Understanding Nutrient & Sediment Loss at Koepke Farms, Inc.

University of Wisconsin – Extension

DISCOVERY FARMS

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Farm, site and study design

Overview of farm operation

Koepke Farms, Inc. is a family dairy business in operation for 75 years with Alan, Jim, David and John as partners, each with their own duties. Alan is in charge of finances and equipment. Jim takes care of crops, nutrient management, and irrigation. David works with breeding, cattle marketing, and herd health. John is responsible for feed purchasing, rations, hiring, and milk marketing. In addition to the four partners, the farm employs eight full time and ten part time workers. The farm is located about five miles north of Oconomowoc, in Waukesha and Dodge counties. The farm is in the Ashippun Creek sub watershed and drains southwest toward the Rock River. Surface water runoff from this watershed eventually drains to the Mississippi River. Local land use is a mix of agriculture (57%) and rural residential development, as the farm is within 25 miles of Milwaukee suburbs.

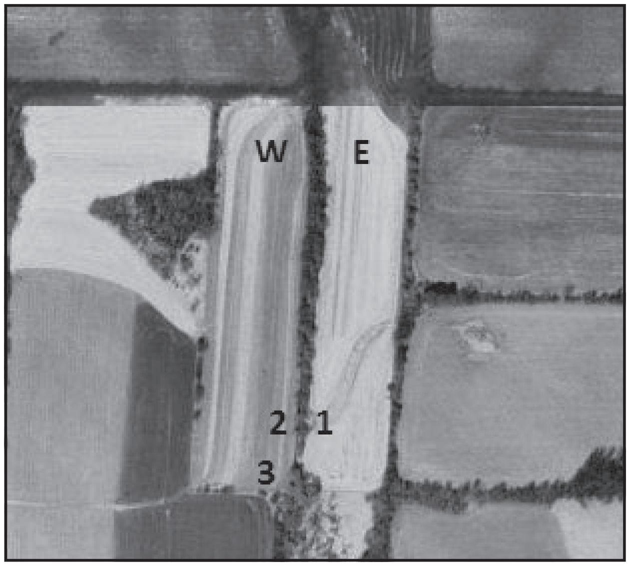


Figure 1. West and east field with surface water and tile line monitoring sites, KP1, KP2 and KP3

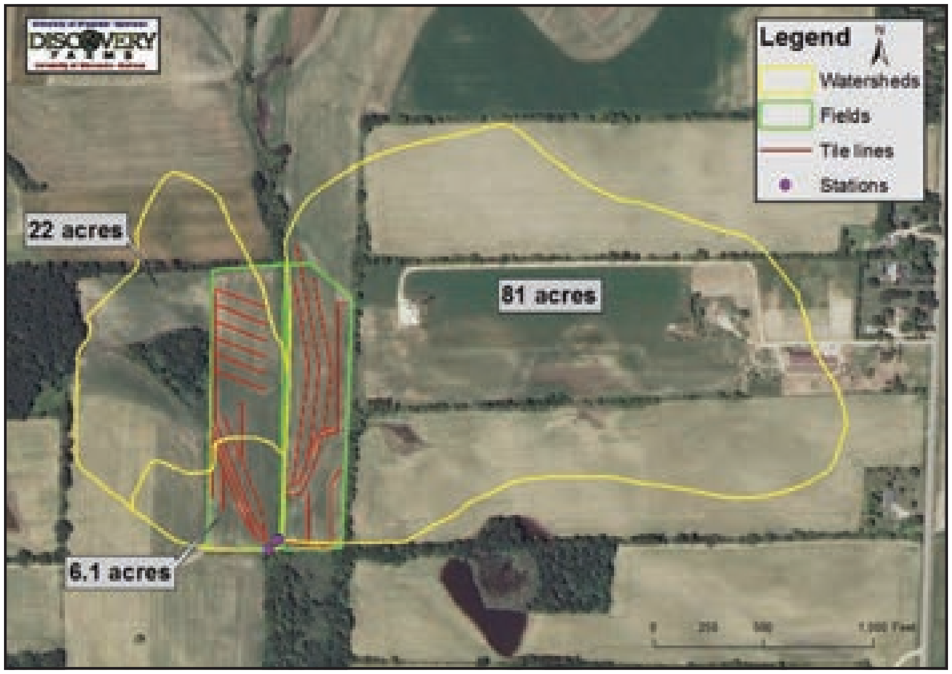


Figure 2. Monitored fields with contributing areas (yellow) and tile line schematic (red)

The landscape on this farm is gently sloping glaciated ground moraine comprised of loam and silt loam soils deposited over glacial till. Cropland fields range from 1-10% slopes on soils that have medium to high moisture holding capacity. Groundwater supplies drinking water for the residence and livestock facilities. This farm irrigates some cropland in times of limited rainfall. Some of the farm's upland crop fields have dense subsoils with low permeability (Hochheim loam and Theresa silt loam), while other fields are lower in the landscape and have seasonally high water tables (Brookston silt loam, Sebewa silt loam and Houghton muck).

Some of the cropland has subsurface tile drainage installed to improve the timeliness of field operations and enhance the crop rooting environment. Many fields in this part of Wisconsin have a network of subsurface tiles buried two to four feet below the soil surface. These tile lines move and discharge a combination of groundwater and infiltrated rain water, depending on the location of the field within the landscape.

The Koepkes manage around 1,000 acres of cropland which is devoted to growing corn grain, corn silage, soybeans, winter wheat and alfalfa to support the dairy enterprise. All crops are established using no-till practices. Semi-solid dairy manure is surface applied on fields that will be planted to corn, and manure is hauled throughout the year.

The dairy operation consists of 320 cows which are housed in a freestall barn with milking parlor facilities. The registered Holstein cows are milked three times each day. Sand bedding is used in the freestall barn. Manure generated during milking, as well as parlor wash water, is stored in a short term concrete manure pit. Manure from this reception pit is hauled daily or weekly when possible. Bulls, steers and heifers are kept on a bedded pack system which generates solid manure. The farm maintains an annual rolling herd average of over 30,000 pounds of milk per cow, and one cow in the herd ("Granny") holds a world record for lifetime milk production.

Soil conservation and nutrient management

The Koepkes have a long history of implementing soil conservation and nutrient management practices. They were one of the first farms in their area to adopt a 100% no-till farming system, and they continue to serve as a resource to other farmers who are considering adopting a similar farming system. Cropping practices on the farm are driven by their desire to reduce soil loss and to improve overall soil quality. Over twenty years of no-till farming has created soils with improved soil aggregation and a well developed macropore structure on their farm.

They developed a CNMP (Comprehensive Nutrient Management Plan), and the farm has a current soil and water conservation plan which maintains soil loss below tolerable levels. Other conservation and water quality practices include low manure application rates; all cropland has current soil tests taken at five acres per sample; areas of concentrated flow have grassed waterways, cover crops are planted, they maintain a barnyard runoff system and practice feed management to combine best livestock nutrition with cropland nutrient management.

Farm selection

This Discovery Farm project was a two site special project conducted between 2003 and 2009. Special projects within the Discovery Farms Program are short, targeted on-farm research studies designed around topics that producers identify as needing immediate attention. Studies by the Department of Natural Resources (DNR) and the United States Geological Survey (USGS) indicate that streams flowing through the Rock River Basin in Southeast Wisconsin are high in nitrogen and phosphorus. Both sites on the farm focused on monitoring water quality from agricultural cropland to better understand the impact of surface applied manure in no-till cropping systems with tile drainage in this region of Wisconsin.

Surface and tile monitoring site layout and equipment Installation

The monitoring sites consisted of two adjacent basins (east and west) divided by a drainage ditch. Slope in the basins ranged from 0-4 percent. The predominant soils were Brookston silt loam—a poorly drained hydric soil with a seasonally high water table; and Theresa silt loam—an upland soil with dense, tightly packed glacial till subsoil. Both basins contained subsurface tile used to drain wet areas of the fields (Figure 1).

One surface water monitoring station was installed in the west basin (KP3), situated at the field edge, in an area of concentrated flow to measure runoff, sediment, and nutrient loss in November 2004. In an effort to further understand the water budget of this farming system, a tile drainage monitoring site (KP2) was installed adjacent to edge-of-field surface water monitoring to collect tile drain water from the same area in December 2004. An additional tile line monitoring site (KP1) was installed immediately across the drainage ditch to measure flow, sediment, and nutrient loss from the east basin in December of 2004.

The surface watershed area of the west basin (KP2 and KP3) included parts of three different fields managed by the Koepkes (Figure 2). The east basin (KP1) included fields not managed by them. Both basins were managed using a no-till planting system, but under different crop rotations. During the course of the study the west basin crop rotation was corn silage, corn grain, soybeans, corn silage, alfalfa, and the east basin crop rotation was alfalfa, alfalfa, corn grain, corn silage, soybeans.

Monitoring site, equipment and procedures

Figure 3. Monitoring equipment

Agricultural water quality monitoring efforts often focus on the growing season (spring – fall), with little or no monitoring occurring in winter months. In Wisconsin, the spring thaw is a very active period for both surface runoff and groundwater recharge. To fully assess annual nutrient and sediment losses, the UW Extension - Discovery Farms Program conducts year-round monitoring. To accurately collect data during winter conditions, equipment was selected, and procedures developed and implemented to provide high-quality, agricultural runoff and water quality data during the full range of weather conditions. Personnel from the U.S. Geological Survey - Wisconsin Water Science Center worked cooperatively with the UW – Discovery Farms Program to collect hydrologic and water quality data from a surface basin and two subsurface tile drainage basins located on Koepke Farms, Inc. from June, 2005 through October, 2009.

Water monitoring equipment

A single walk-in insulated enclosure was used to house equipment for all three monitoring sites and was locked to prevent unauthorized access. Power was provided by an array of six large 12 volt tractor batteries charged by three solar panels. A digital camera mounted to the roof of the enclosure was programmed to take photographs each day to track field conditions (Figure 3).

Based on surface topography, the areas monitored were estimated at 28 and 81 acres for the tile sites, and 6.1 acres for the surface water site. To measure surface runoff volume (discharge), a 2.5 foot pre-rated, fiberglass H-flume was used (Figure 4). To measure tile water runoff volume, pre-rated, fiberglass "extra large", 60 degree, v-throat, trapezoidal flumes were used (Figure 5). The aforementioned basin area sizes were used in all data computations that involved basin area, such as runoff depth (inches) and nutrient loss (pounds per acre).

