 12" tile main). Centerville Creek becomes a perennial stream at the tile discharge site.

Farm and site selection

In general there are four types of monitoring projects done by the Discovery Farms Program: edge-of-field

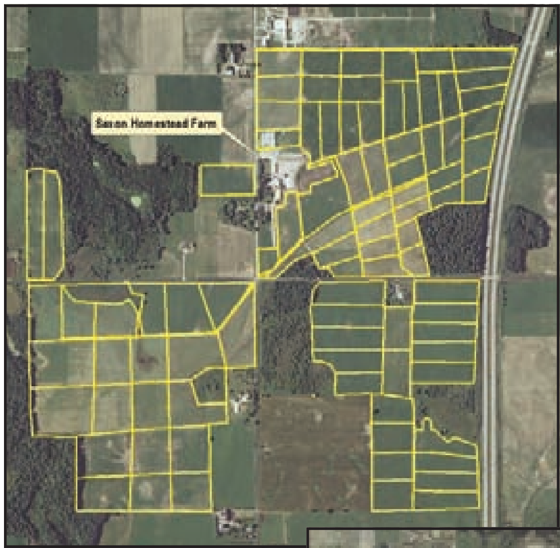

Figure 2. Saxon Homestead Farm, paddocks and acreage

Figure 4. Upstream monitoring equipment install

Figure 3. Centerville Creek Watershed

Figure 5. Tile monitoring equipment installation

surface water, small watershed, tile monitoring and upstream/downstream. This farm was selected to represent this region of the state because it was a grazing farming system that contained several potential field and tile sites.

The sites provided an upstream/downstream study design which involves testing the water prior to entering the paddocks to determine the quality and quantity of water before it comes in contact with the animals. Another monitoring system is placed at the end of the farm where the water flows off the farm. Contributions of sediment and nutrients from the farm in the monitored area can be calculated by subtracting what is coming in from what is exiting. The upstream (Figure 4) and downstream monitoring sites were installed in a grassed waterway which flowed as an intermittent stream during high runoff periods. Prior to a new tile main installed by SHF in this grassed waterway, flow occurred for much longer periods of time.

A third site was installed in a road ditch that delivered water to an area near the upstream site from an intensively tilled field. This site was added to the study to assess a different farming system that could potentially skew the upstream results. It was important to monitor water coming from this neighboring farm to accurately assess the contributions of the grazing system. Monitoring equipment was installed in a road ditch, just up gradient from the upstream monitoring site.

In an effort to further understand the annual water budget of the farm, a tile monitoring site was installed at the outlet of the farm, adjacent to the downstream surface water site (Figure 5).

Surface and tile water monitoring – equipment

Installation of surface water monitoring equipment began in late July 2004 and was completed October 2004. The upstream and ditch sites required significant earthwork downstream of the flume because the relatively low slopes caused poor getaway conditions. The tile monitoring site was initiated and completed in December 2004 (Figure 6). These sites could not have been installed without the assistance of SHF. The first event occurred in early December 2004. The tile monitoring site was running at approximately 50 percent capacity at the time of installation and continued to flow during the duration of the testing period. Data collection at SHF began in October 2004 and the first phase of the study was concluded after snowmelt 2007.

Conclusion

The SHF special project provided information on the impact and comparison of a grazing farming system to a conventional tillage system. In addition, surface water runoff quality and quantity was compared to tile drainage flow at the downstream location of the grazing farm system. This project provided information on tile drainage flow periods and the times and amounts of water that drains from these landscapes (surface and tile). Through the work on SHF we are now able to better identify some of the strengths and challenges facing grazing farm systems in comparison with other agricultural systems and determine management practices that fit grazing farming systems.

Upstream surface site (K1)

Downstream surface site (K2)

Road ditch surface site (K3)

Downstream tile site (K4)

Figure 6. Installation complete on three surface water sites and one tile site

Equipment, Procedures and Sampling

Agricultural water quality monitoring efforts often focus on the growing season, but the UW – Discovery Farms Program collected samples year round at Saxon Homestead Farm, LLC (SHF). Hydrologic and water quality data from two large basins, one tile site and one small basin adjacent to SHF were collected from October 2004 through spring 2007. The study design was an upstream/downstream monitoring scheme in large basins (495 & 641 acres) paired with a tile monitoring site and one additional monitoring site in a small (18 acre) basin that contained a different farming system.

Monitoring stations

Aluminum, clam-style enclosures were used to house equipment designed to measure flow, collect water samples, and provide two-way communications that facilitated data collection and real-time programming (Figure 7). Two sites (K1 and K3) were close enough to have electrical hookups; while the paired downstream surface and tile sites (K2 and K4) utilized solar panels and batteries to power equipment. The enclosures were locked to prevent unauthorized access.

Figure 7. Sampler, program equipment

Water level and discharge equipment

The water, sediment and nutrient loading at upstream subtracted from downstream results in the contribution from the 146 acres of grazed paddocks and farmstead. K3 was installed in a road ditch to assess a different farming system that could potentially skew the upstream site results. K4 measured drainage water leaving the farm. K1 and K2 had 2.5-foot and K3 had 1.5-foot, pre-rated, fiberglass H-flumes to measure surface water runoff volume. K4 had a pre-rated, fiberglass 45-degree Washington State College trapezoidal flume to measure tile flow volume.

An ISCO® 3700R (automated, 24-bottle) refrigerated sampler was used to collect surface and tile water flow samples. A Campbell Scientific CR10X datalogger with a custom USGS program was used to remotely read and store sensor data and control equipment.

Sample collection for flow events

Water samples were retrieved within 24 hours, sample quantity and appearance was recorded and equipment accuracy was checked and noted. Samples were transported to the UW-Stevens Point Water and Environmental Analysis Lab (WEAL) for analysis. The lab tested for the following parameters:

- Suspended sediment and total dissolved solids
- Nitrogen: nitrate/nitrite, ammonium, and total Kjeldahl nitrogen unfiltered
- Phosphorus: total P unfiltered and dissolved reactive P
- Chloride
- Conductivity
- pH

Supplemental data collection

Environmental conditions monitored locally at the monitoring sites and at a central weather station included precipitation (at each site and station), air temperature, relative humidity, wind speed, and wind direction. A camera took one picture daily at all three monitoring locations. These pictures were very helpful identifying crop stage, environmental conditions, manure applications and other factors which influence water quality.

Each station also collected soil moisture data. The upstream and downstream monitoring sites had Sentek EasyAg high-frequency capacitance soil moisture probes taking moisture contents from June 2005 to November 2006 at 10, 20, 30 and 50 centimeters (4, 8, 12 and 20 inches) and had a Campbell Scientific CS616 installed utilizing a time domain reflectrometry soil moisture measurement that monitored the average soil moisture from January 2006 to May 2007 at 0 – 30 centimeters (0 – 12 inches). All sites had telemetry for real-time data collection and storage. Information was transmitted to and from the sites via radio antenna mounted on the aluminum enclosures which allowed programs to be changed "on-the-fly".

