Northern New York Agricultural Development Program
2022 Project Report

Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York Corn Fields, Year 5

Project Leader:

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Background:

Tile drainage is an important practice on farms in northern climates with short growing seasons where improved field trafficability can extend the growing season, significantly increase crop yields, and minimize soil compaction by field equipment. The extended growing season and reduction in the duration of soil saturation can also provide greater flexibility in the timing of manure applications and an ability to adopt conservation practices such as cover cropping.

With proper installation and nutrient management, phosphorus (P) concentrations in tile drainage water are typically substantially lower than in surface water runoff. In addition to enhanced crop production and soil quality, tiling can reduce soil erosion and total P losses in fields that experience surface runoff. Increased export of nitrogen (N) to surface waters can occur with tile drainage due to enhanced drainage efficiency and N mineralization rates compared to undrained soils. However, a longer growing season and enhanced root growth from tiling poorly-drained soils generally results in greater crop yields and crop removal of nutrients over time compared to undrained soils.

Tiling has received heightened scrutiny from some agencies because some degree of nutrient export can occur in tile flows. However, few long-term, year-round, side-by-side comparisons of tile-drained and undrained fields have been performed in Northern New

York (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.

Methods:

Beginning in 2016, an edge-of-field monitoring project was established and conducted on two adjacent farm fields in Keeseville, NY. The fields are similar in size (5.8 and 5.9 acres), composed of the same soil type (somewhat poorly drained silt loam; Tonawanda series) and have mild slopes to direct surface runoff to monitoring stations at a corner of each field. Interceptor ditches and berms around the perimeter of each field ensure that each field is hydrologically isolated from adjacent land. Tile drainage was installed in one of the fields in 2016 at 35 ft. lateral spacing and an average 4 ft. depth. Surface runoff and tile drainage were sampled for every 0.67 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; an estimate of erosion).

Nutrient and sediment loads in runoff from the tile-drained (TD) and undrained (UD) fields were estimated by multiplying sample concentrations by flow volumes for each event. Flow-weighted mean concentrations (FWMC) were calculated for each drainage pathway by dividing the total mass lost from each pathway by the corresponding total volume. Field-scale FWMC were calculated for TD by adding together the exported loads from each pathway and dividing by the combined flow volume.

Corn planting, harvest, and nutrient application data are summarized in Table 1. Fertilizers are shown on an N-P-K basis. Manure and pre-plant fertilizer were applied on the same date and immediately incorporated with a disk harrow. Corn was harvested for silage and the fields were left fallow through the following spring. Manure was sampled at the time of application and analyzed for P and N content. Based on these results and commercial fertilizer application rates, annual nutrient inputs to each field were calculated. Nutrient removal rates for each field were calculated based on individual forage samples and dry matter yields.

The data reported here consist of runoff events between March 29, 2018, and January 3, 2021. Due to New York State business closures in response to the COVID-19 pandemic, samples were not collected during a 24-day period from March 29, 2020 to April 21, 2020. There were two stormflow events during this period which generated a combined 0.82 in of surface runoff from UD and 1.5 inches of tile drainage from TD (no surface runoff occurred at TD). These events were excluded from the data presented in this report as the corresponding nutrient and sediment loads could not be quantified or reliably estimated.

Additionally, in 2022, the tile outlet in the TD field was disconnected belowground from where it connected and drained into the monitoring structure from sometime in mid-February until field work could be undertaken to find and fix the issue on May 2, 2022. Therefore, tile drainage was occurring to some extent during this 2.5-month period, but with the drainage line ending belowground at the field's edge, the drainage efficiency was likely greatly reduced. Adjusted flow and loads for the surface runoff and tile drainage from the TD field were calculated based on the previous four years of monitoring data. The relative differences between flow volumes from the two fields, as well as the previously observed relationships between surface runoff and tile drainage during the late winter/early spring months were used to adjust the data. The adjusted flow values were then multiplied by the FWMC during this period from 2018-2021 to estimate the nutrient and sediment loads.