The surface flume was attached to

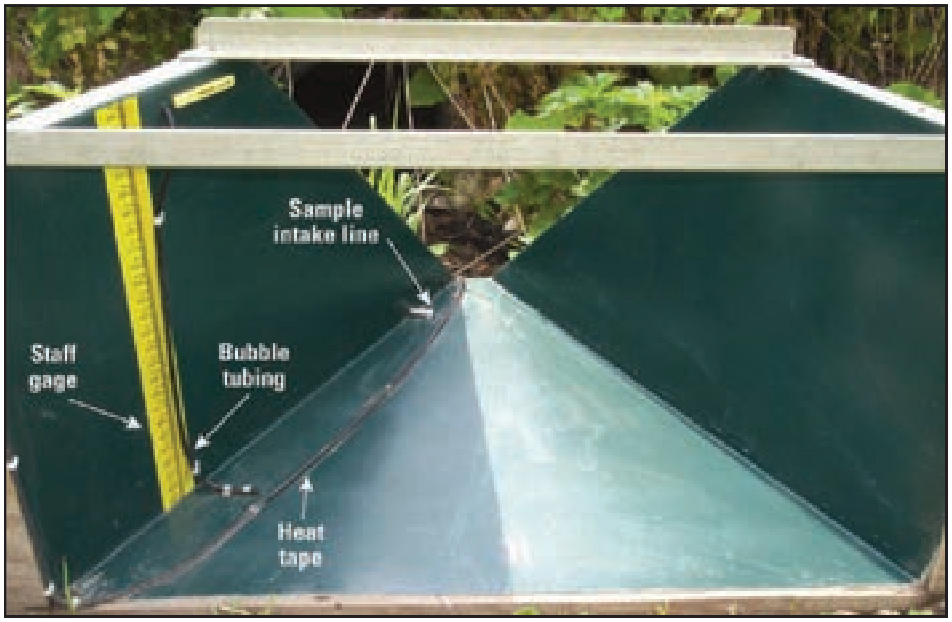


Figure 4. H-flume, bubble and sample lines

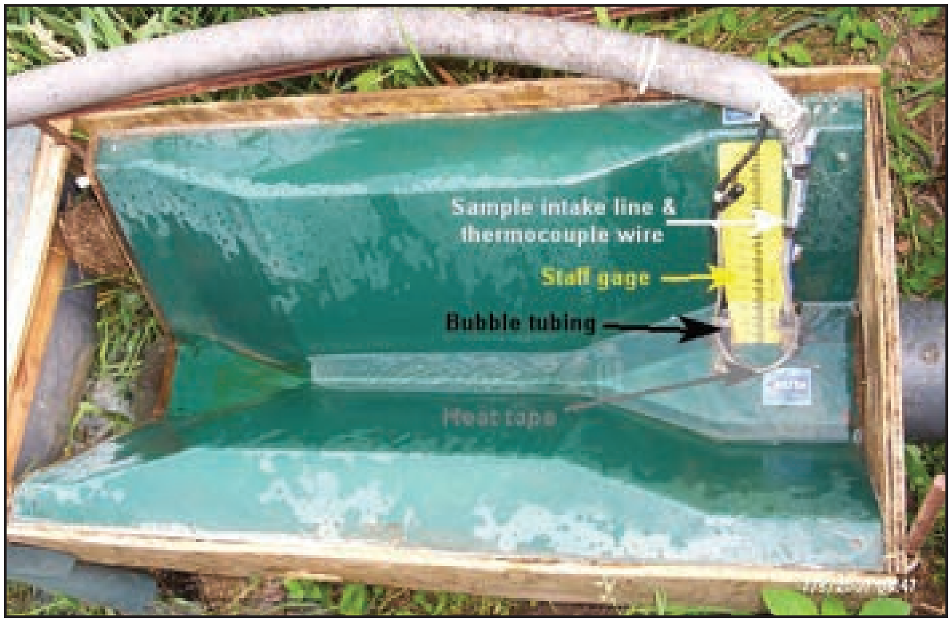


Figure 5. Trapezoidal flume, lines, thermocouple wire & heat tape

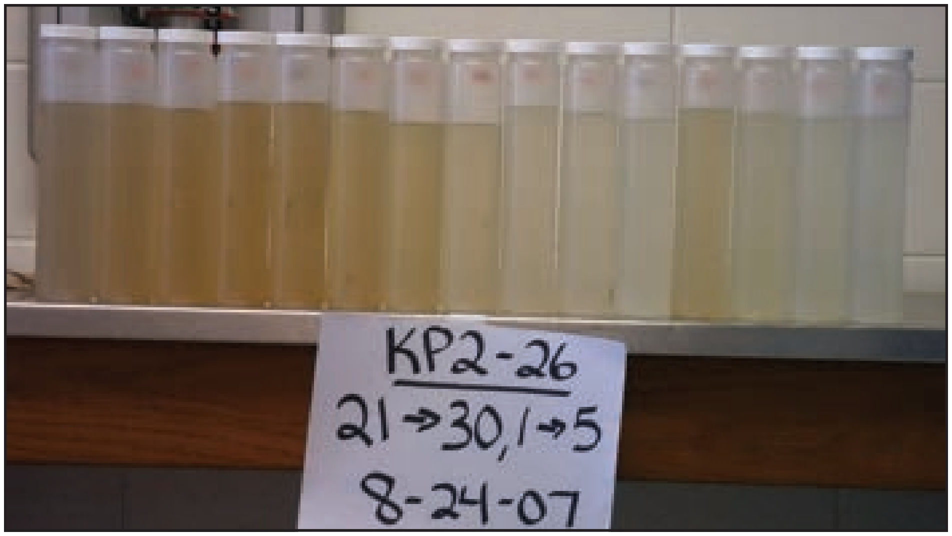


Figure 6. Sample collection bottles from flow event

treated plywood installed perpendicular to the flow in the waterway. Wingwalls and earthen berms were used to direct runoff through the flume. The tile flumes were attached to the pre-existing six inch tile outlets. Since the flumes were pre-rated, discharge could be directly calculated from the water level. Heat tape (six watts per foot) was attached to the bottom of the flume to prevent ice from forming. An automated, refrigerated, 24-bottle ISCO® 3700R sampler was used to collect surface and tile water flow samples. A datalogger with a custom USGS program was used to remotely read and store sensor data and control station equipment.

Sample collection for flow events

A flow event was defined as the time from the onset of rainfall or snowmelt induced surface water runoff or tile water flow until the time when flow ceased. Sampling frequency during an event was controlled and adjusted by the datalogger at each station. Samples were generally retrieved within 24 hours, and equipment accuracy was checked and noted. Samples were labeled, placed in coolers with ice, and transported to the UW-Stevens Point Water and Environmental Analysis Lab (WEAL) for analysis.

WEAL took pictures of the samples for visual analysis (Figure 6). The lab tested for several parameters. The equipment and methods used proved to collect accurate flow data in a wide range of conditions and landscape positions. Use of the USGS NWIS (National Water Information System) database assured long-term data storage. Environmental conditions were also monitored, both locally at the monitoring sites and at a central weather station.

Maintenance

Maintenance was vital to accurately measure quantity and quality of runoff from the surface water station. During spring, summer and fall, the station was periodically maintained by mowing around the gauge and along the wing wall. Through the winter, frequent maintenance visits were necessary to keep the flume free of ice and snow and to provide maintenance for other equipment. Ice in the flume could freeze the bubble tubing and the sample intake line, causing erroneous water level measurements and preventing proper sample collection. Snow and ice were removed from the surface water flume prior to anticipated wintertime runoff events. Snow was removed from the flume and a trench was dug in the snow upstream and downstream of the flume. The flumes were also surveyed with an autolevel at least twice per year to determine if adjustments to the water level discharge were necessary. Although some ice removal was required occasionally, winter maintenance of tile stations was less intensive than the surface stations.

Conclusions from this study

- Year-round (365 day) monitoring is very maintenance intensive, especially during snowmelt conditions. In addition to snow removal prior to snowmelt, freezing conditions often occurred at night during snowmelt. This caused ice to build-up in the flumes that had to be removed prior to thaw conditions the following day.
- Tile drainage flumes installed at tile outlets in drainage ditches or streams should utilize unistrut instead of rebar to reduce flume movement by flowing stream water impacting the side of the flume.

Additional information

For more detailed information on sampling materials and methods, see: Methods of Data Collection, Sample Processing, and Data Analysis for Edge-of-Field, Stream Gauging, Subsurface-Tile, and Meteorological Stations at Discovery Farms and Pioneer Farm in Wisconsin, 2001-2007. The full report is available for download at http//pubs.usgs.gov/of/2008/1015/.

Water budget at Koepke Farms, Inc.

Surface and tile water monitoring

Water monitoring began at Koepke Farms, Inc. at three sites (KP1, KP2, & KP3) on June 1, 2005 and ended in September 2008 for the surface site (KP3) and October 2009 for the tile sites (KP1 & KP2). The study design for the three monitoring sites allowed for water quality analysis under different cropping systems (KP1 & KP2) and comparison of quantity and quality of surface runoff versus tile flow (KP2 & KP3). It became apparent as the study went on that the contributing areas for the two tile sites were influenced by a fluctuating water table.

Due to fluctuating water table elevations, the exact land acreage drained by the tile sites (KP1, KP2) could not be determined. Thus, flow values, sediment and/or nutrient losses reported for the tile sites are identified as volumes (millions of gallons), concentrations (milligrams / liter), or loads for each field year.

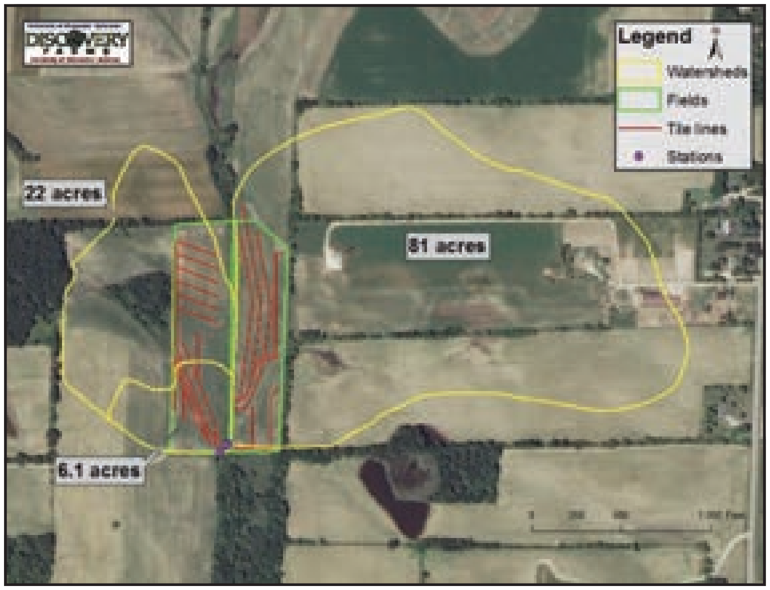


Figure 7. Monitored fields with contributing areas (yellow) and tile line schematic (red)

Since the exact land acreage drained by the surface site (KP3) was known, runoff values, sediment and/or nutrient losses are reported as yield measurements (inches / acre or pounds / acre) for each field year.

The estimated contributing areas, based on surface topography, were 81 acres for KP1, 28 acres for KP2, and 6.1 acres for KP3 (Figure 7). All data is based on the definition of a field year (FY), which is the 12 month period from

October 1 through September 30 of the following year. This allows water monitoring activities to coincide with the crop production cycle such that activities done on a field after harvest are considered to be associated with the following year's crop. All frozen precipitation was converted to liquid equivalent for analysis consistency.

Koepke water budget

The precipitation trend for the study period was slightly higher (8%) than the 30-year average for the Oconomowoc area. Total surface runoff recorded in basin KP3 was divided by the basin size to calculate yield, expressed as inches of runoff per acre. A similar yield comparison of the tiles in inches of discharge per acre was not made because the contributing basin size could not accurately be determined.

Precipitation listed for FY05 reflects rainfall for June - September due to project start-up date. When compared to subsequent years during the same June - September time period, FY06 had 12.2 inches, FY07 had 22.2 inches, FY08 had 17.6 inches, and FY09 had 9.2 inches. No surface runoff occurred in FY05.

FY06 was the first full field year of monitoring. Approximately 92% of the total annual precipitation fell as rain. At KP3, 1.7 inches of runoff, about 5% of precipitation, was measured. Of the total flow through each site, about 26% (KP1), 20% (KP2), and 81% (KP3) was during frozen ground conditions.

More precipitation (about 28% more than average) fell during FY07 than FY06. Of the 43.2 inches of precipitation, 92% was rain. The surface basin (KP3) had 2.1 inches of runoff measured, approximately 5% of the precipitation (Table 1). Of the total flow through each site, about 14% (KP1), 16% (KP2), and 3% (KP3) was during frozen ground.

FY08 was another high precipitation year. About 84% of the 38.6 inches of total precipitation fell as rain, with nearly 30% of the total precipitation falling in the month of June. At KP3, about 16% of the precipitation value was measure as runoff. Of the total flow through each site, approximately 32% (KP1), 36% (KP2), and 7% (KP3) was during frozen ground conditions. This was the final year surface water runoff was monitored.

In the final year of monitoring, 85% of the 31.8 inches of precipitation fell as rain. Monitoring in FY09 consisted only of tile discharge. Of the total flow, about 25% (KP1) and 35% (KP2) was during frozen ground conditions.

Relationship between precipitation, tile flow and surface runoff

Tile flow rapidly responded to precipitation when soils were at high moisture contents. When substantial tile flow was observed (after January 1, 2006) response time in the tile flow ranged from 10 minutes to a few hours, depending on the amount of tile flow preceding the precipitation event. The no-till management system improves soil structure and macropore flow which transfers precipitation water quickly into the tile systems.

Tile flow volumes were different between the two tile sites over time. The basin size defined by surface topography at KP1 was nearly three times larger than KP2. Based on this, we would expect total tile flow volumes to be proportionately higher at KP1 than at KP2. However, total tile flow volume over the study period was nearly equal between basins KP1 and KP2, with 56 and 50 million gallons measured, respectively. The low lying topography of KP2 could have increased the proportion of groundwater intercepted by the tile line, as compared to KP1, accounting for the total flow similarity.

The tile at KP2 typically needed to be flowing at or near capacity in order for the corresponding surface water site at KP3 to run. The well developed soil structure and macropore flow transferred precipitation water efficiently under the no-till system.