Maintenance

During spring, summer, and fall, the stations were maintained by checking over equipment, mowing around the gauge and the wing walls (ensure access and inspection of wing walls and equipment). Flumes were cleaned, kept clear of debris and surveyed at least twice per year. Flumes required more maintenance during winter. Snow and/or ice can fill the H-flume and downstream channel causing backwater conditions. Ice in the flume can freeze the sample intake line, causing erroneously high water measurements and prevent sampling. Snow and ice were removed from the flumes prior to any anticipated wintertime flow event. Winter monitoring of tile was less maintenance intensive because of the ground heat, enclosed equipment and continuous flow.

Conclusions from this study

- Year-round (365 day) monitoring is very maintenance intensive during snowmelt. Removal of snow and freezing conditions which caused ice build-up had to be removed prior to thaw conditions.
- Snow removal prior to snowmelt should only be done immediately (1 – 2 days) before snowmelt occurs.
- Due to long flow periods at tile sites; combined with lack of solar recharge during winter, it was a challenge to maintain sufficient power to operate the equipment at the tile monitoring station.

Water Budget at Saxon Homestead Farm

Surface and tile monitoring

Year-round surface water monitoring began at Saxon Homestead Farm, LLC (SHF) in October 2004 at three sites (K1, K2 & K3) and concluded in spring 2007. Subsurface tile water monitoring began in December 2004 at one site (K4) and was concluded at the end of November 2006 (about 15 days of tile monitoring was missed in year one due to equipment installation - asterisk in graph).

Figure 8. Surface water monitoring basins K1, K2 & K3 and tile water monitoring basin K4

The area between K1 and K2 contained grazed paddocks (majority), the farmstead and a small forested area (Figure 8). The loads at K1 (495 acres) subtracted from K2 (641 acres) equals the contribution from the 146 acres. K3 was installed in a road ditch above K1 to capture runoff from an intensively tilled field (17.6 acres). The tile site was paired with K2 and it was determined that the drainage area would be the same as the surface site at 641 acres.

Water budget at SHF

The data presented in the SHF reports is the 12-month period from December 1 through November 30th. The field year (FY) always represents the calendar year in which it ends, which means the field year ending November 30, 2005, is the 2005 field year (FY2005). Precipitation is either frozen (snow, hail, sleet, etc) or non-frozen (rain). Frozen precipitation was converted to its liquid equivalent so both frozen and non-frozen can be analyzed equally. The general precipitation trends for the study period had one low and one high year compared to the 30-year average of 29.8 inches (Figure 9).

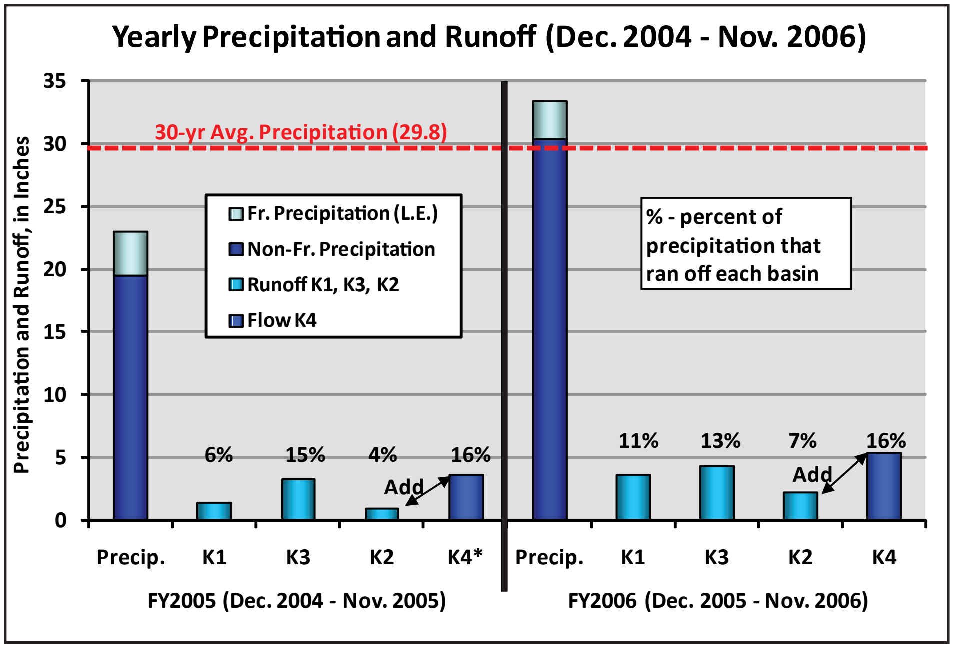

Figure 9. Precipitation versus 30-year average and runoff

2005 field year - For FY05 total precipitation was 23.1 inches. The winter period had multiple rain-on-snow events causing icing in the fields which resulted in runoff in January, February, and March. Snowmelt began the end of March followed by drought through the majority of the summer which generated no surface water runoff after early April. The tile was flowing in December and continued to flow throughout the field year. Springs routed to the tile system and water from the plate cooler (chills the milk) all contributed to the 365 day observed flow.

2006 field year – FY06 had above average fall temperatures and small amounts of frozen ground runoff. Frost depths were much shallower than FY05 and there was little snow left in March. After snowmelt, conditions were dry until significant rains fell in May. May had the majority of surface runoff for the year and also the highest tile flow. The rest of the year was dry with one small runoff event occurring in late July. Tile flowed more substantially than the previous year with significantly higher flow in the summer and fall.

Annual water budget

Runoff varied between sites and years (4% to 16%) (Figure 9). K3 had the highest runoff, higher frequency and larger volume per unit area. In FY06 the runoff lasted longer than expected. Data also shows a decreased percentage of surface runoff at K2 as compared to K1 in both years. It is theorized that water transferred to the tile system via tile blowouts or other well developed flow paths. The tile data indicates that tile needs to flow near capacity before surface flow began.

Conclusions

- Precipitation was slightly lower (4%) than the 30-year average (one year lower, one year higher).
- Surface runoff varied from 4% - 17% of annual precipitation, tile flow accounted for 16% of precipitation.
- K3 (tilled) had substantially more surface runoff in both years as compared to the grazed paddocks.
- On this operation, between 20 – 25% of total precipitation ran off via combined surface runoff and tile flow during the study period. Tile accounted for 80% (FY05) and 69% (FY06) of the total runoff.
- Tile flow occurred 365 days a year at the monitored location due to a combination of backwater conditions at the outlet, springs routed to the tile, and clean water discharging to the tile system.
- The loss of surface water between the upstream and downstream sites, and the rapid transfer of water to the tile; the upstream/downstream study design did not work at this location.

