**Northern New York Agricultural Development Program**
**2021 Project Report**

# Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York Corn Fields, Year 4

## Project Leader:


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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, 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.

Both fields were equipped with pre-calibrated H-flumes and flow-based sampling and monitoring equipment for measuring surface runoff. The tile-drained field was equipped with a tile pumping station and flow-based sampling and monitoring equipment. All sampling locations are connected to the power grid, enabling year-round monitoring. 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 (FWM) concentrations over the three-year monitoring period were calculated at the field scale (TD = surface + tile; UD = surface) by dividing the total mass of nutrient and sediment lost by the total runoff. Individual runoff pathway FWM concentrations were calculated for TD by dividing the total mass lost from each pathway by the corresponding total 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. The analysis within this report primarily focuses on average annual runoff and nutrient losses that have been observed over the nearly four-year monitoring period, thus reducing the impacts of missing individual events.

**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.**

| Year | Plant Date | Manure Application Date | Manure Rate (gal/acre) | Pre-Plant Fertilizer (8-20-30) | Starter Fertilizer (24-8-0) | 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 |

## Results and Discussion:

### Field Hydrology

Over the course of the four-year monitoring period, the mean annual runoff from TD (surface + tile) was 46% greater than UD (surface), with 8.36 in/yr and 5.73 in/yr of linear runoff from each field, respectively (Figure 1). However, there was substantial variation between years, ranging from nearly identical runoff volume production in 2018 to 139% 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 produced in 2018 and 4.25 inches in 2019. Tile drainage also exhibited substantial inter-annual variability, ranging from 3.76 inches generated in 2019 to 7.60 inches in 2021.

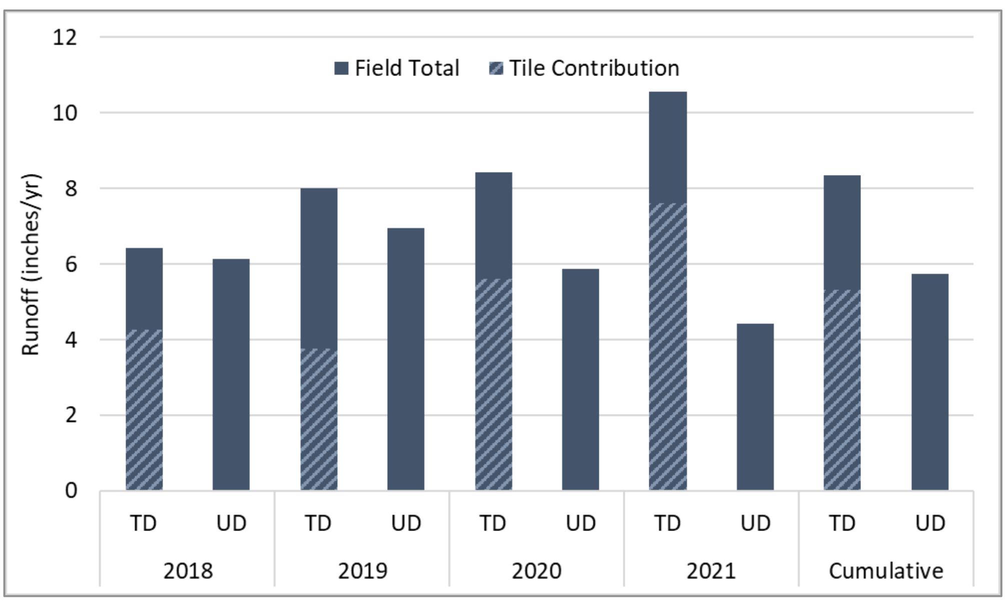


**Figure 1. Annual drainage (in/yr) from TD (surface and tile) and UD (surface only) during each annual monitoring period and the annual mean across all years, March 29, 2018-December 31, 2020; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

The installation of tile drainage not only increases total field drainage, but also changes the primary runoff pathway from surface to subsurface drainage. Surface runoff is often substantially reduced following tile drainage installation due to the increased rate of subsurface drainage, often occurring only when rainfall or snowmelt exceeds the soil infiltration rate or when frozen soil prevents the downward movement of surface water (Skaggs et al., 1994). Surface runoff remained an active pathway in TD, generating 36% of the total field drainage and even exceeding the tile drainage volume in 2019. However, from 2018-2021, TD generated 47% less surface runoff than UD.