Conclusions

- The general precipitation trends for the study period were slightly higher (8%) than the 30-year average for the Oconomowoc area.
- Surface runoff values varied between 5% and 16% of total annual precipitation.
- Substantial flow was not observed in the tiles until January 1, 2006. When the ground began to thaw in early March, 2006, continuous tile flow occurred at both tile outlets for the remainder of the monitoring period thru September 2009. This indicated that the tile lines were intercepting lateral flow, except in very droughty conditions.
- Tile flow rapidly responded to precipitation, especially when soils were at high moisture contents.
- Tile flow volumes were different between the two tile sites over time.
- Tile line drainage had a strong influence over surface runoff. For almost all surface runoff events, surface flow did not occur until the tile line was discharging at or near full capacity.
- The fluctuating water table boundaries that supplied water to tile lines on this farm made it difficult to determine the areas contributing to the monitoring sites.

Field Year	Precipitation (inches/acre)	Surface KP3 (inches/acre)	Tile KP2 (million gallons)	Tile KP1 (million gallons)
2005* (June 1 - Sept 30)	11.3	0.0	0.05	0.03
2006	33.0	1.7	6.0	3.5
2007	43.2	2.1	15.9	15.1
2008	38.6	6.1	17.0	25.9
2009	31.8	n/a	10.6	11.2

* Annotates partial field year

Table 1. Annual precipitation and surface runoff from KP3 (yield) and tile flow volume from KP2 and KP1 (load)

Understanding surface and tile water loss at Koepke Farms, Inc.

When precipitation falls to the ground, it can take many paths: infiltration into the soil, utilization by plants, recharge to groundwater, or runoff 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 at Koepke Farms, Inc.

Water budget

As previously mentioned, data presented in this report are shown as volume, concentrations or loads for tile sites and yields per acre for surface sites. The estimated contributing areas, based on surface topography, were 81 acres for KP1, 28 acres for KP2, and 6.1 acres for KP3. All data is based on the definition of a field year (FY), which is the 12 month period from October 1 through September 30 of the following year. This allows water monitoring activities to coincide with the crop production cycle. All frozen precipitation was converted to liquid equivalent for analysis consistency (Figure 8).

Surface runoff

Rain events late in the growing season when soils were dry, evapotranspiration rates were high, and dense crop cover protected the soil surface had lower runoff totals (see August 2007 with 13.3 inches of rain; ¾ inch of runoff - Figure 9). Rainfall events early in the growing season when the soils were at high moisture levels from spring rain events, crop evapotranspiration rates were low, and the soil surface was not protected

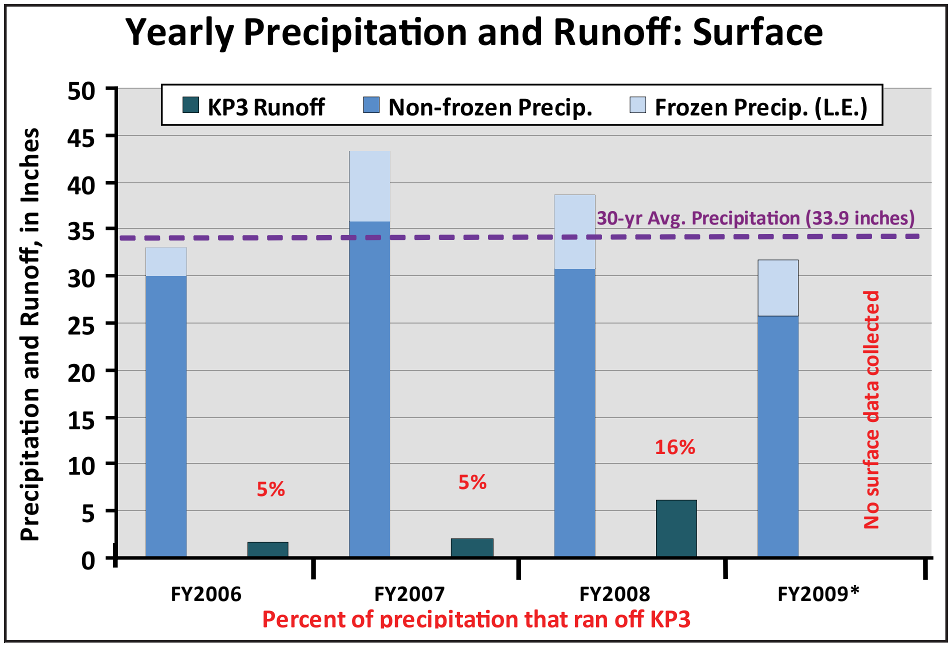


Figure 8. Annual precipitation and runoff from surface KP3

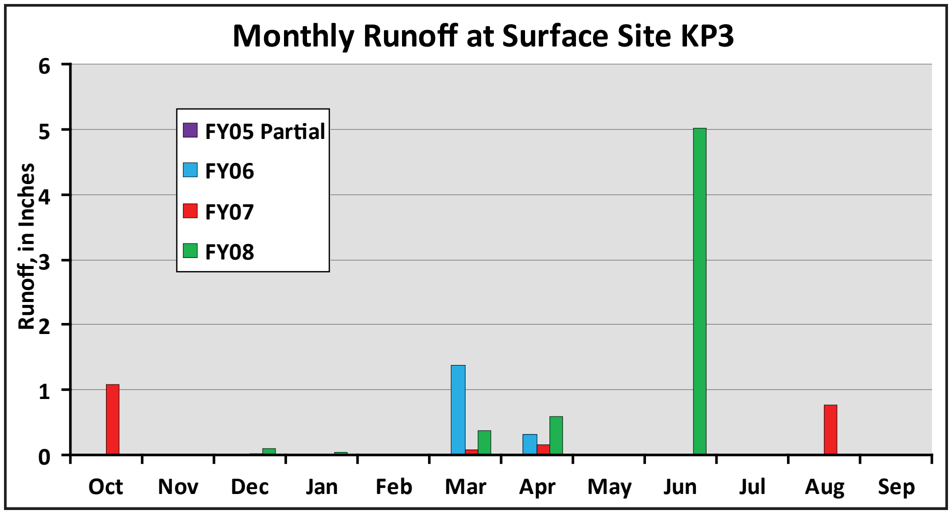


Figure 9. Monthly surface runoff at site KP3

by crop canopy had higher runoff totals (see June 2008 with 9.6 inches of rain; 5 inches of runoff - Figure 9). Runoff occurred each year during March and April, following snowmelt and spring rain events, when soil was frozen or had high moisture content.

Tile flow

The months with the highest average flow for tile sites were April, March, May and June, respectively. Rain events in the spring and early summer often resulted in substantial tile flow. A rapid response time was observed in the tile flow from rainfall events, especially when soil moisture levels were already high. The tile flow observed under alfalfa was significantly lower than flow under the corn during the months of April, May and June. The rapid growth of alfalfa in April and May uses more water than corn planted in May.

Frozen versus non-frozen ground

The date when the ground froze to the depth of an inch varied by 42 days over the four year study period, while the date the soil thawed at all depths monitored only varied by 13 days. The frozen ground period accounted for only 19% of the total surface runoff on this farm. Higher than average non-frozen precipitation totals in FY07 and FY08 caused a larger proportion of surface runoff during the non-frozen months than has been typically seen at other Discovery Farms sites.

Both tile drainage sites had approximately ¼ of total flow occurring during the frozen ground period. Annually, frozen and non-frozen tile flow followed this consistent pattern (Table 2). On this farm, tile flow typically increased significantly during the spring snowmelt period (when the ground thawed in March), and remained high though mid-summer. These high flow periods during non-frozen soil conditions lasted for longer durations than have been observed at the other Discovery Farms sites. The interception of groundwater by the tile drainage system may have resulted in the increased period of high tile flow.

Conclusions

➢ May and August were the highest average precipitation months during the monitoring period, yet these were not the highest months of average surface runoff or tile flow. The highest month for surface runoff was June 2008, driven by 9.6 inches of rain that fell on high moisture content soil.

➢ March and April experienced surface runoff in each year of the study. This was driven by snowmelt during frozen ground conditions in early March and subsequent rains late in March and April.

➢ The highest average flow month for both tile sites was April, followed closely by March, May and June. Snowmelt and spring rains on high moisture content soils resulted in higher tile flow.

➢ Tile flow was lower in April, May and June under established alfalfa compared to tile flow under corn. Establishing a perennial or cover crop may help to reduce the volume of tile flow in early spring.

➢ Precipitation was not an accurate predictor of runoff. The soil moisture content at the time of a rain event, crop cover, and evapotranspiration rates were shown to be the main factors that influenced surface runoff or tile flow. High soil moisture preceding rainfall often resulted in surface water runoff and increases in tile flow.

➢ Over the four year study period, the average date when the ground froze was December 14th (varied by 42 days), and the average soil thaw date was March 22 (varied by 13 days).

➢ The frozen ground period accounted for 19% of the total surface runoff and 25% of the total tile flow.

➢ Preferential flow through macropores within a frozen soil matrix, especially in a no-till cropping system, has the potential to transport nutrients and sediment downward with limited adsorption to the soil. This can become a delivery source to surface water in tile drained cropland if soil macropores intersect tile drain tubes.

Field Year	Period	Surface KP3	Tile KP2	Tile KP1
2006	Frozen	81%	20%	26%
	Non-frozen	19%	80%	74%
2007	Frozen	3%	16%	14%
	Non-frozen	97%	84%	86%
2008	Frozen	7%	36%	32%
	Non-frozen	93%	64%	68%
2009	Frozen	n/a	35%	25%
	Non-frozen	n/a	65%	75%

Table 2. Annual percentage of frozen and non-frozen ground surface runoff and tile flow

Sediment loss at Koepke Farms, Inc.

Surface and tile water monitoring

When precipitation falls on the soil, the force of raindrop impacts 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 had remained aggregated. The potential for agricultural fields to have high levels of soil sediment loss occurs when vegetative cover is limited and/or aggressive tillage has been conducted. This section provides information on sediment loss in surface runoff and tile drainage at Koepke Farms, Inc., as well as the factors influencing measured sediment losses.

Data presented are shown as volume, concentrations or loads for tile sites and yields per acre for surface sites. All data is based on the definition of a field year (FY), which is the 12 month period from October 1 through September 30 of the following year. All frozen precipitation was converted to liquid equivalent for analysis consistency.

Both the east and west basins were managed under a no-till planting system, but under different crop rotations. Manure was surface applied to corn acres in either late fall or spring. A single field in each basin was used to determine the impact of cropping practices on water quality.

Surface sediment loss

The average sediment loss for the surface basin KP3 during the monitoring period was 172 pounds/acre/year. Minimal soil disturbance by the no-till cropping system results in low surface sediment losses. The high amount of crop residue also protects the soil surface from raindrop impact and further sediment transport. The no-till soil environment also retains and infiltrates a large percentage of precipitation into the soil, thus reducing runoff. In addition, the existence of tile drainage at this site removed excess soil moisture quickly and reduced the number of surface runoff events.

During FY06, there was a total surface sediment loss of 40 lbs/acre. Sediment losses occurred only in March and April (Figure 10). The precipitation events for the remainder of FY06 were of lower intensity and more evenly distributed than those observed in March and April. In FY07, a total surface sediment loss of 216 lbs/acre was measured. Of this, 89% was from a storm on October 4, which accounted for 193 lbs/acre of sediment loss. In FY08 the total surface sediment loss was 260 lbs/acre. Of this, 93%, or 242 lbs/acre, was from a storm of 7.3 inches that occurred from June 7 through June 12. A small amount of surface sediment loss occurred each year during snowmelt and rains in March and April, but most of the loss was associated with single storms. Over the three years of monitoring, 84% of the total sediment loss was from two storms; October 2007 and June 2008.

Tile sediment loss

Annual sediment concentration ranges, averages and annual loads for sediment were used instead of yields because of the fluctuating water table (Figure 11). Loads were not calculated in FY09 because only monthly base flow sampling, instead of continuous sampling, was performed.

Higher sediment concentrations were observed in both tile systems during late fall, winter and early spring than during summer. High concentration events often had lower flow volume, resulting in lower load totals. Storms resulting in high total sediment loss often had low to moderate concentrations, but larger flow volumes. Total sediment loads were typically higher under corn and soybeans than alfalfa.