Understanding Water Loss at Saxon Homestead Farm, LLC: Surface and Tile Water

When precipitation falls to the ground, it can take many paths: infiltration into the soil, utilization by plants, recharged to groundwater, or run off to surface water. This section focuses on the timing of both surface runoff and tile flow and explains the conditions that cause surface runoff and tile flow to occur at Saxon Homestead Farm, LLC (SHF).

Timing of surface water runoff and tile flow

The timing of precipitation combined with timing of snow melt, play a major role in the potential for surface runoff and tile flow. The highest precipitation month over the two year study period was May (Figure 10). Likewise, the highest surface runoff month for the three surface sites, was May (Figure 11). During this time on the paddock sites (K1, K2), the grasses are just reestablishing so crop uptake is minimal. At this time the tilled field (K3) was void of almost all surface residue and runoff was significant. Although the three surface sites had the most runoff during May, the tile site flowed at its highest level during March (snowmelt - Figure 11).

July had the second highest precipitation, about one inch less precipitation than May. Interestingly, very little surface runoff occurred in July, and minimal tile flow was also observed (Figure 11). Both the pastures and corn/soybean crops were actively growing in July, crop uptake resulted in nearly no flow. Crop uptake resulting in little to no flow can also be observed in the remaining summer and fall months, most notably in September. The other high surface runoff and tile flow months were February and March. Relatively low amounts of precipitation fell during these months; however, snowmelt or rain on frozen ground resulted in high runoff or tile flow volumes.

The analyses of the runoff potential for the frozen versus non-frozen ground periods show drastic differences between the two years of monitoring (Figure 12). In FY05, surface runoff came during the frozen ground period; 99% - 100% of total surface runoff came on frozen ground. This was due to multiple rain-on-snow events. Following the winter period there was little precipitation to produce runoff events. The majority of the tile flow also occurred during the frozen ground period (73%) in FY05.