Table 1. Summary of field activities throughout project. Pre-plant and starter fertilizers are shown on a N-P-K basis. Sidedress nitrogen was a 32% solution of urea ammonium nitrate (UAN); Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP. 2018-2022.

Year	Plant Date	Manure Application Date	Manure Rate (gal/acre)	Pre-Plant Fertilizer (8-20-30)	Starter Fertilizer (24-8-0 unless specified)	Sidedress Nitrogen (32% UAN)	Harvest Date
2018	May 26	May 24	4,500	NA	8 gal/ac	NA	Sept. 28
2019	June 25	June 24	4,500	200 lb/ac	12 gal/ac	10 gal/ac	Nov. 25
2020	May 26	May 18	4,500	100 lb/ac	10 gal/ac	NA	Oct. 7
2021	May 31	May 29	6,000	100 lb/ac	10 gal/ac	30 gal/ac	Oct. 6
2022	May 27	May 26	4,800	NA	8 gal/ac (32% UAN)	30 gal/ac	Oct. 11

Results and Discussion:

Field Hydrology

Adjusted flow volumes were calculated for the period of tile drainage interruption in late winter 2022. The actual observed flow in TD during this period was 2.01 inches of tile drainage and 4.02 inches of surface runoff. These values were adjusted to 5.00 inches and 3.48 inches of tile drainage and surface runoff, respectively. These adjustments resulted in runoff data much more similar to observations in previous years from these fields.

Over the course of the five-year monitoring period, the mean annual runoff from TD (surface + tile) was 44% greater than UD (surface), averaging 8.38 in/yr and 5.80 in/yr of total runoff from each field, respectively (Figure 1; Table 2). However, there was substantial variation between years, ranging from nearly identical runoff volume production from the two fields in 2018, to 2.4 times more runoff from TD than UD in 2021. The quantity of surface runoff generated by the two fields also varied among years, ranging from a minimum of 4.43 in/yr in 2021 to a maximum of 7.30 inches in 2019 for UD. A similar pattern was observed in TD, with a minimum of 2.16 inches of surface runoff produced in 2018 and a maximum of 4.25 inches in 2019. Tile drainage also exhibited substantial variability, ranging from 3.76 inches generated in 2019 to 7.60 inches in 2021.

Surface runoff remained an active pathway in TD, generating 37% of the total field drainage and even exceeding the tile drainage volume in 2019. However, over the study duration from 2018-2022, TD generated 46% less surface runoff than UD.

The average annual precipitation during the study was 31.3 inches, the same total as was observed in 2022. The strong similarity in the cumulative runoff data and the adjusted 2022 runoff data (Figure 1), due in part to the estimation methods used, those calculations were only implemented for the 2.5-month period of equipment failure in TD. Rather, the similarity is likely due to the precipitation patterns reflecting the average conditions over the study, which was then reflected in the drainage from both fields. The average rate of precipitation recovered in drainage was 27% for TD and 19% for UD.