Since water quality analysis is compiled on a field year (October 1-September 30), soil loss between fall harvest and spring planting is linked to the next year's crop. A field year was used to tie nutrients to a given crop, so that fall nutrient applications and sediment loss are tied to the next crop. For example, the largest concentration of sediment was observed at KP2 in October 4, 2006. Although this event is placed under the soybean crop grown in 2007, the sediment loss should be linked to the previously grown corn crop from FY06; Direct load comparisons between KP1 and KP2 should not be made because the

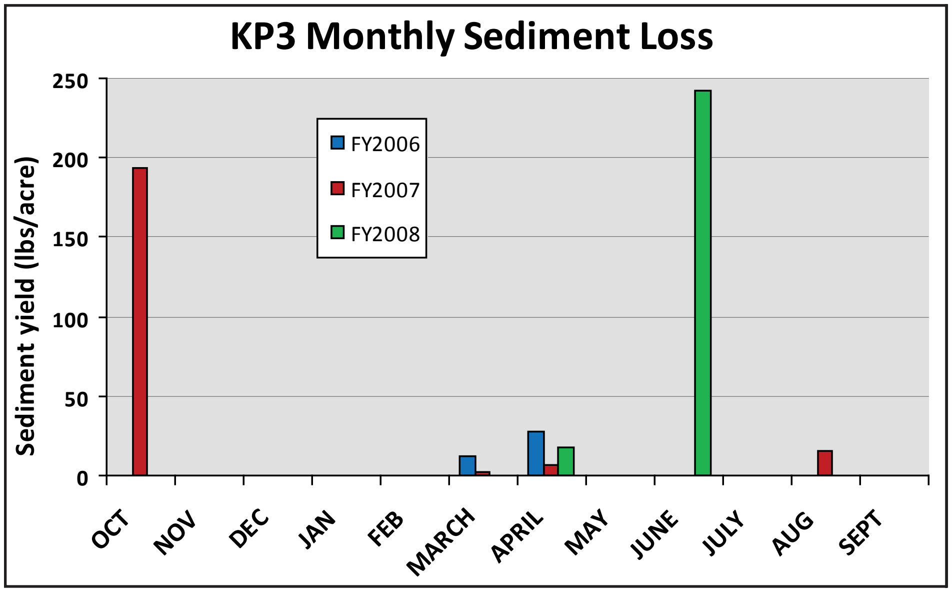


Figure 10. Monthly sediment loss at surface site KP3

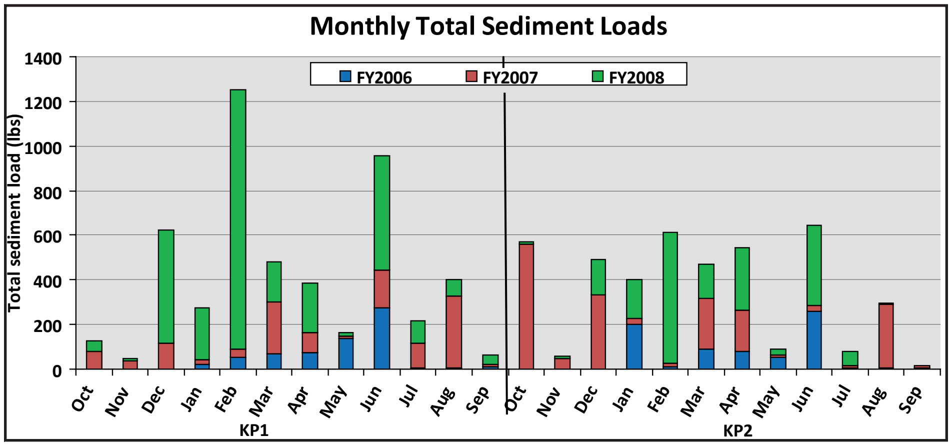


Figure 11. Cumulative monthly tile drainage sediment load at sites KP1 and KP2

	FY2005*	FY2006	FY2007	FY2008	FY2009
KP1	Alfalfa	Alfalfa	Corn grain	Corn silage	Soybean
Concentration Range (Avg.)	5 mg/L (5 mg/L)	<2 - 92 mg/L (21 mg/L)	<2 - 151 mg/L (20 mg/L)	<1 – 168 mg/L (37 mg/L)	<2 – 10 mg/L (5 mg/L)
Load	1.6 lbs	650 lbs	1458 lbs	3106 lbs	-----
KP2	Corn silage	Corn grain	Soybean	Corn silage	Alfalfa
Concentration Range (Avg.)	3 – 4 mg/L (3 mg/L)	<2 – 116 mg/L (25 mg/L)	<2 – 362 mg/L (34 mg/L)	<1 – 158 mg/L (31 mg/L)	<2 – 9 mg/L (6 mg/L)
Load	1.9 lbs	893 lbs	1729 lbs	1817 lbs	-----

*Annotates partial year of sampling — Annotates only monthly base flow sampling

Table 3. Annual crops, tile sediment concentrations and sediment loads for the study period

magnitude of difference between basin sizes is unknown.

The timing of sediment loss in tile was much more consistent than in surface runoff. Unlike surface sediment loss, tile sediment loss was more substantial during frozen ground conditions than non frozen ground. The highest sediment loss months for both tile sites were February and June (Figure 11).

Frozen versus non-frozen ground

Sediment loss occurs more frequently when the soil is not frozen. Total surface sediment loss was 3% of annual total loss during the frozen ground period, while sediment loss in the tile sites was 37% during the frozen ground period. Macropore flow during the frozen ground conditions seem to result in higher sediment loss observed in tile. Macropore flow is responsible for nearly immediate tile flow following rain events on frozen ground and high moisture content soils.

Conclusions

- The average sediment loss for the surface basin (KP3) during the monitoring period was 172 pounds/acre/year.
- The majority of surface sediment loss was associated with single storm events, with a relatively small amount occurring each year during March and April. Over the three year period of monitoring, 84% of the total sediment loss was from two storm events.
- The no-till system at the Koepke Farm limits the transport mechanism of soil loss by retaining water and allowing for infiltration into the soil, thus reducing sediment loss.
- Higher sediment concentrations were observed in both tile systems during late fall, winter and early spring than summer. The highest sediment loss months for both tile sites were February and June.
- Tile sediment loads were typically higher under corn and soybeans than alfalfa.
- Sediment loss timing was very different between surface and tile. During frozen ground conditions, minimal sediment loss occurred at the surface site (3%); whereas, more substantial sediment loss occurred at the tile sites (37%).

Phosphorus loss at Koepke Farms, Inc.

Surface and tile water monitoring

Data presented in this report are shown as volume, concentrations or loads for tile sites and yields per acre for surface sites. All data is based on the definition of a field year (FY), which is the 12 month period from October 1 through September 30 of the following year. All frozen precipitation was converted to liquid equivalent for analysis consistency.

Both the east and west basins were managed under a no-till planting system, but under different crop rotations. Manure was surface applied to corn acres in either late fall or spring. A single field in each basin was used to determine the impact of cropping practices on water quality.

Surface phosphorus loss

During the study period, the average total phosphorus loss for the surface basin (KP3) was 3.1 pounds/acre/year (Figure 12). The observed phosphorus loss was higher in corn years (FY06 & FY08) than soybeans (FY07). Dissolved phosphorus was typically the dominant form of phosphorus loss.

FY07 had the highest precipitation, but phosphorus loss was the lowest likely because no fertilizer or manure was applied. The combination of high runoff, manure application close to the high runoff period, and the lack of crop cover resulted in the highest monitored phosphorus loss in FY08. Phosphorus loss typically occurred during snowmelt, spring runoff in March and April, and during other large runoff events.

Tile phosphorus loss

Because the contributing area for the tile drainage system could not accurately

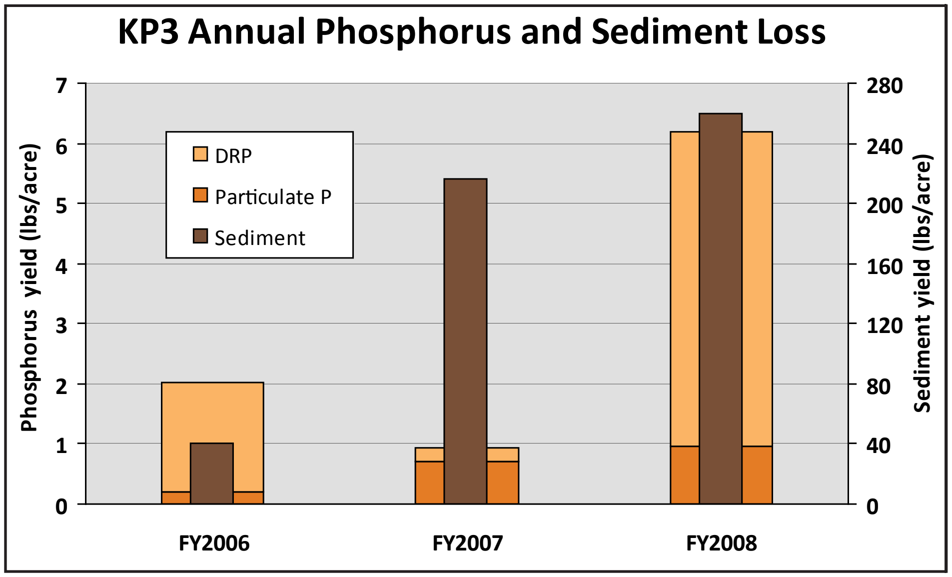


Figure 12. Annual total phosphorus loss at surface site KP3

be determined, phosphorus yields were not generated from the water quality data. Spikes in total phosphorus concentration and load could often be correlated to recent manure applications. Manure applications made in December 2005, December 2007, and March 2008 resulted in elevated phosphorus loads in subsequent months (see red outlined arrows, Figure 13). A manure application made at a lower rate in November 2006 did not result in elevated levels of phosphorus. High tile flow volumes from January 2008 through July 2008 at both KP1 and KP2 may have contributed to the high concentrations and loads observed in FY08. For both tile basins, the greatest phosphorus loss occurred between March and June. Loss patterns mimic the pattern of high flow volume for both tile sites. The majority of phosphorus loss on this farm occurred during the non-frozen ground period for both surface and tile (Figure 14).

Speciation of phosphorus loss

The majority (more than ¾) of phosphorus loss from both the surface and tile sites on this farm was lost as dissolved phosphorus. The no-till system used strongly decreases soil loss and the corresponding particulate phosphorus