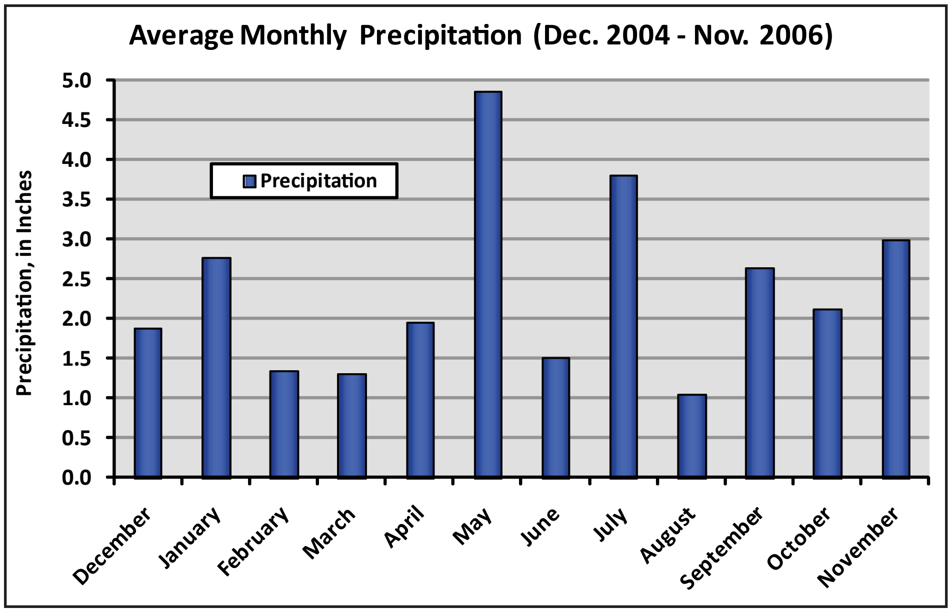

Figure 10. Average monthly precipitation at SHF

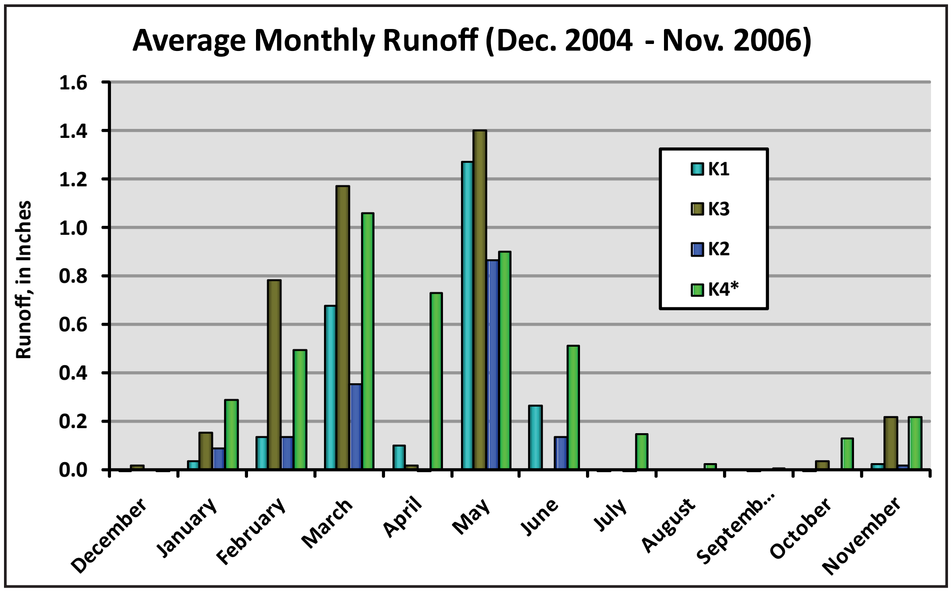

Figure 11. Average monthly runoff at SHF

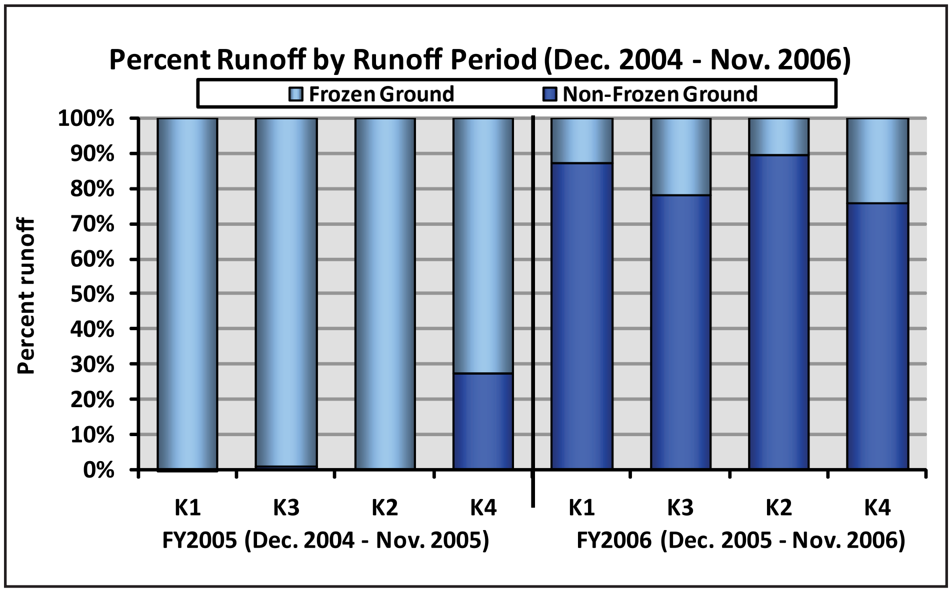

Figure 12. Annual non-frozen versus frozen ground runoff

During FY06 most of the surface runoff was measured during the non-frozen period. In fact, 78% - 90% of the surface runoff came on non-frozen ground, because light snowfall was followed by warming weather that resulted in little to no runoff. Although some frozen ground runoff did occur during snowmelt, the subsequent rainy spring produced more runoff events. Tile drainage followed similar trends as most tile flow (76%) occurred during the non-frozen period in FY06.

Conclusions

- All three surface water sites exhibited the highest monthly runoff during the month of May, which also had the highest average precipitation during the study period. A large amount of surface runoff occurred during snowmelt in the months of February and March. Although other months had relatively high levels of rainfall, low runoff was observed due to crop cover and plant uptake.
- Continuous tile flow was observed from the time monitoring equipment was installed until removal. The highest month for tile flow was during snowmelt in March, but other high flow periods were observed from February through June.
- Weather patterns were significantly different during the two year study. In FY05, frozen ground accounted for over 99% of the surface runoff and 73% of the tile flow. In FY06, frozen ground accounted for only 10% - 22% of surface runoff and 24% of the tile flow.

Sediment Loss at Saxon Homestead Farm

When precipitation falls on soil, the force of the raindrop impact can break up soil aggregates into smaller sand, silt and clay particles. As water travels over the soil in a runoff situation, these particles are more easily transported than if they were aggregated. The lack of vegetative cover, the use of excessive tillage and/or other soil disturbances enhance the potential for agricultural fields to have excessive levels of sediment loss. This section provides the information on sediment loss in surface runoff and tile drainage at the Saxon Homestead Farm, LLC (SHF) and the factors affecting the observed sediment losses.

Year	Crop	Harvest Date	Tillage date
2004	Soybeans	11/7/2004	11/18/2004
2005	Soybeans	10/1/2005	11/24/2005
2006	Corn	10/10/2006	11/15/2006

Table 1. Cropping and tillage history at K3

The agronomic details of cropping history for the field in K3 were not obtained, but information was gathered from site visits and daily photographs (Table 1). The paddocks used by SHF had no tillage for about 10 years prior to the study. Tillage was performed on some paddocks in November 2006 when about 40 acres were tilled for reseeding (upstream of K1).

Surface and tile sediment loss

Paddock sediment loss was minimal compared to the soil loss at other Discovery Farm sites. Losses in the tile were slightly higher when compared to other sites. The timing of sediment loss followed patterns typical at other farms.

