Northern New York Agricultural Development Program
2019 Project Report

Quantifying Surface Runoff and Tile Drainage Flow Nutrient Losses in Edge-of-Field Plots, Year 2

Project Leader:

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Cooperating Producer:

- Miner Institute Dairy Farm, Chazy, NY

Background:

Tile drainage is a critical practice for many farms in northern New York with naturally poorly-drained soils. Research has demonstrated that tile drainage can significantly increase crop yield and quality as well as reduce yield variability (Blann et al., 2009). However, as watersheds continue to struggle with recurring water quality issues (e.g., harmful algae blooms), agricultural tile drainage has come under increased scrutiny as a potential source of excess nutrients (e.g., phosphorus (P) and nitrogen (N)). Although tile drainage does export some nutrients, there have been few studies in our region designed to continuously monitor losses in both surface runoff and tile drainage.

Total runoff and nutrient concentrations can be highly variable across events as well as on an annual basis, and, therefore, long-term studies are necessary to estimate losses from each runoff pathway. The interaction of weather, cropping system, field management, soil type and fertility, landscape position, and other factors will affect the partitioning of runoff and overall levels of nutrient export from surface and tile drainage.

Most edge-of-field research in the region has been conducted in fields managed as corn for silage, however, the impact of drainage on nutrient transport in row crop fields may be substantially different than in fields with perennial cover. Differences in crop growth and nutrient removal characteristics, continuous ground cover, absence of tillage, timing and method (no incorporation) of manure applications are among the primary differences often observed in these systems (Gilliam et al., 1999; King et al., 2015).

The objective of this Northern New York Agricultural Development Program-funded project was to quantify the nitrogen (N), phosphorus (P), and sediment losses in surface runoff and tile drainage from four runoff plots in an alfalfa-grass field.

In broader terms, this research is critical for building the data-driven science needed to accurately guide water quality conservation for New York State, and beyond. For example, the NNYADP water quality project results to-date have been presented to the Lake Champlain Basin Program and other groups in New York and Vermont, the Southern Extension and Research Activity-17 Information Exchange Group, and at international meetings.

Methods:

Surface runoff and tile drainage from four replicate edge-of-field plots were continuously monitored from January 1, 2018 to December 31, 2019. Automated water samplers were used to sample runoff every 30 minutes when weather forecasts indicated that runoff would be likely due to precipitation or snowmelt events. Periods of persistent low flow (baseflow) were manually sampled. Tile and surface samples from each plot were individually composited on a flow-weighted basis when autosamplers were used.

Samples were analyzed for total P (TP), soluble reactive P (SRP), total N (TN), nitrate-N, ammonium-N (amm-N), and total suspended solids (TSS). Each composite sample concentration represents the event mean concentration (EMC). For each event, the EMC was multiplied by the event flow volume to estimate nutrient loading from each runoff pathway for individual runoff events. For baseflow samples, concentrations were assumed to be constant from halfway between the previous sample and subsequent sample for each collection time point and these estimates were multiplied by the corresponding flows.

Annual flow-weighted mean (FWM) concentrations were calculated for surface runoff and tile drainage by dividing the total nutrient and sediment loads by total flow. A "total" FWM was calculated by dividing the the total nutrient and sediment loads (surface + tile) by the total runoff (surface + tile) from the plots. Differences in mean nutrient loads and FWM concentrations in surface runoff and tile drainage were analyzed with a two-tailed t-test. Significance was declared at $P \leq 0.10$ due to the inherent variability present in runoff response at this scale and low number of replicates.

Corn was harvested for silage from the research field plots in fall 2017. Following corn harvest, 8,000 gal/ac of liquid dairy manure was surface applied and incorporated the same day with a disk harrow. Plots were disk harrowed prior to planting a 60/40 mixture of alfalfa and cool season grasses on May 10, 2018. No starter fertilizer or manure was applied in 2018 following the farm's typical management for a first-year alfalfa-grass field. The plots were harvested on July 28, 2018 and September 4, 2018 for hay crop silage. In 2019, broadcast applications of 4,500 gal/ac of liquid dairy manure followed both first and second cut harvest for hay crop silage on July 9 and September 9.