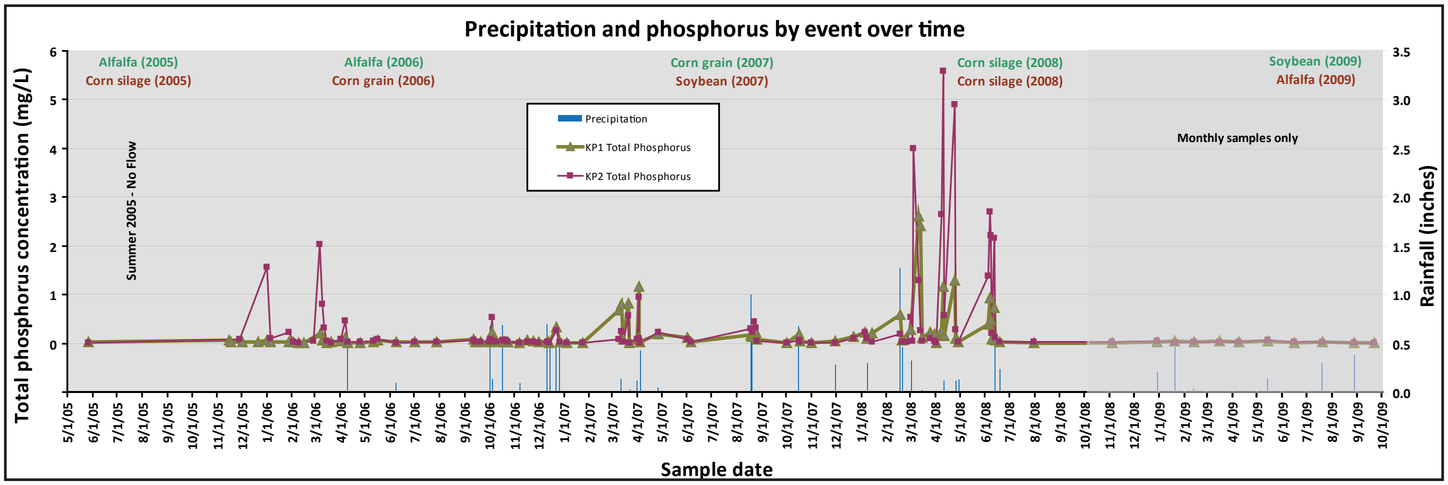


Figure 13. Precipitation and phosphorus load by event over time

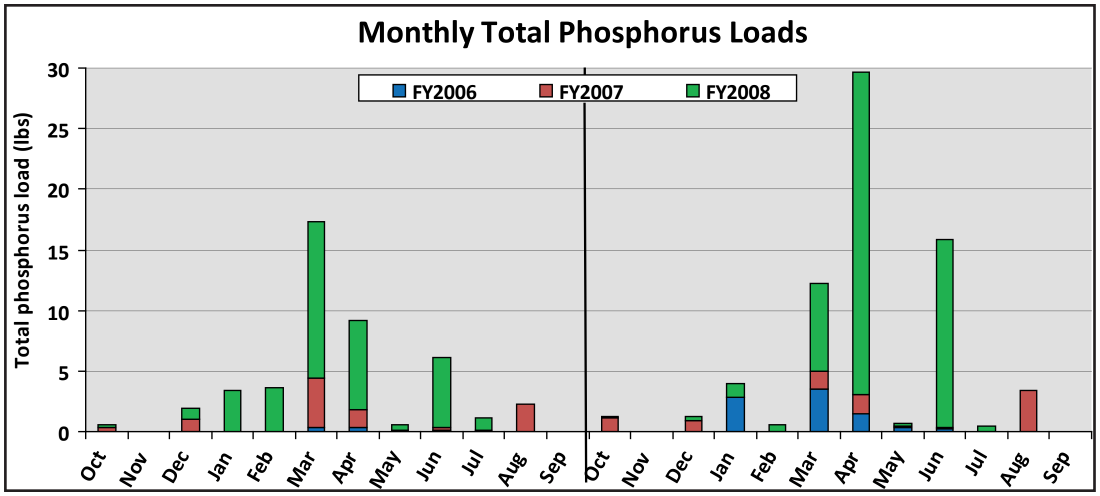


Figure 14. Cumulative monthly tile drainage phosphorus load at sites KP1 and KP2

loss. In surface water, dissolved phosphorus losses were usually higher during frozen ground and early spring runoff periods; and lower when runoff occurred during summer and fall. For the tile system, dissolved phosphorus loss did not show a seasonal trend.

Surface applied manure and phosphorus fertilizers result in high concentrations of phosphorus in upper layers of the soil in no-till systems. Finding a way to mix the top layers of soil, including perennial crops such as alfalfa, or growing winter hardy cover crops, may play a role in reducing dissolved phosphorus loss in these systems.

Conclusions

- The average total phosphorus loss for the surface basin (KP3) during the monitoring period was 3.1 pounds/acre/year. Phosphorus loss typically occurred during snowmelt and subsequent spring runoff in March and April and during large runoff events that occurred throughout the year.
- The contributing area for the tile drainage system could not accurately be determined, so raw water sample analysis concentrations and loads were used to identify trends in tile line water quality data.
- Tile total phosphorus loss under alfalfa was lower than corn and soybeans.
- Increases in total phosphorus concentration and load seen in tile lines could often be correlated to recent manure applications. The timing of manure applications likely had a role in the timing of phosphorus loss, especially in the dissolved form, on this farm.
- The months representing the highest average phosphorus loss in tile often correlated with the months representing the highest average flow volume in tile lines.
- The majority of phosphorus loss in both surface and tile was lost as dissolved phosphorus. Particulate phosphorus loss was strongly linked to sediment loss events, but only made up a small portion of the total phosphorus lost.
- Dissolved phosphorus loss at the surface site was typically high during frozen ground periods and early spring runoff and lower during summer and fall runoff. Tile dissolved phosphorus to particulate phosphorus ratio was variable throughout the years at both tile sites.

Nitrogen loss at Koepke Farms, Inc.

Surface and tile water monitoring

Data presented are shown as volume, concentrations or loads for tile sites and yields per acre for surface sites. All data is based on the definition of a field year (FY), which is the 12 month period from October 1 through September 30 of the following year. All frozen precipitation was converted to liquid equivalent for analysis consistency.

Both the east and west basins were managed under a no-till planting system, but under different crop rotations. Manure was surface applied to corn acres in either late fall or spring. A single field in each basin was used to determine the impact of cropping practices on water quality.

Surface nitrogen loss

The total average nitrogen loss for the surface basin during the monitoring period was 5 pounds/acre/year (Figure 15). Annual surface runoff data show that the timing of surface nitrogen loss and surface water flow are closely related, as are the total annual nitrogen loss and the total runoff volume. Data show that nitrogen loss typically occured during snowmelt, spring runoff events in March and April, and during other large runoff events.

Elevated losses in FY2008 were because of a manure application shortly preceding runoff in March 2008. Other applications during the study period did not influence nitrogen loss as much, because runoff did not occur until several months after those applications.

Tile nitrogen loss

Because the contributing area for the tile drainage system could not accurately be determined, nitrogen yields were not generated from the water quality data. Spikes in total nitrogen concentration and load could often be correlated to recent manure applications. Manure applications made in December 2005, December 2007, March 2008 resulted in elevated nitrogen concentrations in subsequent months (see red outlined arrows, Figure 16). A manure application made at a lower rate in November 2006 did not result in elevated levels of nitrogen. High tile flow volumes from January 2008 through July 2008 at both KP1 and KP2 may have contributed to the high concentrations and loads observed in FY08. For both tile basins,

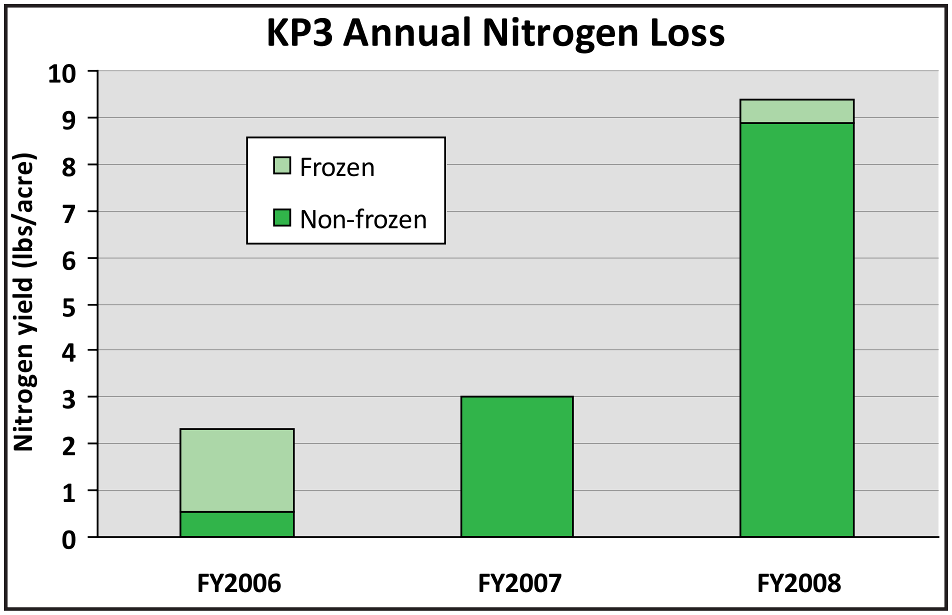


Figure 15. Annual total nitrogen loss at surface site KP3

the greatest nitrogen loss occurred between March and June, with April as the highest month (Figure 17). Loss patterns mimic the pattern of high flow volume for both tile sites. The majority of nitrogen loss on this farm occurred during the non-frozen ground period for both surface and tile. This data would suggest that the flow of water to the tiles collects mobile nitrogen, specifically in the form of nitrate, which is a main driver for nitrogen loss. Most nitrogen loss (84%) occurred during the non-frozen ground period for surface and tile.

Speciation of nitrogen loss

In surface water, the dominant form of nitrogen loss was organic nitrogen

(Figure 18). During frozen ground periods the percentage of ammonium nitrogen significantly increased. Nitrate nitrogen losses were typically lower during the frozen ground period. In tile water, the dominant form of nitrogen loss was nitrate (Figure 19). Losses of ammonium and organic nitrogen to tile mostly occurred during frozen ground conditions, likely because of preferential flow.

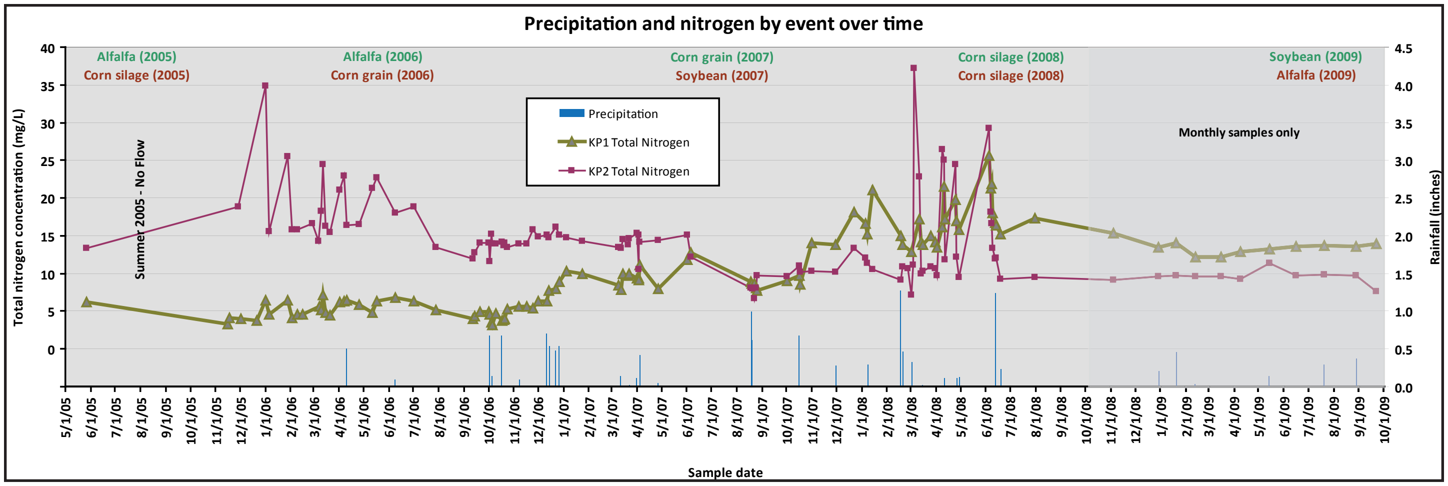


Figure 16. Event precipitation and nitrogen concentration at tile sites KP1 & KP2

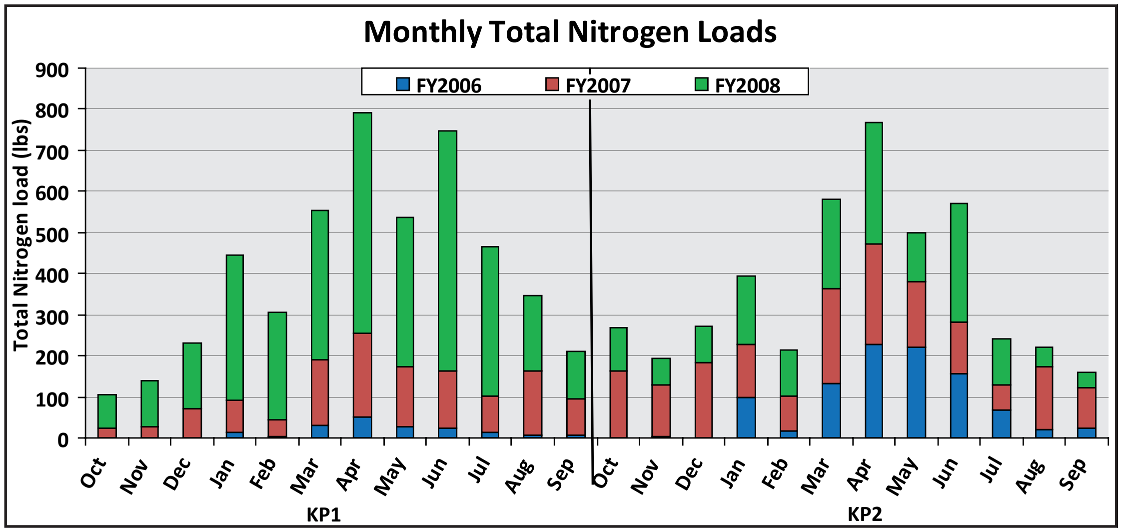


Figure 17. Cumulative monthly tile drainage nitrogen load at sites KP1 and KP2

Conclusions

- The average total nitrogen loss in surface water during the monitoring period was 5 pounds/acre/year. Surface loss of nitrogen is strongly connected to surface runoff in the no-till management system.
- The timing of tile nitrogen loss was very consistent for all years and for both basins. The highest losses were typically in the month of April, with elevated losses from March through June.
- Total nitrogen loss to tile under alfalfa was lower than soybean and corn.
- The majority of nitrogen loss occurred during the non-frozen ground period for both surface and tile.
- In surface water runoff, the organic nitrogen form was most commonly lost. During frozen ground periods the percentage of ammonium nitrogen loss significantly increased, and organic and nitrate nitrogen were typically lower than non-frozen ground periods.
- In tile water, nitrate nitrogen was the dominant form of nitrogen loss. The losses of ammonium nitrogen and organic nitrogen dominantly occurred during frozen ground conditions in tile.