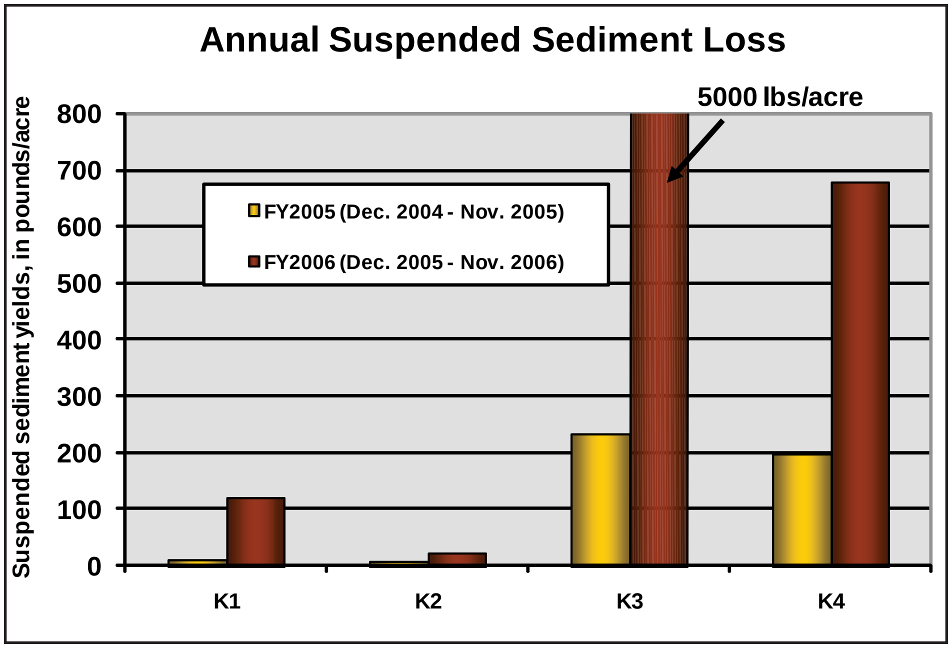

Figure 13. Annual suspended sediment loss

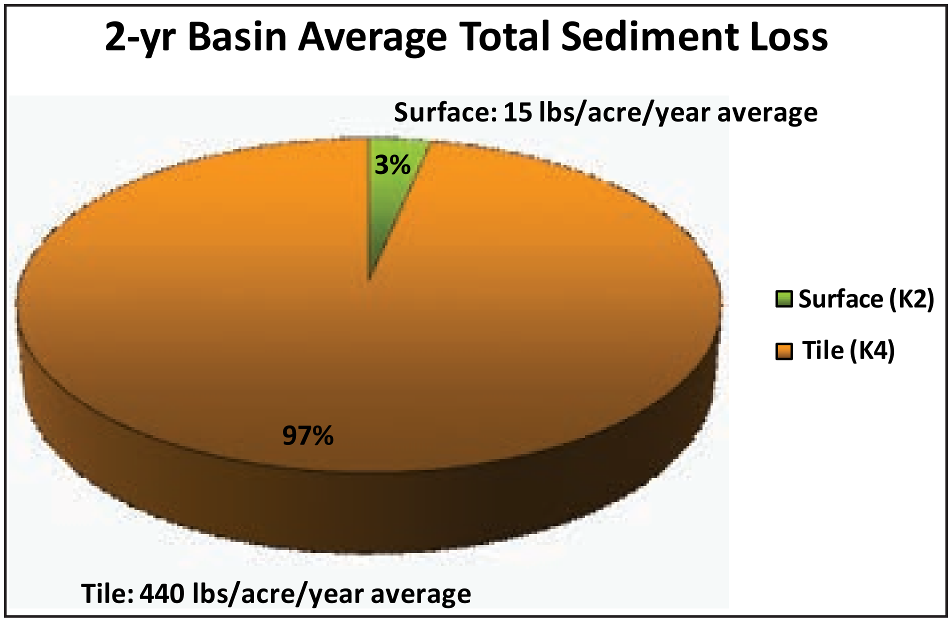

Figure 14. Average sediment loss leaving SHF

Figure 15. Rill and gully erosion observed from K3 field

In FY05, the majority of runoff occurred when the ground was frozen, thus soil loss was minimal. In FY06, most runoff occurred in May when the soil was not frozen, void of residue and had high soil moisture conditions (Figure 13); thus soil loss was significant. Of the 2.5 tons/acre of soil that was lost from the K3 site in FY06, about 2.1 tons was lost in two storms.

Surface and tile sediment loss comparison

When designing management practices to reduce sediment loss from fields, a planner needs to think of the pathways for movement and loss. At SHF, Discovery Farms was able to compare losses from tile and surface flow.

The tile system was the major pathway for sediment loss at SHF (Figure 14). Two factors likely contributed to the low level of sediment loss through surface runoff when compared to tile flow. First, the large volume of water that was transferred from the surface of the soil to the tile system through preferential flow paths. The second factor is the vegetative cover present on the grazed paddocks.

Conclusions

- Sediment loss that occurred from the grazed paddocks at SHF was minimal as compared to observed soil loss at other Discovery Farm sites and the intensively tilled row crop field monitored by site K3.
- The majority of sediment loss occurred during the non-frozen ground period, specifically during early spring rain events after the snowmelt period.
- The intensively tilled row crop field exhibited high soil movement in both visual observations and monitored water quality data (Figure 15). In a four-day period in the spring of 2006, loss exceeded two tons of sediment per acre.
- Visual observations and water quality data showed notable wind erosion and loss of sediment during the frozen ground period from the bare soil at the intensively tilled row crop field, K3.
- From concurrent monitoring of sediment leaving the farm, the major pathway was tile (97%) as compared to surface (3%). The protection offered by the continuous vegetative cover in the paddocks combined with preferential flow to tile likely combined for low surface sediment loss.

Phosphorus and Nitrogen Loss at Saxon Homestead Farm

This section will evaluate phosphorus and nitrogen loss in surface runoff and tile drainage at Saxon Homestead Farm, LLC (SHF).

Surface and tile phosphorus loss summary

- The annual total P loss was slightly higher at all four sites in FY06 than FY05 (Figure 16).
- Sediment losses: K3 had large phosphorus losses in FY06 due to large sediment losses, but phosphorus losses from other sites did not correlate well to sediment loss.
- Late fall and early spring phosphorus loss may have been impacted by the lack of crusting on the grazing-deposited cow manure which allowed detachment and transport of manure particles and most likely resulted in higher nutrient losses during this time.
- Higher soil test P levels in paddocks between K1 and K2 than upstream of K1 combined with stocking density during winter months could contribute to higher phosphorus losses.
- Approximately one-third of total phosphorus was transported via surface runoff.
- Preferential flow of surface water to tile may have resulted in the lower surface runoff and high tile phosphorus loss values.

Phosphorus speciation

- Particulate phosphorus loss was dominant when high sediment losses occurred. Annual sediment loss was relatively high at sites K3 (tilled) and K4 (tile), and 96% and 54% of total phosphorus lost was as particulate (Figure 17).
- The upstream (K1) and downstream (K2) sites exhibited low sediment loss and a high percentage of the