This reduction in surface runoff from TD is also illustrated in Figure 2, which plots the cumulative runoff from each hydrologic pathway and the cumulative precipitation from 2021. The 2021 monitoring period was selected from the larger dataset for clarity of the visual, but a very similar pattern is seen across all study years. Each point on the runoff curves represents an event and the difference in the y-axis values between the two points is the amount of runoff that accumulated during a given event. During large runoff events, the cumulative surface runoff from both TD and UD typically increases, but the surface runoff from UD accumulates at approximately two times the rate of that from TD. However, the difference in drainage between TD and UD is typically largely eliminated when the tile drainage flows are incorporated into the total event flow volumes. Although annual drainage is greater from TD, this is largely due to the tiles intercepting and draining shallow groundwater before and/or after precipitation/snowmelt events, rather than large differences within runoff events.

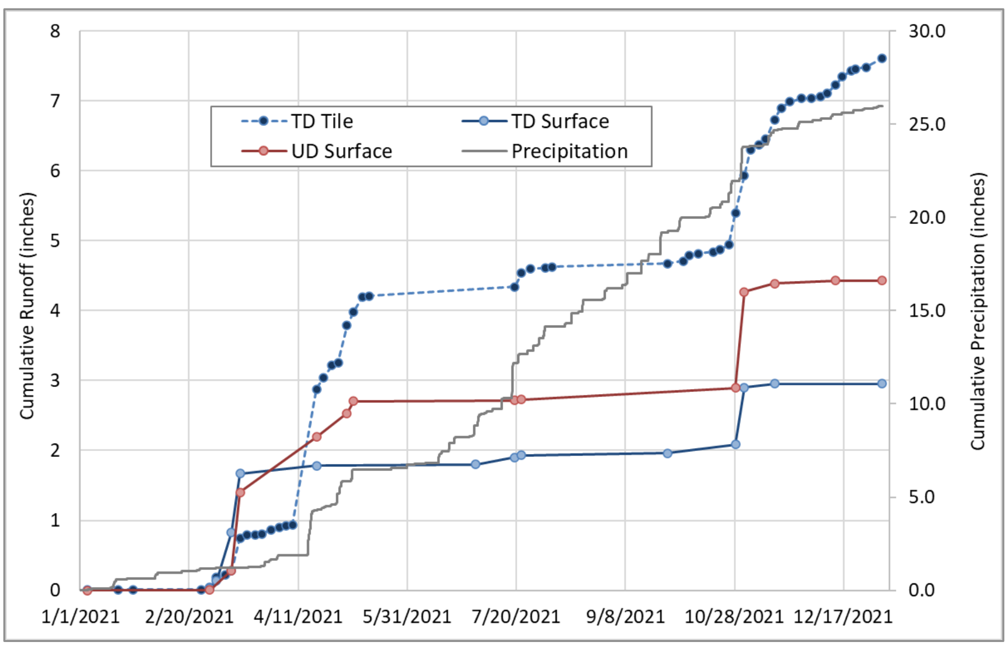


**Figure 2. Cumulative runoff (inches) and precipitation throughout the 2021 monitoring period from each hydrologic pathway; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

Throughout the study, the non-growing season (NGS; October 16–April 15) was consistently the dominant period of runoff from both fields. Despite 57% of the total precipitation occurring during the growing seasons, 81% and 85% of field drainage occurred during the NGS in UD and TD, respectively. In TD, 92% of surface runoff and 81% of tile flows occurred during the NGS. Limited evapotranspiration due to cold temperatures and a lack of crop uptake, snowmelt events, and periods of frozen soil with limited subsurface drainage capacity provide highly favorable conditions for the generation of large runoff events, even in the absence of substantial rainfall. As illustrated in Figure 2, there is minimal runoff accumulation from early May through the end of October (lines remain relatively flat), despite a consistent increase in cumulative precipitation. However, outside the growing season, a relatively small amount of precipitation can result in substantial runoff generation due to the lack of soil water storage capacity.