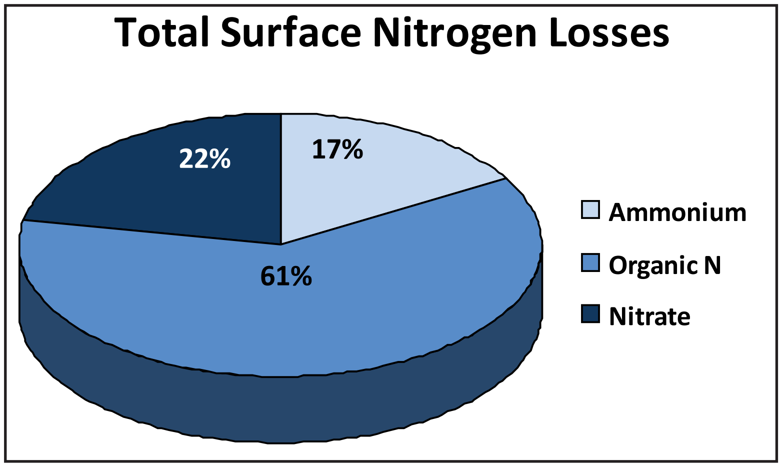


Figure 18. Speciation of surface N loss

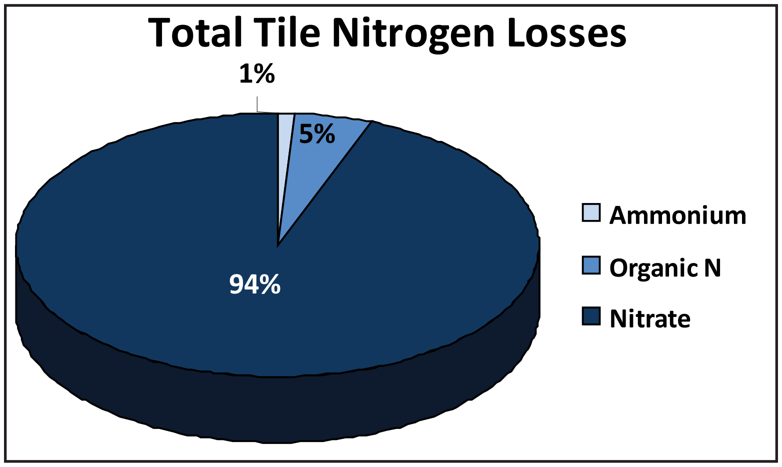


Figure 19. Speciation of tile N loss

Challenges of defining tile drainage subsurface contributing areas in high water table landscapes

Koepke Farms, Inc. is located in an area of Wisconsin where saturated soil conditions sometimes exist because of a fluctuating and often near-surface groundwater table. These hydric soils are characterized by anaerobic conditions in the upper soil profile, which restrict root growth and field operations. Tile drainage is often installed in these hydric soils to move water more quickly through the soil profile and out of the field. Subsurface drainage tile on the farm is typically placed 30 inches below the soil surface, and often intersects the saturated zone of the soil. Tile drainage aids in both field access and crop production.

Surface and tile water monitoring

Based on surface topography, the areas contributing water to our stations were estimated to be 81 acres (KP1), 28 acres (KP2) and 6.1 acres (KP3). It was soon apparent that the two tile sites had a much larger contributing area and that they were influenced by a fluctuating water table. The tile drainage system seemed to have water coming from a much greater area, and this area changed based on the amount of precipitation received. Therefore, an assessment of the amount of water coming through the tile line on a per acre basis (yield) was not possible on this farm. Only the surface runoff site (KP3) was analyzed on a yield basis.

Importance of accurately defining contributing areas

Trend analysis of water quality may be determined by using only concentration data, but more definite conclusions can be made by determining loss on a yield basis. Typically, the concentration of sediment and nutrients in surface water are higher than the concentration in tile. However, the flow volume is typically higher in tile than surface sites. Although the losses could be relatively equal on a yield basis, one event could be of high concentration and low volume similar to surface runoff and the other could be of low concentration and high volume similar to a tile flow event.

Challenge of determining tile drainage basin contributing areas in hydric soils

The surface area of the basin at these sites was determined by walking the basin and referencing topographic maps. The areas defined by the surface topography did not accurately depict the basin size because of hydric soils on the farm. In hydric soils, tile lines are influenced by both rainfall percolating down into tile, as well as groundwater moving up into the tile.

Subsurface water, moving laterally, can come from an unspecified distance outside the defined basin; so water observed in the tile may not be from the designated field(s). Even during periods when crops exhibited drought stress, flow was observed from the tile lines. The actual age of the water is also unknown, so nutrient losses may not all be due to the events currently happening on the land surface. In order to properly associate yields and concentrations to a specific field(s), field verification of the tile drainage contributing area needs to be performed.

As the water table raises and lowers, the contributing areas seem to change in size. As the water table rises, the area contributing to tile flow enlarges the basin (like filling a funnel; the deeper the water, the wider the surface). The drainage area that influences a tile during a lower water table may vary significantly compared to higher water levels. It is also unclear how much discharge is due to water percolating through the soil and how much is intercepted groundwater. To accurately monitor in hydric soils, specific attention should be given to determining the subsurface contributing area, and how this area changes with the rise and fall of the groundwater level.

Simulation of tile drainage contributing areas

In an effort to better define the basins for the tile systems, the USGS performed modeling of the groundwater basins contributing water to the tile systems. The groundwater-flow model was refined for the area around this farm to simulate groundwater discharge to tiles and ditches and to estimate the general area from which the tiles and ditches capture recharge.

The model parameter values were adjusted manually in order to roughly match the measured flows in the tiles, ditches and streams. No well information was available to check the simulated water levels.

In the east basin (KP1), the modeled subsurface basin differs significantly in size and shape from the surface water basin. The modeled KP1 subsurface contributing area is almost half (47 acres) of the assumed contributing area defined by surface topography (81 acres). Conversely, the modeled subsurface basin in the west basin (KP2) was larger (43 acres) than the assumed contributing area defined by surface topography (28 acres). It should be noted in Figure 20 that the blue line annotating the modeled subsurface basin for the east basin is the single blue area on the lower right. The west basin includes the blue area on the lower left, as well as the three disconnected basins near the upper portion of the figure.

It is unlikely that the modeled subsurface basins are the actual contributing areas, but it points out the complexity of the subsurface flow of water in this region. The model was run assuming steady-state conditions during a base flow period. If periods of higher or lower flows were used to manually adjust the model, the boundaries of the subsurface basins would expand and contract.

However, the model did more accurately assess the relative size of the basins based on flow information than the contributing areas from surface topography. The total flow over all years was approximately 56 million gallons at KP1 and approximately 50 million gallons at KP2. These values coincide much better with the modeled values of 47 and 43 acres than the surface topography defined areas of 81 and 28 acres.

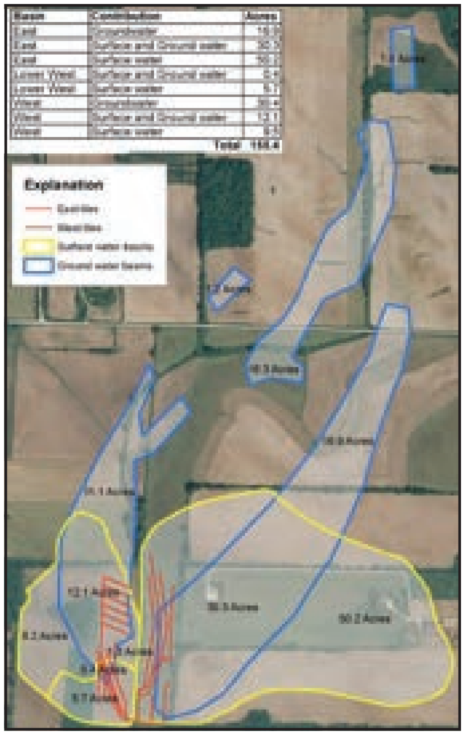


Figure 20. Basin contributing areas defined by surface topography (yellow) and groundwater modeling (blue) to tile drainage system (red).

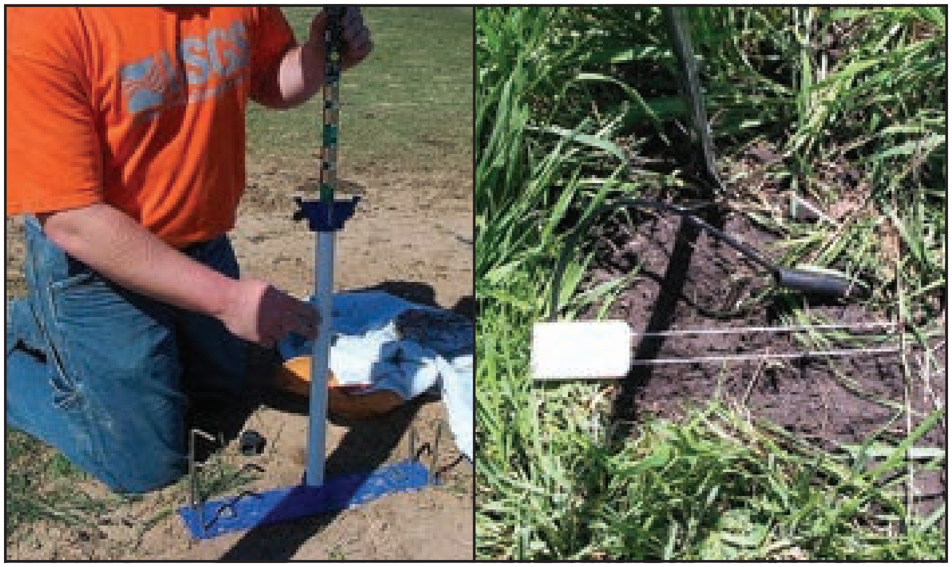
As exhibited in both flow and modeling data, it is very difficult to accurately define the areas contributing to tile where groundwater is in close proximity to a tile system. Also, these contributing areas likely change as the saturated zone rises and falls. The accurate determination of contributing areas is critical to comprehensively analyze water quality data and correlate it to land use practices. Future tile monitoring studies in landscapes where groundwater is in close proximity of the tile should implement methods to more accurately determine subsurface contribution areas.

Conclusions

- A determination of subsurface areas contributing water to the tile drainage system could not accurately be performed in this study. To develop yield information in settings where groundwater is in close proximity or intercepts the tile drainage system, it is important to accurately delineate the surface and subsurface contributing areas.

- The analysis of tile drainage water quality data in this study was limited because an accurate determination of contributing areas could not be made. The magnitude of loss of applied nutrients could not accurately be determined from concentration and load data.
- Modeling of the subsurface contributing areas resulted in boundaries that were much different in both size and location from the areas defined by surface topography.
- Although yield data could not be accurately determined, concentration and load data allowed for a comprehensive assessment of the impacts of land use activities on subsurface water quality.

Soil moisture and the potential for runoff



Sentek EasyAG (left) and Campbell Scientific CS616 (right) soil moisture probes

In an unsaturated soil, some or all of a given amount of water infiltrates depending on the water holding capacity of the soil, the intensity (or rate) of the water being introduced, and the amount of pore space already filled with water. The amount (%) of water in a soil is inversely proportional to the amount (%) of air space. As the amount of water goes up, the amount of air space goes down. In soil, this space that is occupied by either water or air is referred to as "pore space". A measurement of pore space in the soil that is occupied by water is called soil moisture. Soil moisture is most often given as a percent of the whole, not as a percent of space used. Once a soil is saturated (air space is gone), there is no remaining capacity to retain additional water and runoff often occurs.