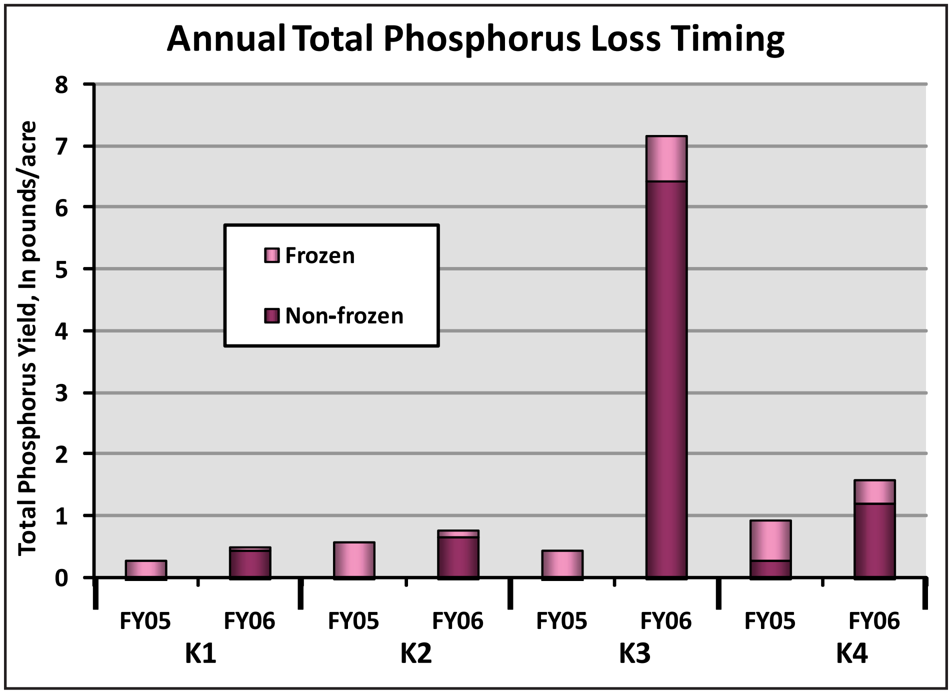

Figure 16. Annual phosphorus loss and timing

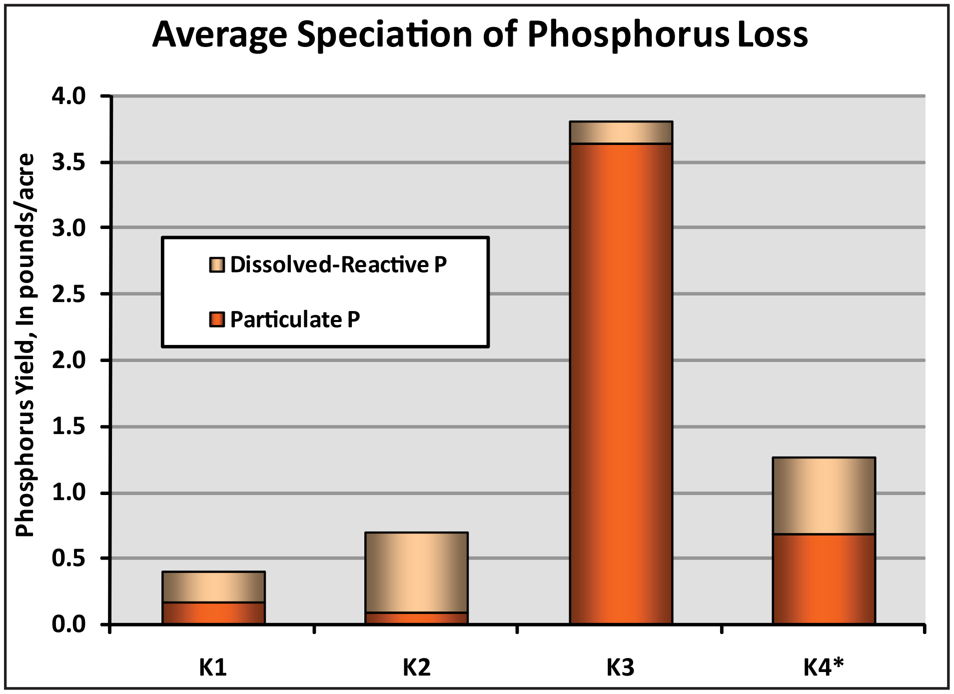

Figure 17. Speciation of phosphorus loss

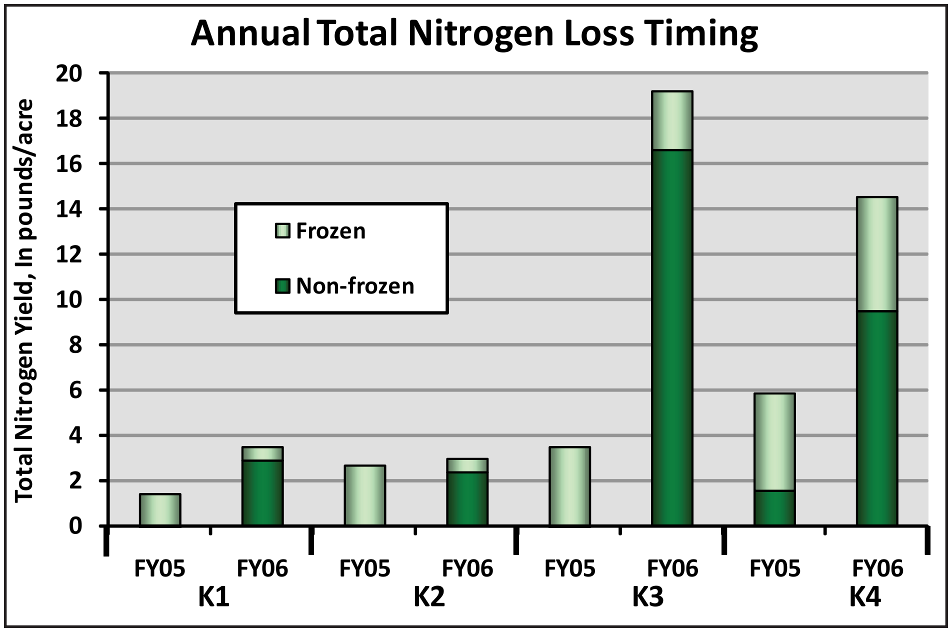

Figure 18. Annual nitrogen loss and timing

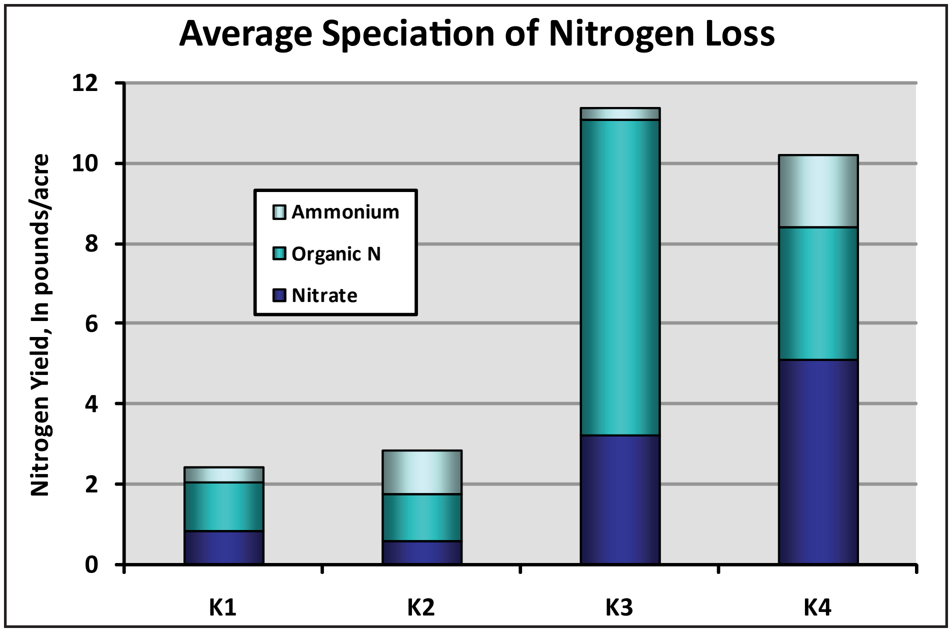

Figure 19. Speciation of nitrogen loss

phosphorus lost was in the dissolved form.

- The ratio of dissolved to particulate phosphorus was typically higher during the frozen ground period as compared to the non-frozen period.

Surface and tile nitrogen loss summary

- Total annual N loss was slightly higher at all four sites in FY06 than FY05 (Figure 18).
- Nearly all surface nitrogen losses at sites K1, K2 and K3, and a high percentage of tile losses, occurred during the frozen ground period in FY05. Runoff events in May accounted for most of the annual nitrogen loss in FY06.
- Total nitrogen values in both the surface and tile are low in comparison to other farming systems monitored by UW – Discovery Farms.
- High soil movement at site K3 with low soil cover during the spring was the reason for high total nitrogen losses.
- Approximately three quarters of nitrogen loss occurs via tile drainage, while one quarter is lost via surface runoff. Although the ratio is similar to that of previously measured row crop fields, the value for both surface and tile total nitrogen loss is lower at SHF than what has been observed at other UW – Discovery Farms sites.

Nitrogen speciation

- The speciation of nitrogen in the upstream (K1) and downstream (K2) sites are typical to values observed from fields planted to row crops (Figure 19).
- Overwintering of animals in the contributing area likely led to the higher relative percentage of ammonium at K2 as compared to K1. The ammonium losses were typically higher during frozen ground conditions.
- The high percentage of nitrogen in the organic form at K3 is likely due to the excessive soil loss that occurred with runoff on bare ground in May 2006.
- It is likely that preferential flow of surface water to the tile system resulted in the high values of ammonium and organic nitrogen in the tile, since nitrate losses are more common on other UW-Discovery Farms.