**Phosphorus Export**

Despite the substantially higher rates of total field drainage from TD, the field exported 14% less total P (0.17 lb/acre/yr) than UD (0.20 lb/acre/yr) (Table 2). As seen in Figure 3, the only year in which total P exports from TD exceeded those from UD was in 2020 when tile flows generated above average total P losses and the TD surface runoff generated substantially more total P than was observed in UD. Across all four years, despite being the dominant hydrologic pathway, tile drainage contributed just 20% of the cumulative total P losses from TD. This was also true for SRP, for which the tiles contributed 30% of the field load across all study years. Although TD generated 75% more SRP losses than UD, with SRP representing only 6-12% of the total P load for both fields, the losses remain very low from both fields. Interestingly, the majority of the SRP load from TD came from surface runoff, rather than tile drainage.

**Table 2. Mean annual runoff, nutrient and sediment loads from the tiled (surface + tile) and untiled (surface only) fields, March 29, 2018-December 31, 2020: Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

| | Runoff<br>in/yr | SRP | Total P | Nitrate-N | Amm-N | Total N | TSS |
|---|---|---|---|---|---|---|---|
| | | ---------------------------- | lb/acre/yr | ---------------------------- | | | |
| Tiled Field | 8.36 | 0.021 | 0.170 | 13.40 | 0.25 | 14.48 | 117.3 |
| Untiled Field | 5.73 | 0.012 | 0.199 | 2.31 | 0.23 | 4.21 | 106.3 |
| Tiled – Surface runoff | 3.05 | 0.015 | 0.136 | 0.48 | 0.20 | 1.10 | 96.7 |
| Tiled – Tile drainage | 5.31 | 0.006 | 0.035 | 12.92 | 0.05 | 13.38 | 20.6 |

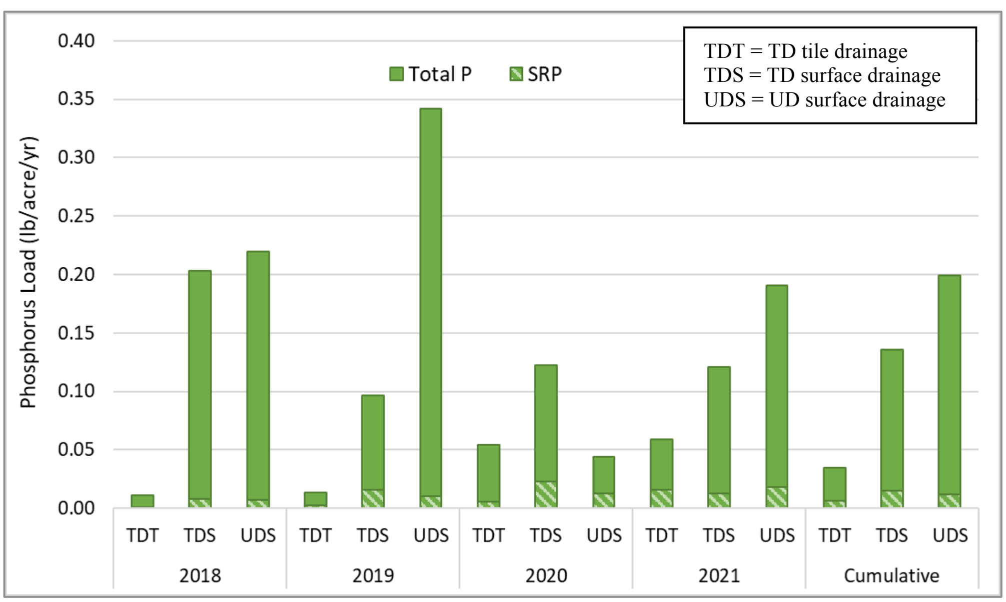


**Figure 3. Annual SRP and total P loads in surface runoff and tile drainage (in/yr) from TD and UD during each annual monitoring period and the annual mean across the 4-yr monitoring period, March 29, 2018-December 31, 2020; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