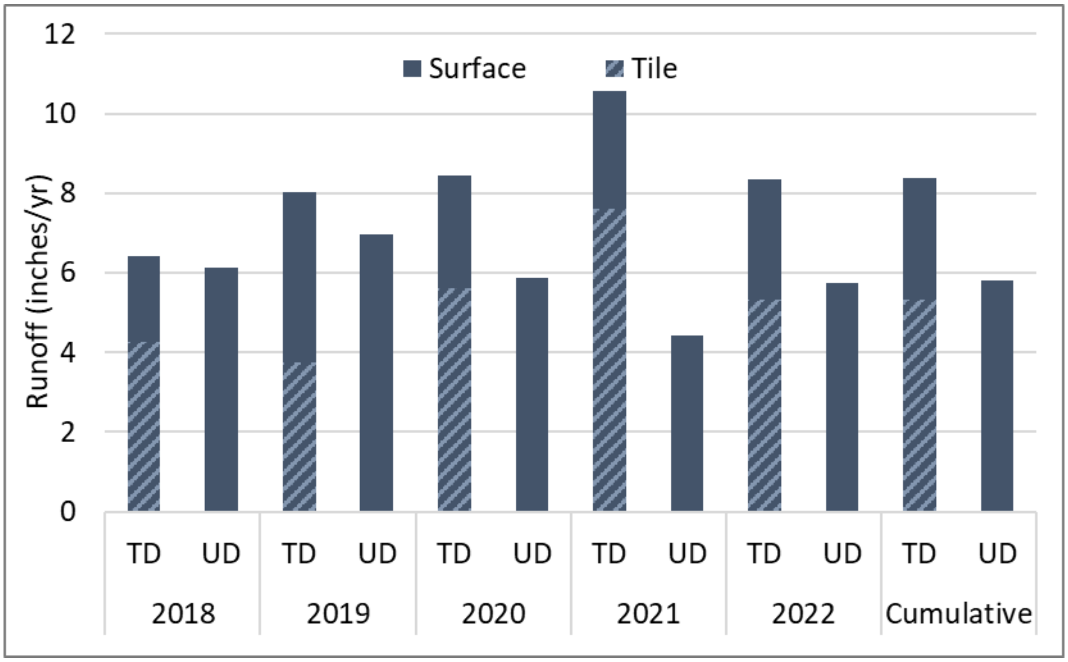

Figure 1. Annual drainage from TD (surface and tile) and UD (surface only) during each annual monitoring period and the annual mean across the 5-year monitoring period; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.

Phosphorus Export

Despite the substantially higher rates of total field drainage from TD, the field exported 28% less total P (0.21 lb/acre/yr) than UD (0.27 lb/acre/yr) throughout the study (Table 2). The 2020 monitoring period was the only year in which total P exports from TD exceeded those from UD, but this was also the year of the lowest losses from both fields. Despite being the primary hydrologic pathway in TD, tile drainage contributed just 19% of the cumulative total P losses from TD. This was also true for SRP, for which the tiles contributed 28% of the field load across all study years. Although TD exported more SRP than UD, with SRP representing approximately 10% of the total P load for both fields, the losses were very low from both fields (Table 2).

Table 2. Mean annual runoff, nutrient and sediment loads from the tiled (surface + tile) and untiled (surface only) fields, March 29, 2018-December 31, 2022: Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP, 2018-2022.

	Runoff in/yr	SRP	Total P	Nitrate-N	Amm-N	Total N	TSS
		---------------------------lb/acre/yr---------------------------					
Tiled Field	8.38	0.024	0.211	14.03	0.26	15.34	147.1
Untiled Field	5.80	0.019	0.270	2.24	0.22	4.23	137.1
Tiled – Surface runoff	3.13	0.017	0.170	1.03	0.21	1.78	126.2
Tiled – Tile drainage	5.25	0.007	0.041	13.00	0.06	13.55	21.0