Conclusions

- Annual loss of total phosphorus and total nitrogen was slightly lower in FY05 than FY06.
- Much of the observed phosphorus loss did not correlate well to sediment loss.
- A high percentage of phosphorus was lost in the dissolved form unless a high sediment loss event occurred, producing high particulate phosphorus loss.
- Nitrogen speciation was typical in some instances to row crop fields. Higher speciation in the ammonium form was observed during overwintering of livestock. Uncharacteristically low nitrate speciation in tile was noted in comparison to other UW – Discovery Farms data.

Challenges with Experimental Design and Tile Monitoring at Saxon Homestead Farm

The upstream/downstream monitoring design at Saxon Homestead Farm, LLC (SHF), aimed to determine the water quality impact of 146 acres of grazed paddocks and farmstead through identifying the levels of water, sediment and nutrients at the upstream site (K1) and the downstream site (K2), and subtracting them from each other. As a result of high surface water flow volumes, large volumes of water entering the tile system between the upstream and downstream sites, combined with the difficulty in accurately measuring tile water quantity, monitoring locations were shifted to alternative sites to provide an accurate assessment of the farming system and management practices.

Water, sediment and nutrient loss from surface to tile

Prior to the installation of any monitoring equipment in the grassed waterway, the underlying tile main was repaired to fix blockages caused by road construction. The producer noted that surface runoff flowed at higher volumes and longer periods prior to the tile repairs, and after repairs, surface runoff flowed for shorter durations and lower volumes. The tile flowed at or near capacity before surface runoff began at the downstream site.

Usually, the amount of water, sediment, and nutrients are reported on a yield (pounds per acre) basis. When the data is analyzed on a load (total amount instead of amount per acre) basis, it is clear that water and sediment are being lost via preferential flow paths to tile. The levels of water and sediment through the surface downstream site (K1) are lower than levels seen at the upstream site (K2) (Table 2). The low values in both the upstream and downstream in respect to the much larger values in the tile (K4) shows that much of the water and sediment was transferred from the surface runoff to the tile drainage system.

Even though lower flow and sediment loads were observed, loads of phosphorus and nitrogen were higher at the downstream (K2) site than at the upstream (K1). The runoff contributing area contained overwintering paddocks with high stocking densities for extended periods of time as compared to other paddocks on the farm. Higher losses of phosphorus and nitrogen from these paddocks occurred during the frozen ground period, when preferential flow is not as prevalent. The intensively tilled (K3) and tile (K4) sites measured higher phosphorus and nitrogen losses per acre than both the upstream and downstream sites.

		K1	K2	K3	K4
Water	**FY2005**	18.9	16.3	1.3	65.5
(million gallons)	**FY2006**	49.1	39.9	1.8	93.9
Sediment	**FY2005**	5,012	4,546	4,109	126,242
(pounds)	**FY2006**	60,202	15,624	88,054	436,068
Phosphorus	**FY2005**	139	383	119	604
(pounds)	**FY2006**	252	521	126	983
Nitrogen	**FY2005**	687	1,729	62	3,756
(pounds)	**FY2006**	1,743	2,008	339	9,137

Table 2. Annual load of water, sediment and nutrients

Figure 20. Sediment in K3 flow just upstream of K1

Rating development for tile water volume monitoring

To accurately assess the amount of water, sediment and nutrients leaving the farm, it was crucial to correctly determine tile flow. At the tile site, the flume experienced backwater conditions, largely because the outlet of the discharge pipe was either partially or fully submerged where the tile emptied into Centerville Creek, thus the rated discharge for the flume was not appropriate.

Several discharge measurements at the outlet of the tile showed that as the stage approached limits of the flume, the measurement-modified flume rating was appropriate down to 0.37 feet (suspected point of backwater control). An extended rating was developed for flows exceeding the limits of the flume, but it was suspected that the discharge record was still inappropriate due to velocity changes in the tile when the tile was surcharging.

To better calculate flow volume, a velocity meter was installed on the upstream side of the flume in the tile. This velocity meter showed changing velocities outside the flume range (above 1 foot depth). Also, the velocity meter's discharge coincided with the measurement-modified flume rating when the water was confined in the flume. However, two types of flow velocity meters were installed to more accurately measure flow, but both were problematic to sustain operation.

A new stage discharge rating was developed after comparing all the methods of measurement. The new stage rating is comprised of a linear relationship between the stage and discharge within the limits of the flume and a polynomial relationship outside of the limits of the flume. This new rating is a best fit rating and is not completely accurate. The rating was applied to portions of the discharge record in which the velocity meters were not installed or operating correctly. For periods that the velocity meters were operational, the area-velocity is the rated discharge.

Potential of water volume to hide changes in water quality – the dilution effect

The original study design was not optimal for the goals of this study because the large basin sizes contributed large volumes of water monitored through these sites. The concentrations of sediment and nutrients were often so low that changes in management made on a small scale would be hard or impossible to detect.

Upstream site K1 flowed for days or weeks, while intensively tilled site K3 only flowed for hours to days. Therefore the peak flow at K3, which should have the highest sediment movement, would be sampled at K3 but may have sampled at K1 before or after the peak discharge, because of the irregularities in sample frequency. Therefore, the short pulse of the highest discharge at K3 may be missed at K1 (Figure 20).

The high quantity of sediment observed at K3 should have gone almost completely through K1 due to the close proximity of the discharge of K3 to K1. However, it can be observed that the two values are nearly equal in FY05 and K3 is significantly higher than K1 in FY06 (Table 2). Because of the dilution effect, some of the sediment monitored in the lower volume going through K3 is masked by the large volume of water going through K1.

Conclusions

- ➢ Loss of surface water to tile in the upstream/downstream study design made it difficult to assess what was coming from the land between the two surface sites.
- ➢ Preferential flow from surface to tile was evident as the tile flowed at near capacity before runoff was produced at the downstream surface site. Also, the load of water and sediment through the downstream surface site was lower than at the upstream surface site.
- ➢ Backwater and surcharged conditions made tile flow monitoring extremely difficult. Although two types of flow velocity meters were installed to more accurately measure flow, both were problematic to sustain operation.
- ➢ The dilution effect from high volumes of flow with low concentrations of sediment and nutrients made the correlation of land management to water quality difficult. Because of the large basin size, small changes in water quality could be masked by the large volume of water.