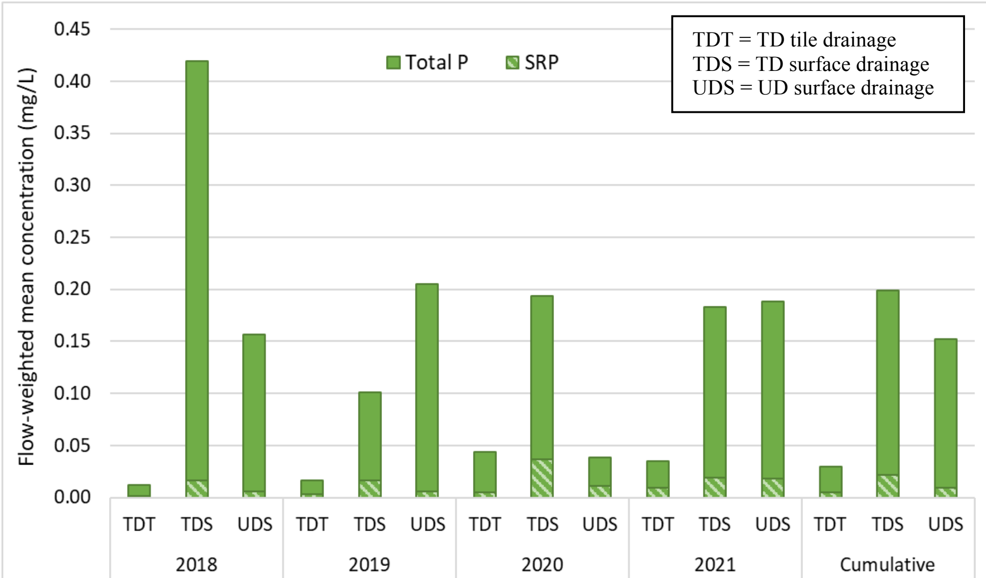


**Figure 4. Annual FWMC of SRP and total P in surface runoff and tile drainage (lb/acre/yr) from TD and UD during each annual monitoring period and the cumulative FWMC across the 4-yr monitoring period, March 29, 2018-December 31, 2020; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

The reduced risk for both SRP and total P loss from the tiles despite higher flow rates is demonstrated by the flow-weighted mean concentrations (FWMC), which represent the average drainage water quality for a given time period. Figure 4 depicts the FWMC of SRP and total P for each annual monitoring period as well as the complete 4-yr dataset. The higher concentrations of total P and SRP in surface runoff compared to tile drainage during individual runoff events are evident in these FWM concentrations. The cumulative SRP and total P FWMC in the tile drainage in TD were 0.005 mg/L and 0.029 mg/L, respectively. In contrast, the cumulative surface runoff FWMC from UD and TD ranged from 0.009 mg/L to 0.022 mg/L for SRP and 0.152 mg/L to 0.199 mg/L for total P.

As with runoff, the vast majority of SRP and total P losses occurred during the NGS. For TD, the NGS runoff (85% of the annual total) produced 80% and 87% of the SRP and total P losses, respectively. Similarly, 81% of the annual runoff from UD occurred during the NGS and contained 83% and 70% of the SRP and total P losses, respectively.

**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 4-yr monitoring period were 13.40 lb/ac/yr and 14.48 lb/ac/yr, respectively, as compared to 2.31 lb nitrate-N/ac/yr and 4.21 lb total N/ac/yr from UD. Tile drainage produced 96% of nitrate-N and 92% of total N losses from TD. These results are consistent with previous drainage research, in which increased subsurface drainage via tile systems has consistently resulted in greater nitrate loss (Gilliam et al., 1999). Additionally, 83-86% of the nitrate-N and total N loads from both fields occurred during the NGS, further demonstrating the importance of understanding NGS hydrology and nutrient loss mechanisms during this period.