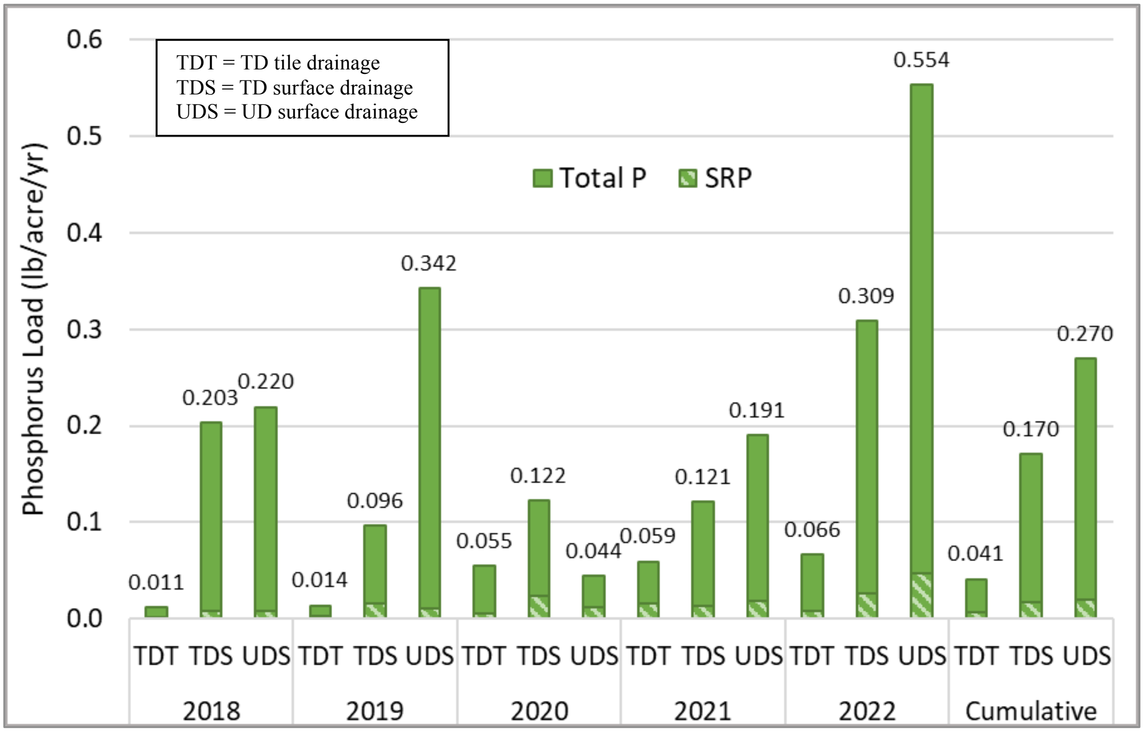

Figure 2. Annual SRP and total P loads in surface runoff and tile drainage from TD and UD during each annual monitoring period and the annual mean across the 5-yr monitoring period; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP, 2018-2022.

