Northern New York Agricultural Development Program
2018 Project Report

Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York

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Background:

Tile drainage is an important practice in northern climates with short growing seasons where improved field trafficability can extend the growing season and minimize soil compaction by field equipment. With proper installation and nutrient management, phosphorus (P) concentrations in tile drainage water can be substantially lower than typically found in surface water runoff.

In addition to enhanced crop production and soil quality, tiling can reduce soil erosion and total P losses. Increased export of nitrogen (N) to surface waters can occur with tile drainage due to greater drainage water export and N mineralization rates compared to undrained soils. However, enhanced root growth from tiling results in greater crop yields and uptake of nutrients over time compared to undrained soils.

Tiling has received heightened scrutiny from some agencies due to the fact that some degree of nutrient export can occur in tile flows. However, few side-by-side comparisons of tile-drained and undrained fields have been performed in NNY to evaluate nutrient losses and crop yields under these different management approaches. Since some level of nutrient loss is inevitable with field crop production, benefits of tiling must be evaluated with respect to both farm economics and measured water quality impacts. There is a clear need for more long-term studies in NNY to better quantify the costs and benefits of tile drainage.

Methods:

An edge-of-field monitoring project was conducted on two adjacent fields in Keeseville, NY. The fields are similar in size (5.8 and 5.9 acres (ac)), composed of the same soil type (somewhat poorly drained silt loam; Tonawanda series), and have mild slopes to enable surface runoff monitoring at a corner of each field. The fields were graded to direct all surface flows from within the field to a corner of the field where monitoring equipment was installed. Interceptor ditches and berms around the perimeter of each field ensure that they are hydrologically isolated from adjacent areas. Tile drainage was installed in one of the fields in 2016 at 35 ft lateral spacing and an average 4 ft depth.

Both fields were equipped with flumes and flow-based sampling and monitoring equipment for measuring surface runoff. The tile-drained field (TD) was equipped with a tile pumping station and flow-based sampling and monitoring equipment. All sampling locations were equipped with power, enabling year-round monitoring.

Surface runoff and tile drainage were sampled for every 0.32 mm of runoff and composited into a 15 L plastic container. Composite samples were collected two times per week and analyzed for soluble reactive P (SRP), total P (TP), nitrate-N, ammonium-N, total N (TN) and total suspended solids (TSS). Nutrient and sediment loads from the tile-drained and undrained (UD) fields were estimated by multiplying sample concentrations by flow volumes for each event. Annual flow-weighted mean (FWM) concentrations were calculated at the field scale and for each hydrologic pathway (surface and subsurface) by dividing total nutrient and sediment loads by total flow. Correlation analysis was performed on individual event sample concentrations using the Spearman rank order-order correlation test.

The fields were left fallow following corn harvest in 2017. Liquid dairy manure was applied to the fields at a rate of 20 tons/ac on May 24, 2018, and incorporated the same day. Corn for silage was planted on May 26, 2018 with 8 gal/ac of 24-8-0 starter fertilizer. Corn was harvested on September 28, 2018.

Erosion during runoff events in early winter 2018 created channels around the surface runoff flumes in both fields and allowed water to exit the field without being measured or sampled. Once field conditions allowed, the front of the flume was excavated and a plywood board was attached to the front lip of the flume, extending from the top of the flume to a depth of 2 ft below the soil surface, and 4 ft past the edges of the flumes. A 12-ft-wide by 20-ft-long impermeable fabric was attached to the plywood at the soil surface in order to cover the soil in front of the flume. These modifications have prevented any further undercutting of the flume and stabilized the area where the surface water becomes concentrated and channelized prior to entering the flume. The site improvements were completed on March 27, 2018, and there were no further issues with data collection. The data reported here consist of runoff events that occurred between March 27, 2018, and January 3, 2018.

Results and Discussion:

Field Hydrology

Total runoff from TD (surface + tile) was 9% greater than the undrained plot (UD), (surface), with 6.65 inches (in) and 6.09 in of linear runoff from each field, respectively (Table 1).

In a review of the scientific literature, King et al., (2015), found that tile drainage typically increases total runoff by 10-25%. Our results are just outside this range and it is possible that the inability to monitor runoff throughout the winter months when significant runoff can occur could have impacted these results.

Table 1. Runoff, nutrient and sediment loads from the tiled (surface + tile) and untiled (surface only) fields. Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York, NNYADP, 2018.