Infiltration rates are affected by both external and internal variables with respect to soil properties and conditions. External variables include slope, precipitation intensity, total volume of water, surface residue, surface roughness, and the presence of tile drainage. Internal variables include soil moisture, soil compaction, soil type and the depth of saturation. For this report, when looking at days with a certain range in soil moisture, all data were included. However, when looking at yearly trends, only years with full datasets were used. For rain events, only events with greater than or equal to 0.1 inches of precipitation were used. Events smaller than this were considered insignificant.

Non-frozen ground

From FY06 - FY08, 81% of surface runoff occurred on non-frozen ground. Soil moisture was divided into three categories low (< 25%), medium (25 - 35%), and high (> 35%). Through the study period, on average, soil moisture conditions were low 5% of the year, 41% of the time was medium, and 26% of each year had high soil moisture conditions. During the remaining 28% of the year the ground was frozen (Figure 21). Precipitation on frozen soils has runoff frequency similar to that of high moisture soils.

Closer study of the distribution of soil moisture (Figure 22) shows that only one year had many low moisture days (FY06 – 14% or about 50 days) while the other two years had none or one day. FY07 was a high precipitation year (almost 10 inches above average) and soil moisture was high for 146 days (40%).

Of the total runoff occurring on non-frozen ground, 96% occurred during high soil moisture conditions and the remaining 4% occurred during medium soil moisture conditions. The no-till farming system increases plant residue on the soil surface and provides for increased water infiltration into the soil. This farm experienced some large volume and intense rain events on low/medium soil moisture levels that did not result in runoff.

The no-till farming system also enhanced soil macropores which rapidly

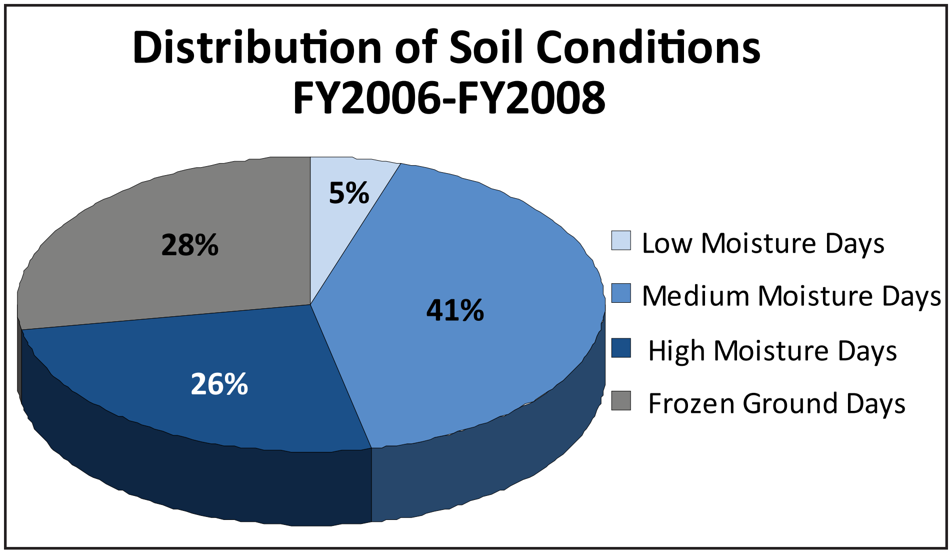


Figure 21. Distribution of soil moisture conditions

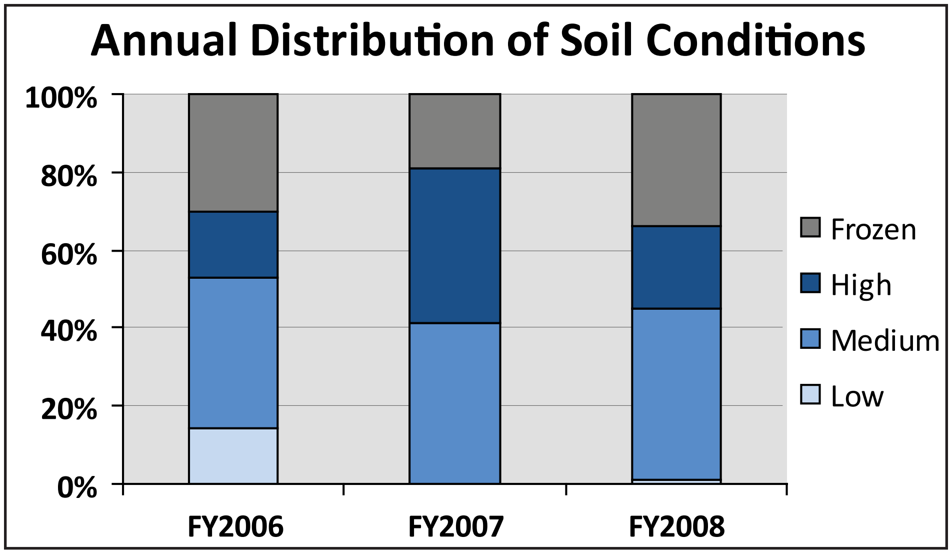


Figure 22. Annual distributions of soil conditions

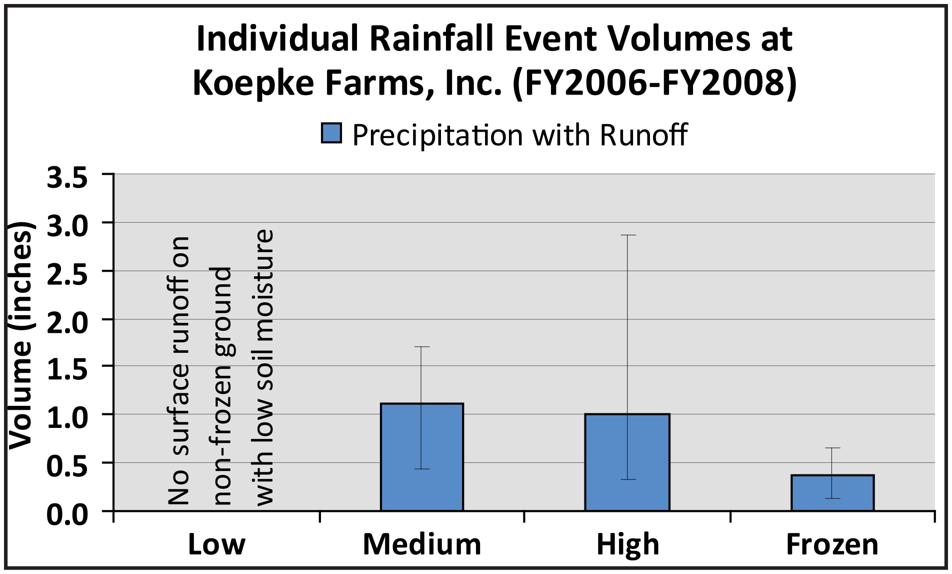


Figure 23. Runoff with soil moisture and storm volume

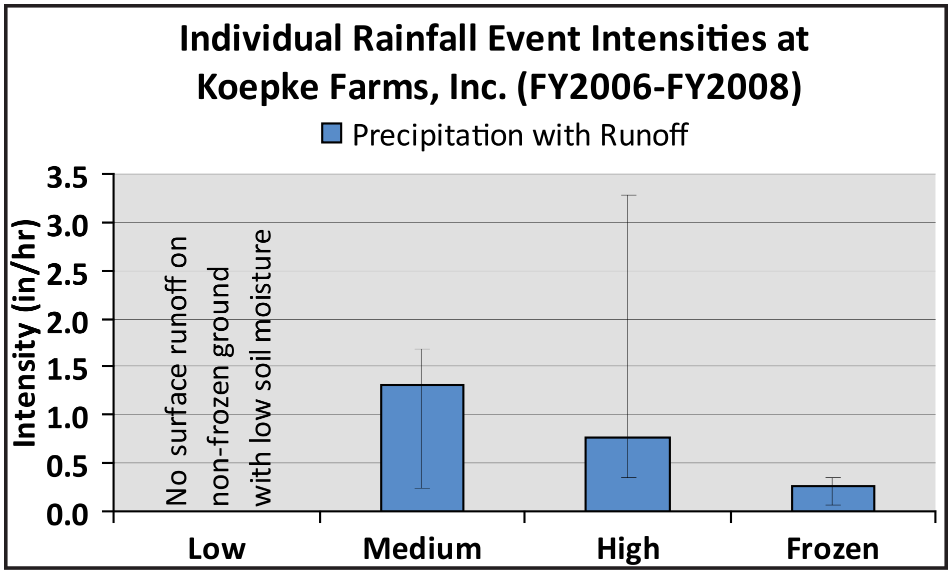


Figure 24. Runoff with soil moisture and storm intensity

transfer water to the tile drainage system. On this farm, unless the tile drainage system was flowing at capacity, surface runoff events typically did not occur. Of all rain events that occurred on non-frozen ground, only 15% resulted in surface runoff. Runoff never occurred when rain fell on low soil moisture fields, it occurred 5% of the time when rain fell on medium soil moisture fields and 29% of the time on fields with high soil moisture.

Rain events and surface runoff

With lower soil moisture, a higher volume of water can Infiltrate into the soil to fill remaining pore spaces.

There were no runoff events on soils with low soil moisture regardless of the volume of rain or the storm intensity. When soil moisture was greater than 25%, it took approximately 1 inch of rain to generate runoff (Figure 23).

If rainfall intensity exceeds the soil infiltration rate, runoff will occur. For medium moisture soils, it took an average intensity of 1.3 inches/hour to produce runoff. When runoff occurred for high soil moisture conditions, the average intensity was 0.8 inches/hour (Figure 24).

Conclusions

- Approximately 50% of the time soil moisture conditions were either low (< 25%) or medium (25-34%), while the remaining 50% had either high soil moisture (> 35%) or frozen ground conditions.
- During non-frozen ground, 96% of the total non-frozen surface runoff occurred at high soil moisture. The no-till farming system likely reduced runoff in low and medium soil moisture conditions.
- Of all rainfall that occurred on non-frozen ground, only 15% resulted in surface runoff. Precipitation on low and medium soil moisture generated runoff 0% and 5% of the time respectively; high moisture soils resulted in runoff 29% of the time.
- Smaller events in volume and intensity generate more runoff when soil has high moisture or is frozen compared to times of low or medium soil moisture content.
- Soil moisture, precipitation volume, and precipitation intensity all combine to influence whether runoff occurs. This information can be utilized to make better management decisions when it comes to spreading fertilizer or manure.

Single storm event loss comparison to total annual sediment and nutrient loss

Single storm event loss comparison to total annual sediment and nutrient loss

The majority of the losses (both sediment and nutrients) from Koepke Farms, Inc. occurred during one or two major storms during each year. The combination of environmental and management factors play a large role in both total annual losses and single storm losses of nutrients and/or sediment. For surface runoff, the largest volume runoff events generally resulted in the largest sediment, phosphorus and nitrogen loss.

To determine the impact of a large single storm event, the highest loss event for each field year was determined for sediment, phosphorus, and nitrogen. This quantity was then compared to the total annual losses at that site.

Surface losses

Sediment loss in one storm can provide nearly 90% of the total annual loss (FY07). Generally, high sediment loss is related to large rainfall and runoff events (Figure 25).

Phosphorus in surface runoff from a single storm can contribute over 80% of the annual loss (Figure 25). The highest surface phosphorus loss generally occurred during snowmelt (March) or large summer storms (Table 4). Dissolved phosphorus was always the dominant form of phosphorus lost, whether the ground was frozen or not, even during events with high sediment losses.

Single storm nitrogen loss in surface water can contribute more than 70% of the annual loss (Figure 25). The highest surface nitrogen loss events occurred at the same time as the largest runoff events (% Total Flow, Table 4) whether they were derived from snowmelt or heavy rains.

Tile sediment and nutrient loss

It appears that large storms have more impact on surface runoff than tile flow. This is likely due to the large number of tile flow events compared to a small number of surface runoff events. In tile, the events with the largest losses were of a lower percentage of the annual flow volume compared to surface runoff (% runoff, Table 5). The tile on this farm ran almost continuously and the length of flow events varied from a few days to more than a month. This means that single storm analysis of tile events is not comparable to surface events. Variation in the sampling period means that it's difficult to determine whether a constituent is from a storm or from base flow.