Results and Discussion:

Precipitation and Drainage

The experimental site received average precipitation in 2018 (29.2 inches) and above average precipitation in 2019 (36.7 inches), relative to the 30-year Clinton County average (30.5 inches). The increased precipitation in 2019 was reflected in greater rates of total runoff from the plots than in 2018. The average total runoff from the plots (surface + tile) was 11.2 inches in 2019 as compared to 5.6 inches in 2018 (Table 1).

Table 1. Mean runoff and exported nutrient and sediment loads from the runoff plots in 2018 and 2019, Quantifying Surface Runoff and Tile Drainage Flow Nutrient Losses in Edge-of-Field Plots, Year 2 Project, NNYADP.

Year	Pathway	Runoff	SRP	Total P	TSS	Nitrate-N	Total N
		in	--------------------------lb/ac--------------------------				
2018	Surface	2.30	**0.360**	**0.494**	10.55	**0.88**	**3.52**
2018	Tile	3.34	**0.006**	**0.021**	5.08	**28.66**	**31.30**
2018	Total	5.64	0.366	0.515	15.63	29.54	34.82
2019	Surface	**1.01**	0.016	0.040	**5.81**	**0.17**	**0.57**
2019	Tile	**10.19**	0.058	0.156	**22.72**	**28.30**	**30.32**
2019	Total	11.20	0.075	0.196	28.53	28.47	30.89

* Means highlighted in bold text are significantly different at $P \leq 0.10$.

In addition to greater total runoff, the partitioning of runoff between hydrologic pathways was also different in 2019. While there was no difference in total runoff between surface runoff and tile drainage in 2018, the tiles generated significantly more runoff volume than surface runoff (Table 1; $P = 0.004$) in 2019.

The majority of surface runoff in 2018 (77%) occurred during a single snowmelt event in February 2018. Prior to March 28, 2018, there was no tile flow in any plot, indicating that the soil was likely frozen and preventing downward transport of runoff from the surface to the tiles (Figure 1). In contrast, the tiles flowed during runoff events throughout the winter of 2019, and this enhanced subsurface drainage resulted in minimal surface runoff, even during periods of substantial rain and snowmelt.

Additionally, the plots were fallow following corn harvest in 2017 prior to the alfalfa-grass seeding in May 2018. However, the alfalfa-grass mixture in 2019 provided cover throughout the nongrowing season, defined here as November through April, and the biomass may have inhibited the movement of surface runoff during periods of snowmelt. Absent fall tillage in 2019, preferential flow pathways also likely increased the rate of infiltration and downward percolation of drainage water relative to the fallow period in 2018.

The majority of runoff from both hydrologic pathways occurred during relatively short periods of time (Figure 1):

- the 54-hour snowmelt event in February 2018 generated 54% of the surface runoff over the two-year monitoring period.
- tile flows between March 28, 2018 and May 11, 2018 (42 d) and March 14, 2019 and June 11, 2019 (89 d), which represents 18% of the monitoring period, were responsible for 62% of all tile drainage.

These periods of elevated runoff are not due to greater rates of precipitation (Figure 1), but rather low rates of evapotranspiration due to limited crop growth and cold temperatures.