	Runoff	SRP	Total P	Nitrate-N	Amm-N	Total N	TSS
	in	-------------------------------	-------------------------------	-------lb/ac-------	-------------------------------	-------------------------------	-------------------------------
Tiled Field	6.65	0.009	0.214	9.75	0.30	10.46	225.48
Untiled Field	6.09	0.007	0.217	2.33	0.26	3.55	273.80
Tiled - Surface	2.19	0.008	0.203	0.22	0.22	0.54	212.68
Tiled - Tile	4.46	0.001	0.011	9.53	0.08	9.93	12.80

Although total runoff was similar between fields, the primary runoff pathway was different. Tile drainage comprised 67% of the total runoff from TD (Table 1). The increased subsurface drainage capacity of TD resulted in 2.8-fold less surface runoff (2.19 in) than from UD (6.09 in).

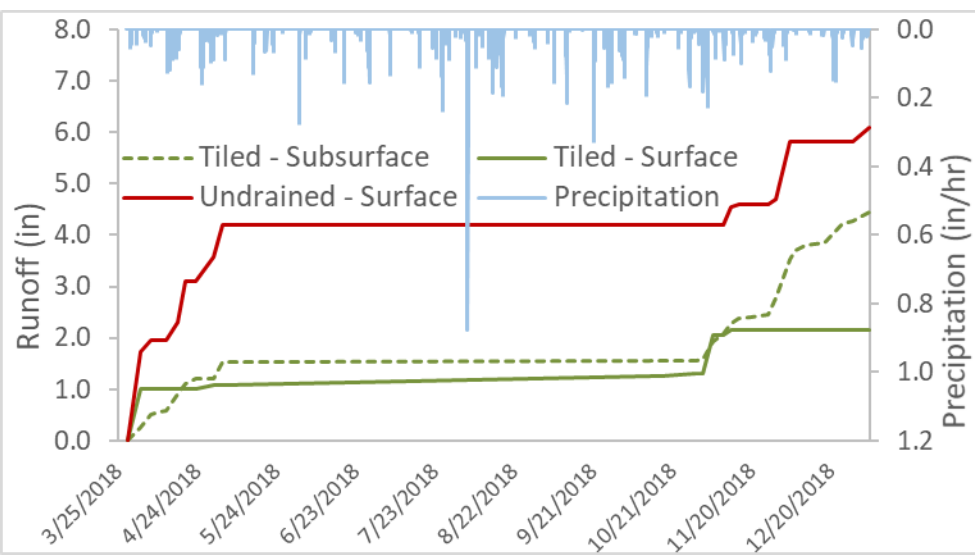

Figure 1. Cumulative runoff from the tiled and untiled fields. Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York, NNYADP, 2018.

There was a very uneven distribution of runoff between the growing (May 1 – Oct. 31) and nongrowing season (NGS, Nov. 1 – Apr. 30) in both fields (Figure 1). Runoff during the NGS was 91 and 90% of the total annual runoff for TD and UD, respectively. Both surface runoff and tile drainage from TD also predominately occurred during NGS (tile = 92%; surface = 89%).

Nongrowing season losses often represent a significant proportion of annual losses, but this year the proportion of NGS runoff was likely above average. Although this was the first year of monitoring at this site and, thus, comparisons with previous years is not possible, there were substantially fewer surface and subsurface runoff events during 2018 than have been observed in previous years at other Miner Institute edge-of-field monitoring sites. This was likely due to low soil moisture levels resulting from below-average precipitation and above-average temperatures during a majority of the growing season.

Phosphorus Export

Minimal levels of P were exported from both TD and UD (Table 2). The undrained field lost 0.007 lb/ac of SRP and 0.22 lb/ac of TP. Losses were very similar in TD, with 0.009 lb/ac of SRP and 0.21 lb/ac of TP lost in surface runoff. Despite contributing 67% of the total field runoff, the tiles were only responsible for 11.4 and 5.4% of SRP and TP losses, respectively from TD. The distribution of P losses followed the same pattern as runoff, with 90% of TP losses from both fields occurring during the NGS. These low rates of P loss are reflected in the flow-weighted mean (FWM) concentrations of SRP and TP (Table 2).

Table 2. Mean nutrient and sediment flow-weighted mean concentrations from each field and by runoff pathway in the tiled field. Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York, NNYADP, 2018.