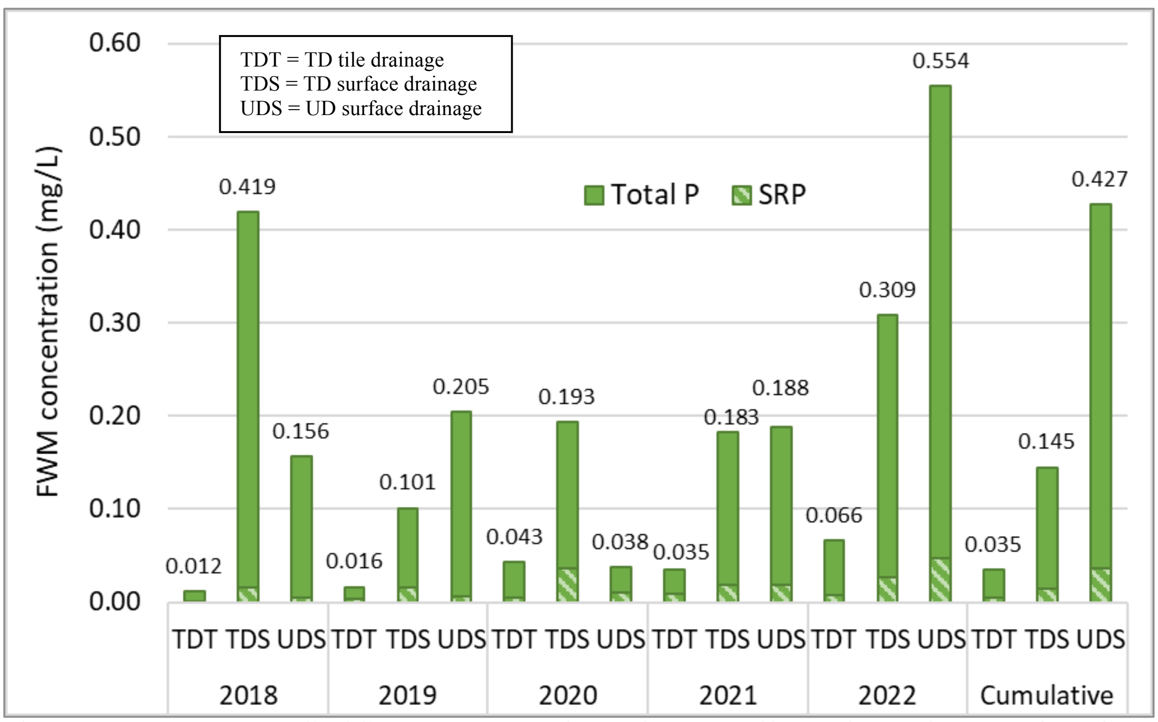

Figure 3. Annual FWMC of SRP and total P in surface runoff and tile drainage (lb/acre/yr) from TD and UD during each annual monitoring period and the cumulative FWMC across the 5-yr monitoring period; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP, 2018-2022.

The reduced risk for both SRP and total P loss from the tiles despite higher flow rates is demonstrated by the FWMC, which represents the average drainage water quality for a given time period. Figure 3 depicts the FWMC of SRP and total P for each annual monitoring period as well as the cumulative 5-yr dataset. The tendency for higher concentrations of total P and SRP in surface runoff compared to tile drainage during runoff events are evident in these FWMC. The cumulative SRP and total P FWMC in the tile drainage in TD were 0.006 mg/L and 0.035 mg/L, respectively. In contrast, the cumulative surface runoff FWMC from UD and TD ranged from 0.015 mg/L (TD) to 0.036 mg/L (UD) for SRP and 0.145 mg/L (TD) to 0.430 mg/L (UD) for total P.

Nitrogen Export

In contrast to what was observed with P loading, the increased subsurface drainage in TD resulted in substantially greater loads of nitrate-N and total N relative to UD (Table 2). Annualized nitrate-N and total N loads from TD over the 5-year monitoring period were 14.0 lb/ac/yr and 15.3 lb/ac/yr, respectively, as compared to 2.2 lb nitrate-N/ac/yr and 4.21 lb total N/ac/yr from UD (Figure 4). Tile drainage produced 93% of nitrate-N and 86% of total N losses from TD.