Impact of UW-Discovery Farms Research on: Agricultural Management at Saxon Homestead Farm, Public Perception, and Future Discovery Farms Research Criteria

Saxon Homestead Farm, LLC (SHF) is a spring seasonal calving, pasture based dairy farm located one mile west of the town of Cleveland in Manitowoc County, Wisconsin. The installation of surface and tile water monitoring equipment was completed in December 2004. Two monitoring sites, in an upstream/downstream set-up, were installed in an intermittent stream running through the grazed paddocks, and a tile drainage monitoring site was also installed adjacent to the downstream surface water site. A third surface water site was installed to monitor runoff from an intensively tilled field that entered the upstream site via a road ditch.

Concurrent monitoring at surface and tile sites was conducted until November 30, 2006. The monitoring shifted at SHF, after this initial large basin study, to a smaller, edge-of-field basin size. Data collected from this second phase of monitoring will be discussed in a subsequent set of fact sheets.

Major lessons learned

Discovery Farms initially decided to study relatively large basins at SHF. Because of the large basin size, management changes implemented on a portion of the basin were masked by the large volume of water flowing from the basin. This lesson was valuable for determining future monitoring basin size selection. The data collected from this initial large basin study indicate that nutrient and/or sediment loss from edge-of-field sites highly overestimated the typical delivery observed from the intermittent stream monitoring. The monitoring at SHF demonstrates the importance of both surface and tile drainage with respect to sediment and nutrient loss. The UW – Discovery Farms Program and the Manitowoc County Discovery Farms Advisory Committee brought together a unique forum for dialogue between researchers, producers, policy makers and the public to discuss Discovery Farms research and other issues relating to agricultural management and production.

Changes in agricultural management at SHF

Management changes based on the data and information generated through Discovery Farms research is a crucial aspect to determine the success or failure of any research and outreach project. It is difficult to assess management changes based solely on Discovery Farms data and outreach, as other factors often contribute to management changes. Although influences apart from information learned through Discovery Farms may have played a role, the following changes were noted on the farm:

- Soil sampling conducted during the project showed elevated phosphorus levels on some paddocks. Discussions between Discovery Farms and SHF staff on where to best utilize nutrients from the manure storage occurred and manure applications were reduced on fields with high soil test phosphorus levels.
- A high stratification of phosphorus in the upper layers of the soil was observed in some paddocks through incremental depth soil sampling, especially in the paddocks where cows are overwintered. During the project, SHF decided to renovate paddocks previously not tilled for 12 years. The incorporation of stratified phosphorus deeper in the profile showed that paddock renovation could reduce soluble phosphorus loss, and also provided benefits in increased feed quality.
- During late fall and spring periods, it was noted that some manure in areas where water collected and flowed was often moved by the flowing water. In response to this, SHF devised a system of temporary fencing to restrict access to flow concentration areas (in field waterways) during time periods when the potential for movement by water is high, and began scheduling access to paddocks containing established flow paths during less critical time periods.

SHF is very active in the community and opened their farm to numerous tours and field day exhibits in addition to participating and hosting their own meetings. It is hard to assess changes made on neighboring farms because of the information learned at SHF, but two factors are believed to enhance the information passed through this method. First, information delivered to local producers or passed word-of-mouth is likely to reach a broader audience than by educational events sponsored by the UW – Discovery Farms Program and other outreach organizations. Second, this information is likely to have a higher level of adoption due to significance of local conditions, therefore more applicable to farms in the local region.

Changes in public perspective of agricultural losses

The formation of the Manitowoc County Discovery Farms Advisory Committee was very beneficial to the success of the UW – Discovery Farms Program. The group discussed initial Discovery Farms findings, local issues with agriculture, and facilitated discussion between agricultural producers, governmental agencies, and environmental groups. Some ideas presented to the public through the group included:

- Limited effectiveness of buffers along streams to dramatically reduce the amount of phosphorus entering surface waters (Lake Michigan). While buffers are very effective at reducing particulate phosphorus loss, buffers have little to no effect on dissolved phosphorus, which is carried in the water. The research conducted by Discovery Farms indicated that a large proportion of losses were in the dissolved fraction, thus increasing the size of buffers will likely have limited effect on reducing phosphorus losses. This management practice would have taken extensive amounts of land out of production and placed a high burden on the local/state tax base. Discussions between producers and environmental groups then focused on viable options for reducing dissolved phosphorus losses.
- Discovery Farms staff and farm personnel are committed to collecting factual data regardless of the results to empower participants to improve management and make better decisions. Demonstrations showed that only qualified Discovery Farms or USGS personnel have access to locked research sites. Discovery Farms personnel were able to address this concern with the public.
- A groundwater model was purchased to better inform youth and the general public on where drinking water comes from and the potential contamination issues that can negatively impact groundwater resources.
- Discussing other topics at committee meetings including monitoring challenges at Discovery Farms sites, manure spill response procedures, development of a soil moisture risk management assessment tool, anaerobic digesters, flush systems, pathogen testing, state and local agricultural regulations, nutrient management planning, and certification at the county level for custom manure haulers.

A variety of educational events, many organized through the Manitowoc Extension office and Discovery Farms, included public meetings, tours of the farm and research stations, exhibits, and formal speeches. The events facilitated education and open discussion between diverse audiences and helped to educate the public on how farmers are using BMPs to protect the environment while growing their operations.

Changes in research site criteria for future Discovery Farms sites

The following lessons learned at SHF have improved our site selection criteria for future monitoring stations:

- ➢ Concurrent surface water and tile monitoring in a basin.
- ➢ Close to power (near power lines or buildings).
- ➢ Easy access by road (able to plow in winter).
- ➢ 40 acre basin or less.
- ➢ Single field per basin if possible.
- ➢ All/majority of agricultural land in the basin under control of participant.
- ➢ No backwater (good slope away from surface site and clear discharge path for tile).
- ➢ Cooperative and good recordkeeping participant.
- ➢ Perform comprehensive evaluation of basins to be monitored and continue evaluating during study period.

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This insert is a summary of the initial phase of on-farm research conducted on Saxon Homestead Farm, Manitowoc County, WI. Project results are presented in 9 fact sheets. The series includes: History of the Manitowoc County Discovery Farms Project Area; Farm, Site and Study Design; Equipment, Procedures and Sampling; Water Budget at Saxon Homestead Farm; Understanding Water Loss at Saxon Homestead Farm: Surface and Tile Water; Sediment Loss at Saxon Homestead Farm; Phosphorus and Nitrogen Loss at Saxon Homestead Farm; Challenges with Experimental Design and Tile Monitoring at Saxon Homestead Farm; Impact of Discovery Farms Research on: Agricultural Management at Saxon Homestead Farm, Public Perception, and Future Discovery Farm Research Site Criteria.

Fact sheets, briefs and presentations are available from the UW-Discovery Farms Office, PO Box 429, Pigeon Falls, WI 54760, 715-983-5668 or at our website: www.uwdiscoveryfarms.org.