	SRP	Total P	TSS	Nitrate-N	Amm-N	Total N
	-----------------------------------			mg/L		----------------------------------
Tiled Field	0.006	0.142	149.6	6.47	0.20	6.94
Untiled Field	0.005	0.157	198.3	1.69	0.19	2.57
Tiled - Surface	0.016	0.409	428.14	0.44	0.43	1.08
Tiled - Subsurface	0.001	0.011	12.67	9.43	0.08	9.82

Overall, SRP and TP concentrations from the individual runoff events in tile drainage were low (Figure 2). They were also consistently lower than concentrations in surface runoff. Only one sample from the tiles tested higher than 0.137 mg/L TP and 81% of the samples were less than 0.020 mg/L TP. Soluble reactive P concentrations in surface runoff were also consistently low, with only one sample with a concentration greater than 0.022 mg/L. Concentrations of TP in surface runoff were considerably higher than those in tile drainage, ranging from 0.025 mg/L to 0.814 mg/L TP. The EPA recommends that water draining to surface waters not exceed 0.1 mg/L TP and there were several instances where surface runoff exceeded that threshold.

The difference in TP loads and concentrations between surface runoff and tile drainage is likely due to differences in TSS export. Surface runoff typically has higher levels of sediment as the water moving across the surface carries soil particles that have been detached by the force of falling raindrops and the shearing action of water as it moves across the soil surface (Skaggs et al., 1994). This was evident in the differences in TSS exports between tile drainage and surface runoff exports from both fields (Table 1). Subsurface runoff only exported 12.8 lb/ac of TSS, much less than what was lost in surface runoff from TD (212.7 lb/ac) and UD (273.8 lb/ac).

There was a significant correlation ($\rho = 0.91$, $P < 0.0001$) between the concentrations of TP and TSS in the runoff, indicating that as TSS concentrations increased, TP concentrations increased as well.

The soil test P (STP) status of the field is 4.5 lb/ac (Modified Morgan extractant), falling into the medium range according to Cornell University guidelines.

Given the positive correlation between TSS and TP and that the STP status is on the lower end of where many dairy farm crop fields are managed, it is important to recognize that as the STP status of the fields increase, there is a strong probability that the TP exports from the field would increase as well. While TP losses from both fields were low, had the growing season not been atypically dry, the levels of TP export could have been greater in both fields.

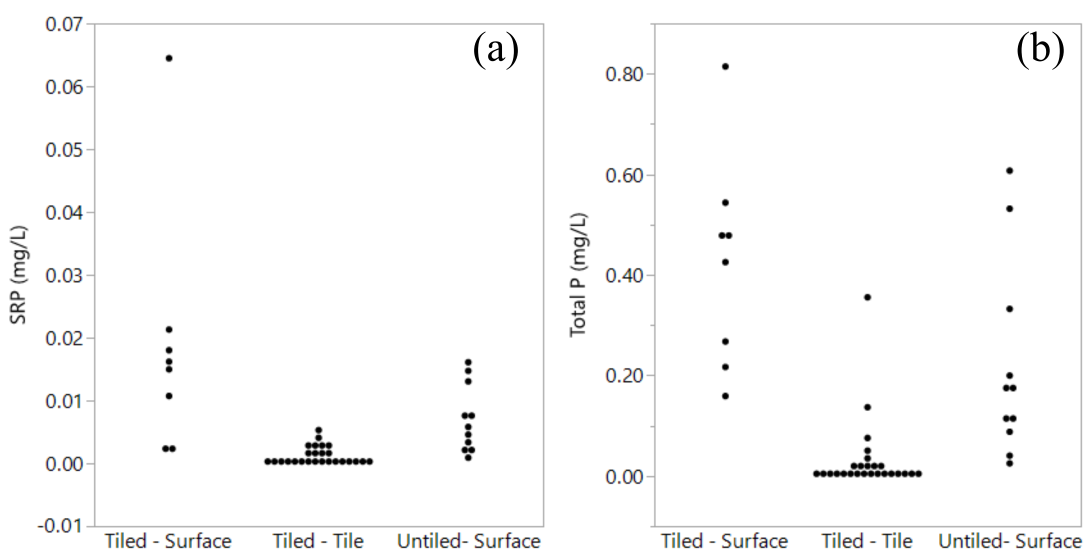

Figure 2. Each dot represents the concentration of (a) Soluble reactive P and (b) total P of composite samples from individual events for each runoff source. Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York, NNYADP, 2018.

Nitrogen Export

The tiled field exported 10.46 lb/ac of TN, nearly 3-fold greater than the amount exported by UD (3.55 lb/ac; Table 1). Tile drainage generated 95% of N exports from TD. Nitrate-

N was the dominant form of N lost from TD, constituting 93% of TN losses. This was not unexpected as research has consistently demonstrated that increasing subsurface drainage rates with tile drainage increases nitrate-N loss (*Gilliam et al., 1999*).