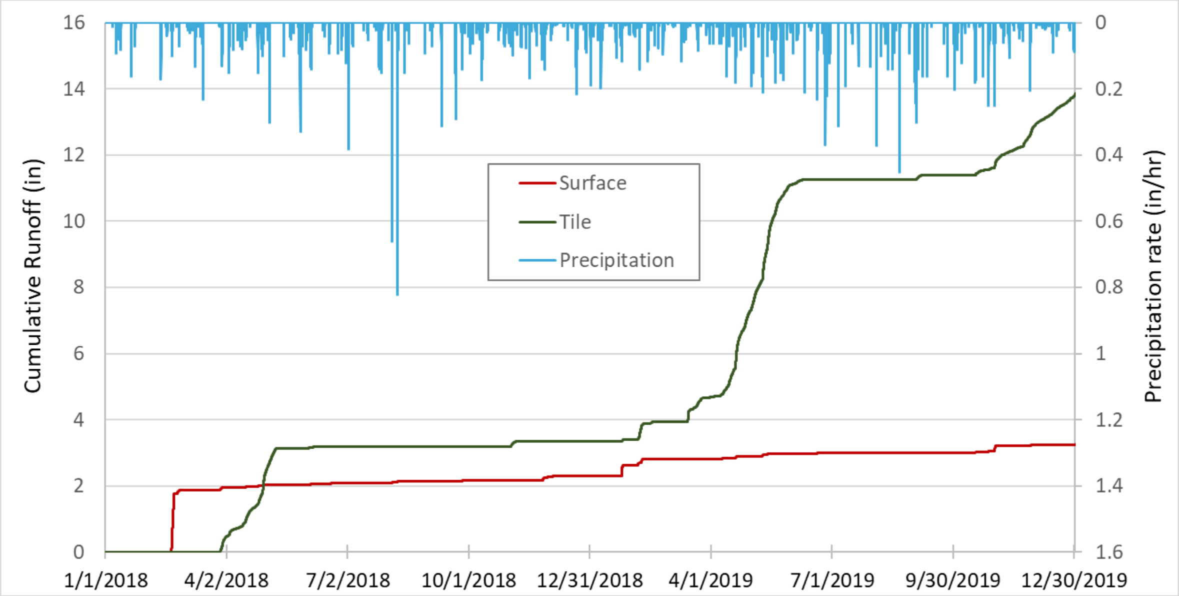

Figure 1. Precipitation and average cumulative surface runoff and tile drainage from January 1, 2018 to December 31, 2019, Quantifying Surface Runoff and Tile Drainage Flow Nutrient Losses in Edge-of-Field Plots, Year 2 Project, NNYADP.

Phosphorus Losses

A combined mean (surface + tile) of 0.20 lb/ac of TP was exported from the runoff plots (Table 1) in 2019. This was 62% less than in 2018, despite the plots generating approximately twice as much runoff. Only 0.08 lb/ac of SRP was lost in 2019, 85% less than was exported in 2018. The primary transport pathway of P differed between the two years, with tile drainage responsible for 80% of TP losses in 2019. This is not surprising given the low occurrence of surface runoff. However, the TP FWM concentrations (Table 2), which represent the annual average concentration, were significantly higher for surface runoff in both 2018 ($P = 0.05$) and 2019 ($P = 0.05$). Therefore, the reduction in surface runoff due to the enhanced subsurface drainage rates in the 2019 nongrowing season may have contributed to the reduction in overall TP losses.

The EPA recommends that drainage waters not exceeed 0.100 mg/L of TP to limit the risk of eutrophication in receiving surface waters. The TP FWM concentrations in 2018

Table 2. Mean nutrient and sediment flow-weighted mean concentrations from the runoff plots in 2018, 2019, and for the cumulative monitoring period, Quantifying Surface Runoff and Tile Drainage Flow Nutrient Losses in Edge-of-Field Plots, Year 2 Project, NNYADP.

Year	Pathway	SRP	Total P	TSS	Nitrate-N	Total N
		------------------------	mg/L	---------------------------		
2018	Surface	**0.587**	**0.780**	**22.53**	**1.89**	**5.74**
2018	Tile	**0.008**	**0.031**	**7.09**	**37.39**	**40.65**
2018	Total	0.284	0.386	11.69	24.84	29.14
2019	Surface	**0.063**	**0.182**	10.56	**0.67**	**2.02**
2019	Tile	**0.024**	**0.066**	35.01	**11.14**	**11.97**
2019	Total	0.028	0.075	10.88	10.86	11.78
Cumulative	Surface	**0.485**	**0.688**	21.08	**1.35**	**5.27**
Cumulative	Tile	**0.020**	**0.056**	8.78	**17.99**	**19.46**
Cumulative	Total	0.112	0.180	11.20	14.71	16.67

Means highlighted in bold text are significantly different at $P \leq 0.10$.

and 2019 were both below this guideline, at 0.031 mg/L and 0.066 mg/L, respectively. While only contributing a small amount of total drainage during the two-year monitoring period, surface runoff was consistently above this benchmark, with 0.780 mg/L and 0.182 mg/L in 2018 and 2019, respectively.

In addition to the differences in drainage characteristics between 2018 and 2019, there were additional differences that likely contributed to the reduction in exported TP in 2019. The majority of P losses in 2018 occurred during the fallow period between corn harvest in 2017 and the alfalfa-grass seeding in May 2018. There was also a late fall manure application in 2017. Bare soil and manure applications in the nongrowing season are both known to increase the risk of erosion and P losses as there are high rates of runoff and no growing crop to uptake and immobilize the nutrients in manure (King et al., 2015). There were no manure applications during 2018, continuous ground cover following stand establishment, and manure applications synchronized with crop uptake (following 1st and 2nd cuts) in 2019, all factors which decrease the risk of offsite P transport.