FY07 and FY08 both had flow volumes of less than 3% during the period of highest phosphorus and sediment

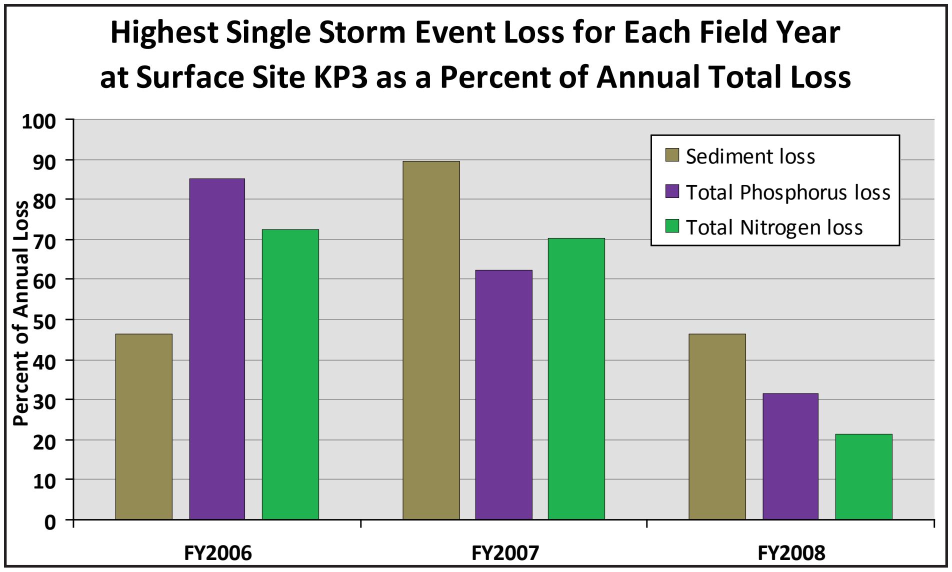


Figure 25. Highest losses from a single storm at KP3

	Total Sediment		Total Phosphorus		Total Nitrogen	
	% runoff	% total	% runoff	% total	% runoff	% total
Surface	32.9	60.7	55.9	59.6	55.9	54.6
Tile	5.7	27.1	3.1	18.4	13.1	13.6

Table 5. Highest single storm loss average of sediment, phosphorus and nitrogen for the entire monitoring period in surface and tile

losses. Nitrogen loss closely followed flow volumes for events in tile. While high surface losses typically occurred on the same date; sediment, phosphorus, and nitrogen events usually occurred during different storms in tile.

The highest loss for sediment in FY08 occurred during the frozen ground period. Tile phosphorus loss from a single storm was up to 27% (FY06) of the annual loss. High losses were observed during spring snowmelt and large early spring rain events. The highest nitrogen loss reached 18%, and the highest loss for both tile sites occurred on the same storm event, unlike sediment and phosphorus.

Only total nitrogen losses had a close relationship to flow in tile and a smaller relationship in surface runoff.

Sediment is most influenced by a single storm and nitrogen is least influenced. (Table 5)

Site	Year	Sediment Date	Sediment % Total Flow	Sediment % Total Sediment	Phosphorus Date	Phosphorus % Total Flow	Phosphorus % Total Total P	Nitrogen Date	Nitrogen % Total flow	Nitrogen % Total Total N
KP3 (surface)	FY2006	04/07/06	9.1	46.3	03/09/06	78.2	85.1	03/09/06	78.2	72.4
	FY2007	10/04/06	51.7	89.4	10/04/06	51.7	62.2	10/04/06	51.7	70.3
	FY2008	06/08/08	37.8	46.4	06/08/08	37.8	31.5	06/08/08	37.8	21.3
KP1 (tile)	FY2006	05/17/06	12.1	33.5	04/07/06	8.8	19.5	05/17/06	12.1	12.9
	FY2007	11/30/06	1.7	21.9	03/12/07	1.8	16.4	04/27/07	12.5	14.3
	FY2008	02/20/08	2.4	27.9	03/13/08	1.2	17.6	06/19/08	16.1	15.6
KP2 (tile)	FY2006	05/17/06	15.5	31.9	01/01/06	3.2	26.7	05/17/06	15.5	18.0
	FY2007	10/04/06	1.1	30.4	08/22/07	2.3	12.8	04/27/07	10.3	11.0
	FY2008	02/20/08	1.4	16.8	04/25/08	1.3	17.4	06/19/08	12.1	9.7

Table 4. Highest single storm losses for each field year at each monitoring site

Conclusions

- ➢ Surface runoff from a single storm can contribute nearly 90% of the sediment loss, over 80% of total phosphorus loss, and over 70% of total nitrogen loss for the entire field year.
- ➢ Data provided for tile drainage was performed on a sampled event basis.
- ➢ Tile flow from a single event basis delivered over 30% of the sediment loss, up to 27% of total phosphorus loss, and 18% of total nitrogen loss for the entire field year.
- ➢ Single storm events that contribute the majority of the total annual sediment, phosphorus, and nitrogen loss appear to have more effect on surface runoff than tile flow.
- ➢ Some of the storms resulting in the highest loss of sediment, phosphorus, and nitrogen exceed the design criteria for the 25-year, 24-hour storm which conservation practices are designed to handle.

Impact of UW – Discovery Farms research on agricultural management at Koepke Farms Inc, public perception, and future Discovery Farms research site criteria

The selection criteria for Koepke Farms, Inc. included a strong emphasis on monitoring tile and surface water quality in a no-till cropping system, and the ability to determine how surface applied manure and field management affect sediment and nutrient loss.

The study on this farm compiled useful information on a variety of topics including an improved understanding of surface and tile drainage flow patterns in hydric soils, land management influence on nutrient and sediment loss, and environmental factors contributing to management challenges in these landscapes.

Major lessons learned

The comparison of tile drainage systems under different landscapes: Two of the more common landscapes where tile drainage is utilized in Wisconsin are the red clay soils, common throughout Eastern Wisconsin, and hydric soils, common throughout the southern half of the state. Tile drainage systems located on hydric soils frequently intercept lateral groundwater flow. Other Discovery Farms tile monitoring studies have been conducted on red clay soil in Northeastern Wisconsin, where tile lines are primarily influenced by precipitation, and do not intercept lateral groundwater flow. Understanding how the different hydrology between these two landscapes affects flow volume and the duration of tile flow is critical for determining appropriate best management practices for each landscape, as well as future tile monitoring site selection and study designs.

How does tile drainage monitoring in hydric soils reflect losses from individual fields? This study suggests that losses from edge-of-field tile monitoring sites in hydric soils can not accurately estimate losses from the individual fields. Since groundwater flow can originate from areas well outside of the defined monitoring area, it is difficult or impossible to determine the source of nutrients and/or sediment collected from tile lines under these conditions.

Changes in agricultural management

Management changes based on the data and information generated through Discovery Farms research is a crucial aspect to determine the success or failure of research and outreach projects. Although influences apart from information learned through Discovery Farms may have played a role, the following changes were noted on the farm:

- After taking soil nitrate tests, the farm's primary rotation was changed to corn-corn-soybeans following alfalfa to capitalize on the value of second year alfalfa nitrogen credits and reduce the potential for nitrate loss to the environment.
- With over 75% of the phosphorus loss as dissolved phosphorus, experimentation with different cover crops across the farm began to help reduce dissolved phosphorus loss and reduce the potential for nitrate loss.
- The farm was able to evaluate the strengths and weaknesses in their nitrogen management program, and make adjustments accordingly by utilizing end of the year stalk nitrate tests.
- Manure storage was constructed in 2008 so that they could minimize manure applications on frozen ground and when soil moisture was high.

The Koepke families have a long history of being very active in the community and were anxious to share information gained on the farm with other producers in their area. They opened their farm to numerous tours and field day exhibits, hosted "Ag in the Classroom," as well as local school events on the farm.

For example, Discovery Farms staff received requests from neighboring farmers to provide assistance in calibrating manure spreaders so they could better account for their manure applications. Several of these farmers went on to participate in a Nutrient Management Education Program conducted by local University of Wisconsin – Extension staff and their partners to prepare a nutrient management plan for their own farm. The Oconomowoc FFA students, after attending the 2008 field day, requested assistance in planting a plot on a local farm so that they could study different cover crops and collect information as to how cover crops can be adapted to local growing conditions.

The farm is located on the "urban edge" and numerous urban neighbors attended field days and gained a better understanding of the environmental challenges facing farmers, and what farmers are doing to protect natural resources.

Changes in public perception of agriculture

In 2008 more than 140 people representing agriculture industry, farm producers, environmental groups, nearby urban communities, and government agencies gathered at the farm to learn about Discovery Farms monitoring results, tour the research sites, and engage in an open exchange of ideas. Some of the issues addressed at this field day, and other outreach include:

- Understanding nitrogen losses in farming systems: Participants learned about the dynamics of the soil nitrogen cycle, and factors that producers have within their control to limit nitrogen loss potential.
- Using cover crops to manage nitrogen losses: Traditional BMPs like vegetative buffers and reduced tillage do not have a significant impact on reducing dissolved phosphorus and nitrate loss, especially in agricultural systems utilizing tile drainage. Cover crops have the potential to reduce both dissolved phosphorus and nitrate loss to tile drainage by scavenging nutrients in fall and early spring, and by reducing the quantity of water that moves through the tile drainage system.
- The value of soil quality: A soils pit was used to visually illustrate the environmental and agronomic soil quality benefits that a long term no-till system can provide.
- Finding ways to educate the public on environmental issues in the area: Water quality data was presented to the Rock River Coalition, whose mission is, in part, to educate the community on water quality within southern Wisconsin's Rock River Basin.
- Information gathered at Discovery Farms sites provide science based information to county and state level agencies, agriculture industry, and farm producers in order to make informed management decisions.

Changes in research site criteria for future Discovery Farms sites

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

Identification of contributing subsurface drainage area for tile sites in hydric soil conditions. The challenge of tile line monitoring in hydric soils, which are influenced by lateral subsurface flow, is to accurately determine the size of the contributing subsurface drainage area. This area can vary in size as the water table fluctuates. In order to associate yields and concentrations to a specific field or basin, verification of the tile drainage contributing area must be done.

Concurrent surface water and tile monitoring in a basin. Further analysis of the timing of runoff in surface and tile indicated that when the tile system was at or near capacity, surface water flowed. This data also identified a strong interconnection of preferential flow between the surface and the tile. In tile drained agricultural landscapes, it is important to utilize both surface and tile drainage monitoring, when possible, to accurately assess the potential loss of sediment and nutrients so management practices affecting losses can be better understood.

Close to power (near power lines or buildings). The three monitoring sites did not have direct-wired AC power. Large solar panels and additional batteries were not ideal to power tile line monitoring, which has longer flow periods and increased sampling frequency compared to edge of field stations.

Easy access by road (able to plow in winter). The three monitoring sites were not easily accessible to a town road. Significant staff hours were spent accessing these sites during snow or high moisture conditions when vehicle travel was difficult.

Cooperative and good recordkeeping participant. This farm had a good recordkeeping system and family members were always available to share their records and management information with Discovery Farms staff. Without this type of cooperation and comprehensive recordkeeping of what happened on the land, linking water quality data to land management would be impossible.

By Nancy Drummy, Eric Cooley, Aaron Wunderlin, Amber Radatz, Dennis Frame and Kevan Klingberg, UW-Extension/Discovery Farms

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This insert is a summary of on-farm research conducted at Koepke Farms, Inc., Oconomowoc, WI. Project results are presented in 11 fact sheets. The series includes: Farm, Site and Study Design; Monitoring Site, Equipment and Procedures; Water Budget at Koepke Farms, Inc.; Understanding Water Loss at Koepke Farms, Inc.: Surface and Tile Water; Sediment Loss at Koepke Farms, Inc.; Phosphorus Loss at Koepke Farms, Inc.; Nitrogen Loss at Koepke Farms, Inc.; Challenges of Defining Tile Drainage Subsurface Contributing Areas in High Water Table Landscapes; Soil Moisture and the Potential for Runoff; Single Storm Event Loss Comparison to Annual Sediment and Nutrient Loss; and Impact of UW-Discovery Farms Research on Agricultural Management at Koepke Farms, Inc., Public Perception, and Future Discovery Farms 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.