Nitrate-N was also the dominant form of N lost from UD (66%), although ammonium-N (7%) and organic N (27%) were present in the runoff in greater quantities than in tile drainage. The surface runoff from TD had a different proportion of N forms compared to that in UD, with 41% nitrate-N, 41% ammonium-N, and 18% organic N. The increase in ammonium-N and decrease in organic N relative to UD may be a result of TD having conditions more favorable (well-aerated) for organic N mineralization to occur.

The FWM concentrations of nitrate-N from all sources were below the EPA drinking water standard of 10 mg/L (Table 2). Tile drainage was close to this level at 9.43 mg/L but surface runoff in TD (0.44 mg/L) and UD (1.69 mg/L) was well below. The highest single event concentration was 11.9 mg/L and only three other events reached levels above 10 mg/L. However, these events were the four events with the highest rates of subsurface runoff and accounted for 40% of tile drainage during the monitoring period.

Nutrient Budgets

Corn yields were 30% greater from TD (8.6 tons dry matter/ac) than from UD (6.6 ton DM/ac; Table 3). This increased yield resulted in 10.9 lb P/ac and 48 lb N/ac greater crop removal by TD. However, both fields removed more P and N than was applied in manure and fertilizer.

The relatively large difference in corn yield is somewhat surprising, given that there was minimal precipitation during the growing season and TD seemed unlikely to gain much benefit from its increased drainage capacity. However, as previously discussed, the increased drainage rates in TD during the spring may have resulted in increased N mineralization rates and, therefore, more available N for crop growth. The fields also did not receive a sidedress N application and this may have amplified the benefits that corn in TD may have experienced from higher levels of available soil N.

Both TD and UD showed low rates of P loss as a percent of P applied (Table 3). The percentage of N lost in runoff was slightly higher, however, this is expected as N is water soluble and can be difficult to retain in the field. The rates of N loss were greater for TD as a result of the higher rate of export by the tile drains. However, as monitoring did not begin until March 27, these measurements of loss may be an underestimation of what would have been lost for the entire year, as the NGS typically has high rates of runoff.

Table 3. Total P and N inputs, corn yield, crop removal, and % P and N lost in runoff relative to nutrient applications. Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York, NNYADP, 2018.

Field	P inputs lb/ac	N inputs lb/ac	Corn yield tons DM/ac	P removal lb/ac	N removal lb/ac	P Loss %	N Loss %
TD	15.1	89.0	8.6	46.9	206.4	1.4	11.8
UD	15.1	89.0	6.6	36.0	158.4	1.4	4.0

Conclusions:

The results reported in this research summary indicate that tile drainage systems can have mixed effects on water quality. While there was no difference in P losses between the two fields, there were higher rates of surface runoff and sediment losses from UD, which could lead to higher rates of P loss in some situations. However, corn yields were substantially greater in TD and therefore had greater nutrient efficiency than UD.

Tile drainage substantially increased the transport of N and practices should be implemented that limit the loss of N in tile drainage in an effort to reach water quality goals and maximize farm profits. Practices such as cover cropping have shown promise in immobilizing soil N during the nongrowing season which can then be released to the soil in the spring for uptake by the following crop. With greater retention of N in the soil, the rate of commercial fertilizer applications can be reduced.

Outreach:

A summary of the findings presented here will be published in a future issue of the Miner Institute *Farm Report*. Results will be presented at the next Crop Congress at Miner Institute and on April 8, 2019 with the Vermont Agency of Agriculture, Food and Markets Tile Drainage Advisory Group. Results from this project are also being used to aid the revision of the New York Phosphorus Index by Cornell University's Nutrient Management Spear Program.

Next Steps:

Monitoring efforts were not possible for the majority of January through March. As the nongrowing season is a critical time for runoff and nutrient loss, this represents a significant gap in the data. The limited precipitation during the growing season also may have influenced results due to a much smaller number of runoff events than typically occurs on an annual basis. This project will continue in 2019 and additional data will aid in our understanding of the impacts of tile drainage on water quality.

Acknowledgments:

We would like to thank Adirondack Farms for the opportunity to establish a research site at these fields and for its ongoing cooperation in our monitoring efforts. We would also like to thank the Northern New York Agricultural Development Program for funding this research.

For More Information:

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