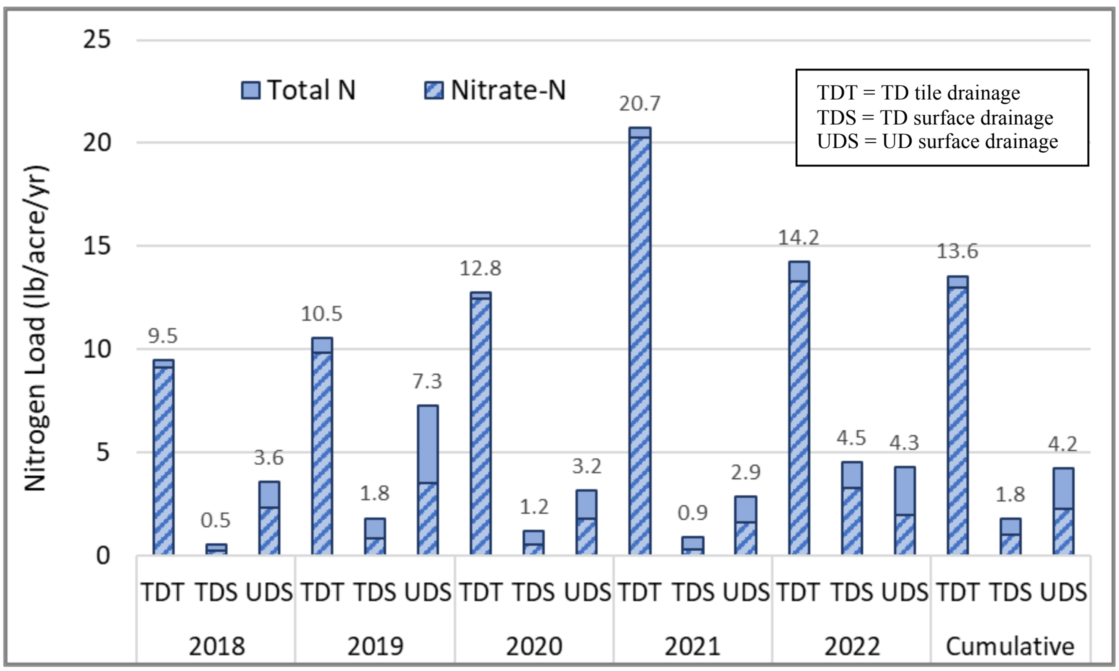

Figure 4. Annual nitrate-N and total N loads in surface runoff and tile drainage from TD and UD during each annual monitoring period and the annual mean across the 5-yr monitoring period; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP. 2018-2022.

The annual FWMC of nitrate-N and total N depicted in Figure 5 demonstrates the importance of tile drainage in generating N losses. The tile drainage FWMC of total N is consistently 3-4 times greater than was observed in surface runoff from either field. Additionally, nitrate-N comprised 92% of the total N load and when combined with the high flow rates from the tiles, the loss of this highly mobile and biologically available form of N has both financial and environmental consequences.