Nitrogen (N) Losses

Total N losses were driven by nitrate-N losses through tile drainage in both 2018 and 2019 (Table 1). Tile drainage contributed 90% and 98% of total N losses in 2018 and 2019, respectively, with an average of 92% of the TN in tile flow occurring as nitrate-N.

Despite the much higher drainage volume in 2019, there was slightly higher TN export in 2018 (34.82 lb/ac) than in 2019 (30.89 lb/ac). This is reflected in the substantially higher TN FWM concentration for tile drainage in 2018 (40.65 mg/L) versus 2019 (11.97 mg/L). As with the reduction in P losses, the combination of ground cover and manure management likely contributed to these reductions. With an established stand in the fall and early spring, crop uptake can draw down residual soil N that was mineralized during the growing season and prevent those nutrients from being lost during the nongrowing season. Applying manure in coordination with crop growth will also increase the likelihood of N being removed by the growing crop, thereby reducing the risk of loss in drainage.

Although the TN FWM concentrations were much lower in 2019, they were still at a level of concern and total exports remained elevated. These N losses represent a risk to water quality, as the tile drainage nitrate-N FWM concentrations were above the drinking water standard (10 mg/L) set by the EPA in both years. Reducing these losses also represents a financial opportunity as crop yields could be improved or commercial N inputs reduced if the N is retained in the soil for crop uptake. A second NNYADP-funded is more closely evaluating how tiling impacts economic factors.

These high rates of N loss are likely related in part to the soil characteristics of the plots. The plots consist of a combination of a coarse-textured soil (Colosse-Trout River complex) with high saturated hydraulic conductivity and a fine-textured, poorly drained soil (Adjidaumo). The coarse-textured soil is classified as excessively well-drained, and mineralization (conversion of organic N to ammonium) and nitrification (conversion of ammonium to nitrate) in these soils tend to occur more rapidly than in more poorly drained soils (Ketterings et al., 2001). With this rapid transformation of organic N to highly mobile forms of N, it is much more susceptible to leaching losses. When tile drainage is installed in soils such as these, there is a very high risk of nitrate-N loss as the tiles further enhance drainage and intercept subsurface water before plants have a chance to utilize the plant available N in the water. The upslope area of the plots that primarily consists of this coarse-textured soil likely contributed the majority of the N load and demonstrates one reason why it is not beneficial to install tile in naturally well-drained soils.

Conclusions:

The nongrowing season is often the period of the highest drainage rates and nutrient exports due to low rates of evapotranspiration. The majority of runoff and nutrient losses from both hydrologic pathways occurred between March and early June in both 2018 and 2019. Frozen subsoils had a substantial impact on the partitioning of runoff and may relate to subsequent N and P loading rates. Improved timing of manure applications to coincide wtih nutrient uptake by the crop and a continuous cover in the nongrowing season in the second year of monitoring contributed to substantially lower N and P losses despite much more total runoff.

Outreach:

Results were presented at the Miner Institute Dairy Day on December 11, 2019, and at the joint annual meeting of the Soil Science Society of America, Crop Science Society of America, and American Society of Agronomy in San Antonio, TX on November 11, 2019. Results were used to inform the revision of the New York Phosphorus Index (regional research funded by NNYADP) by Cornell University's Nutrient Management Spear Program.

Next Steps:

Edge-of-field monitoring studies typically benefit from multiple years of observation as variable weather conditions, as well as other factors, can generate a range of results. The below-average precipitation in the first year of monitoring (2018) resulted in fewer runoff events than have typically been observed at the research site; additional funding provided for 2020 will allow for continued monitoring at this site with the same experimental design. There is limited data in the northern NY and Northeast regions regarding the impacts of drainage on nutrient losses from perennial crop production and this long-term dataset will improve our understanding of the benefits and risk factors present in these systems.

Acknowledgments:

We would like to thank the Miner Institute Dairy Farm personnel for their help with this project. We would also like to thank the Northern New York Agricultural Development Program for funding this critical agricultural and conservation field research.

Reports and/or articles in which results of this project have been published:

A summary of the findings presented here will be published in a future issue of the Miner Institute *Farm Report*.

For More Information:

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