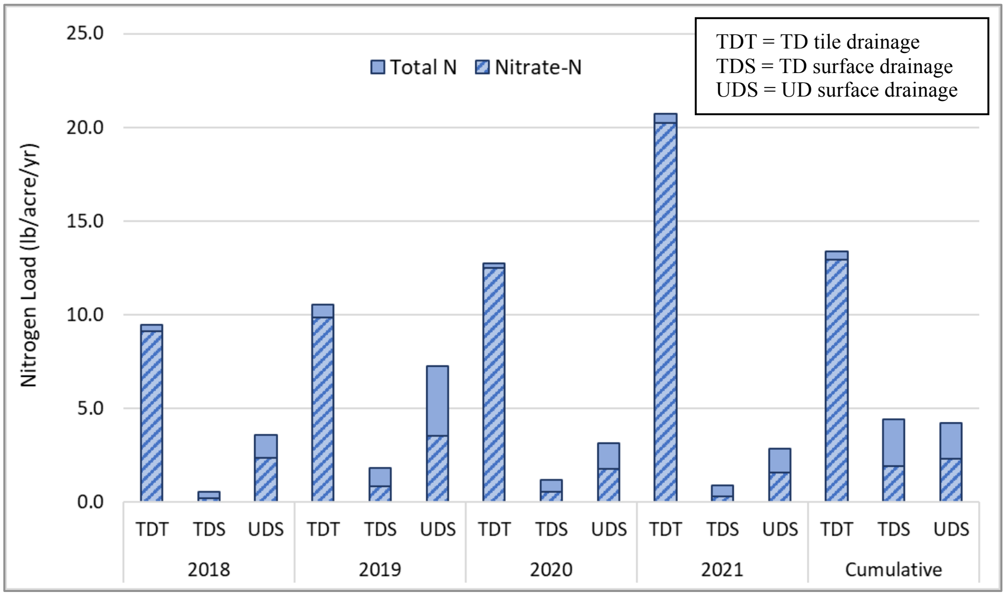


**Figure 5. Annual nitrate-N and total N loads in surface runoff and tile drainage (in/yr) from TD and UD during each annual monitoring period and the annual mean across the 4-yr monitoring period, March 29, 2018-December 31, 2020; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

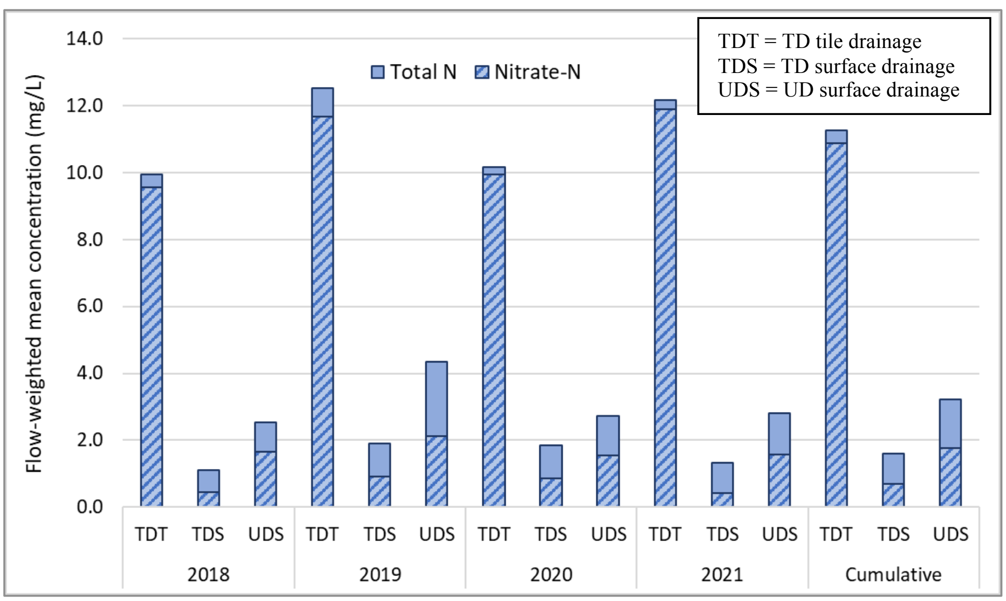


**Figure 6. Annual FWMC of nitrate-N and total N in surface runoff and tile drainage (lb/acre/yr) from TD and UD during each annual monitoring period and the cumulative FWMC across the 4-yr monitoring period, March 29, 2018-December 31, 2020; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

The annual FWMC of nitrate-N and total N depicted in Figure 6 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 comprises 97% of the total N load and the loss of this highly mobile and biologically available form of N represents an economic loss to the farmer as well as an environmental risk.