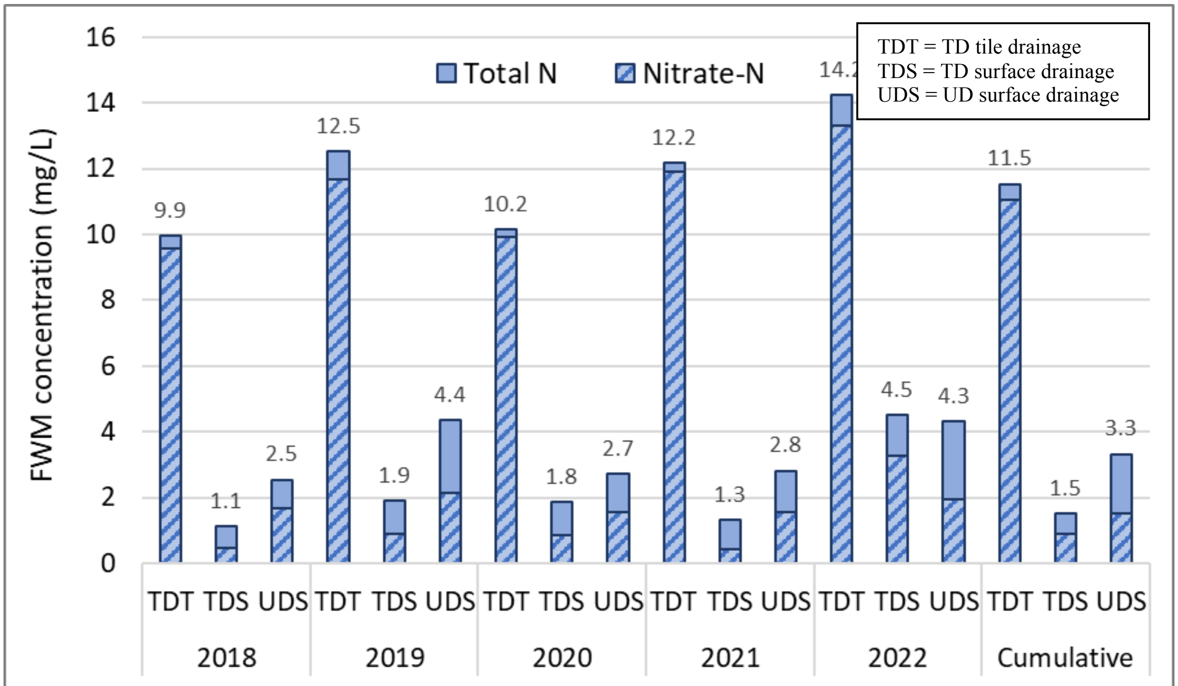

Figure 5. Annual FWMC of nitrate-N and total N in surface runoff and tile drainage from TD and UD during each annual monitoring period and the cumulative FWMC across the 5-yr monitoring period; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP, 2018-2022.

Nutrient Budgets

Excluding 2021 when an equipment error prevented the collection of yield data in TD, TD averaged 7.0 tons dry matter (DM)/acre compared to 6.5 tons DM/acre in UD. Although we cannot definitively ascribe this to the presence of tile drainage, the only year in which UD outperformed TD was in 2019 when unusually dry conditions existed throughout the growing season and the tiles were unlikely to impart any benefits. This also resulted in slightly more efficient use of P and N in TD than in UD (Table 3). Overall, only 0.9% and 1.1% of total P and 8.9% and 2.4% of total N applied was lost in drainage from TD and UD, respectively.

Table 3. Nutrient inputs/uptake, dry matter (DM) yield, and percentage of P and N lost in runoff versus nutrient applications for TD and UD; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP, 2018-2022.

Year	Field	Total P inputs lb/acre	Total N inputs lb/acre	Corn Yield DM ton /acre	P uptake lb/acre	N uptake lb/acre	P Loss %	N Loss %
2018	TD	16.1	89.0	8.6	34.3	206.0	1.3	11.3
2018	UD	16.1	89.0	6.6	26.4	158.5	1.4	4.0
2019	TD	26.4	183.5	4.0	14.5	103.1	0.2	6.2
2019	UD	26.4	183.5	4.9	18.7	126.1	0.3	2.6
2020	TD	36.4	129.2	9.7	38.8	232.9	0.5	10.8
2020	UD	36.4	129.2	9.1	38.2	174.7	0.2	3.0
2021	TD	29.1	233.7	-	-	-	0.6	9.2
2021	UD	29.1	233.7	7.2	24.6	152.7	0.7	1.8
2022	TD	11.4	229.3	5.8	20.3	140.3	3.3	8.2
2022	UD	11.4	229.3	5.3	18.7	126.3	4.9	1.9

Conclusions:

Tile drainage continues to demonstrate mixed water quality impacts. The reductions in total P losses are promising and can have important implications for the P reduction efforts ongoing in the Lake Champlain Basin. However, the improved P retention comes at the cost of an increased risk for N mobilization. Additional practices that can mitigate this increased risk should be implemented in tandem with systematic tile drainage. Research has demonstrated that practices such as drainage water management and cover cropping can be effective in preventing the downward movement of nitrate out of the root zone.

Outreach:

Results from this project were presented at the Miner Institute Dairy Day in December 2022, and will be presented at the 2023 joint meeting of the Soil Science Society of America, Crop Science Society of America, and American Society of Agronomy.

Next Steps:

A NNYADP grant was received to begin a new phase in the project in 2023. The presently untiled field will be equipped with identical systematic drainage with the paired tiled field and monitoring equipment will be installed to monitor the tile drainage. The fields will otherwise be managed in the same manner as in 2018-2022. Data collected post-installation will be compared to the current dataset which will allow for a more scientifically robust assessment of the impacts of tile drainage on field hydrology and nutrient losses.

Acknowledgments:

We thank Adirondack Farms for the opportunity to establish a research site at these fields and its ongoing collaboration and assistance with the project. We also thank the Northern New York Agricultural Development Program for funding this research.

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

A summary of this report will be published in a 2023 issue of the Miner Institute *Farm Report*.

For More Information:

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