Elevated loads and concentrations of nitrate-N and total N were observed during 2021 relative to the previous three years. This is likely due to a combination of factors. First, the field received a higher rate of total N and plant available N in 2021 than in any of the previous years, providing a larger pool of N to be at risk of transport by runoff. Second, the abnormally dry conditions in fall 2020 and throughout much of 2021 can provide a favorable environment for the bacterial populations that are responsible for converting organic (plant unavailable) N into ammonium and nitrate. When these dry conditions are followed by a large flush of water as happened with snowmelt and runoff events in March and April 2021, the newly mineralized N is highly mobile and susceptible to loss with the subsurface drainage water. Although the fields received N applications in accordance with nutrient management recommendations based on their expected yield, the combination of favorable conditions for N mineralization and a slight yield drag may have resulted in excess nitrate in the soil following corn harvest.

**Nutrient Budgets**

Due to equipment failure in the yield monitoring technology, 2021 corn yield data could only be obtained for the UD trial. Therefore, comparisons of crop nutrient removal and nutrient use efficiencies between the two fields is not possible for the 2021 monitoring period (please see the 2020 final report at www.nnyagdev.org for a discussion of this data during the first 3 years of monitoring). The nutrient inputs, crop yield and nutrient removal rates, and percentage of applied total P and total N lost in runoff are summarized in Table 4. Note that the N inputs are based on total N in the manure, not predicted plant available N, as the organic fraction will become available in subsequent years. The low rates of P loss are reflected in the very small fraction of applied P that is recovered in runoff, less than 1% in all years except 2018. As would be expected given the mobile nature of inorganic N, the rates of N loss are slightly higher in UD and range between 6 and 11% for TD and between 1.8-2% for UD.

**Table 4. Total P and N inputs, corn yield, crop uptake, and percentage of P and N lost in runoff relative to nutrient applications for TD and UD in 2018 and 2019; Quantifying Long-Term Agronomic and Water Quality Impacts of Tile Drainage in Northern New York; NNYADP.**

| 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 | 17.7 | 103.1 | 0.2 | 6.2 |
| 2019 | UD | 26.4 | 183.5 | 4.9 | 25.6 | 126.1 | 0.3 | 2.6 |
| 2020 | TD | 36.4 | 129.2 | 9.7 | 42.7 | 232.9 | 0.5 | 10.8 |
| 2020 | UD | 36.4 | 129.2 | 9.1 | 47.3 | 174.7 | 0.2 | 3.0 |
| 2021 | TD | 29.1 | 233.7 | - | - | - | 0.6 | 9.2 |
| 2021 | UD | 29.1 | 233.7 | 7.2 | 37.6 | 152.7 | 0.7 | 1.8 |

## Conclusions:

Tile drainage continues to demonstrate mixed water quality impacts. The reductions in exported P and sediment 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 and future research is needed to identify practices, or more likely suites of practices, that can improve these water quality parameters simultaneously. Given the dominance of the NGS with regard to runoff generation and nutrient losses, practices that address this time period are necessary to curbing losses and improving water quality and farm profitability.

## Outreach:

Results from this project will be presented at the 2022 virtual joint annual meeting of the Soil Science Society of America, Crop Science Society of America, and American Society of Agronomy and the Miner Institute/Cornell Cooperative Extension Crop Congress.

## Next Steps:

Monitoring efforts at the trial fields will continue through 2022. Long-term data collection is crucial when evaluating the impacts of management practices on nutrient budgets and water quality as results can vary significantly with changing weather patterns and infrequent, extreme events. Continued monitoring of these sites will enhance our understanding of the impacts of tile drainage on water quality and farm economics and provide insight for the development and refinement of such conservation and production management tools as the statewide New York Phosphorus Index. After the 2022 monitoring period, the implementation of additional conservation practices to enhance nutrient mitigation at this site will be considered following discussion with the cooperating farmer and the gathering of input from crop and nutrient management professionals.

## Acknowledgments:

We thank Adirondack Farms for the opportunity to establish a research site at these fields and its ongoing cooperation in our monitoring efforts. We would also like to 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 the findings presented here will be published in a future issue of the Miner Institute Farm Report. After the final year under the current experimental design (2022), the 5-yr dataset will be summarized and submitted for publication in a peer-reviewed journal.

## For More Information:

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