ONFARM

Water Quality Technical Report 2024-2025

March 31, 2025

Acknowledgements

The On-Farm Applied Research and Monitoring (ONFARM) program is a nine-year, applied research initiative delivered by the Ontario Soil and Crop Improvement Association (OSCIA) on behalf of the Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA) to support soil health and water quality research across farms in Ontario. This program is currently funded by the Sustainable Canadian Agricultural Partnership, a five-year federal-provincial-territorial initiative. OSCIA would like to acknowledge the support of several organizations and members of the agricultural community for their contributions to the program:

- Soil health data is collected, compiled, and analyzed by The Soil Resource Group (SRG) located in Guelph, Ontario. SRG plays an instrumental role working directly with ONFARM cooperators to organize and execute the soil health trials, and collect soil health data for the edge-of-field sites.
- Three partnering Conservation Authorities (CAs) implement the edge-of-field monitoring component of ONFARM. They collect key water quality, water quantity, and land-use data to achieve the program objectives. CAs also provide technical advice and work directly with cooperators to carry out ONFARM outreach activities. Partnering CAs include: Ausable Bayfield Conservation Authority (ABCA), Lower Thames Valley Conservation Authority (LTVCA), and Upper Thames River Conservation Authority (UTRCA).
- Representatives from Agriculture and Agri-Food Canada (AAFC), Environment and Climate Change Canada (ECCC), and OMAFA who sit on the ONFARM Technical Working Group and provide valuable input on several technical aspects of the program, such as data management and collection.
- OSCIA would like to highlight the critical role of the participating ONFARM Cooperators in accommodating the research program's objectives on their respective farms. ONFARM is an applied research program that is being implemented on working farms across the province. ONFARM would not be possible without the dedication of cooperating farmers and the agricultural community.

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1.0 Introduction

The On-Farm Applied Research and Monitoring (ONFARM) program is a nine-year applied research initiative that supports soil health and water quality research on farms across Ontario.

The program is currently funded by the Sustainable Canadian Agricultural Partnership, a five-year federal-provincial-territorial initiative. Developed by the Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA) and delivered by the Ontario Soil and Crop Improvement Association (OSCIA), ONFARM builds on work accomplished under the Great Lakes Agricultural Stewardship Initiative's (GLASI) Priority Sub-watershed Project with an expanded emphasis on soil health. The program encompasses a range of activities, including rigorous monitoring of soil health and water quality on working farms across the province and examining the effectiveness of different agricultural best management practices (BMPs) through paired trials and how they impact soil health, water quality, and productivity.

ONFARM has three primary objectives:

1. Evaluate soil health indicators and test BMPs through continued paired plot trials at sites across Ontario.
2. Study impacts of BMPs on in-field soil-water dynamics and water quality.
3. Engage with farmers and stakeholders to transfer knowledge on BMP implementation and impact.

With the success of ONFARM's initial phase from 2019-2023, the program was renewed for continuation through 2028.

The program's renewal allows for the continued collection of critical data supporting BMP outcomes from the long-term soil health trial and edge-of-field water quality monitoring sites. This will enable a deeper understanding of the impacts of BMPs, such as cover cropping and organic amendment application, and the novel soil health indicators being tested.

Additionally, the program's extension aims to uncover insights into how these BMPs support good soil-water dynamics for crop resilience and learn more about how profitability and site-specific agronomy can support farmers' management decisions.

1.1 Organization Structure and Research Sites

ONFARM can be divided into three components based on the three pillars: Soil Health, Water Quality, and Outreach and Engagement. OSCIA administers all components and the Soil Health and Water Quality activities are guided by the ONFARM Technical Working Group. Established in 2019, the Technical Working Group acts as a scientific advisory committee. The Technical Working Group supported the selection of sites and BMPs for the soil health trials and provides guidance to ensure best practices for data collection, analysis, and reporting across the program. The Technical Working Group includes members from the following organizations:

- Ontario Soil and Crop Improvement Association (OSCIA)
- Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA)
- The Soil Resource Group (SRG)
- Ausable Bayfield Conservation Authority (ABCA)
- Lower Thames Valley Conservation Authority (LTVCA)
- Upper Thames River Conservation Authority (UTRCA)
- Agriculture and Agri-Food Canada (AAFC)

In addition to their roles in the Technical Work Group, SRG and the CAs play an instrumental role in collecting ONFARM soil and water data. SRG is responsible for carrying out activities in the soil health component and partnering CAs are responsible for carrying out the edge-of-field water quality component.

The ONFARM program is being implemented on working farms across the province in collaboration with partner organizations and cooperating farmers. The locations of ONFARM trials are shown in Figure 1. Each research site is owned and operated by an agricultural producer who has agreed to work with researchers to manage the field plots where trials are conducted. There are 25 active Soil Health sites, of which three are new sites started in 2024, and for the first time include two sites in northern Ontario. The other seven sites are Edge of Field (EOF) water quality monitoring stations.

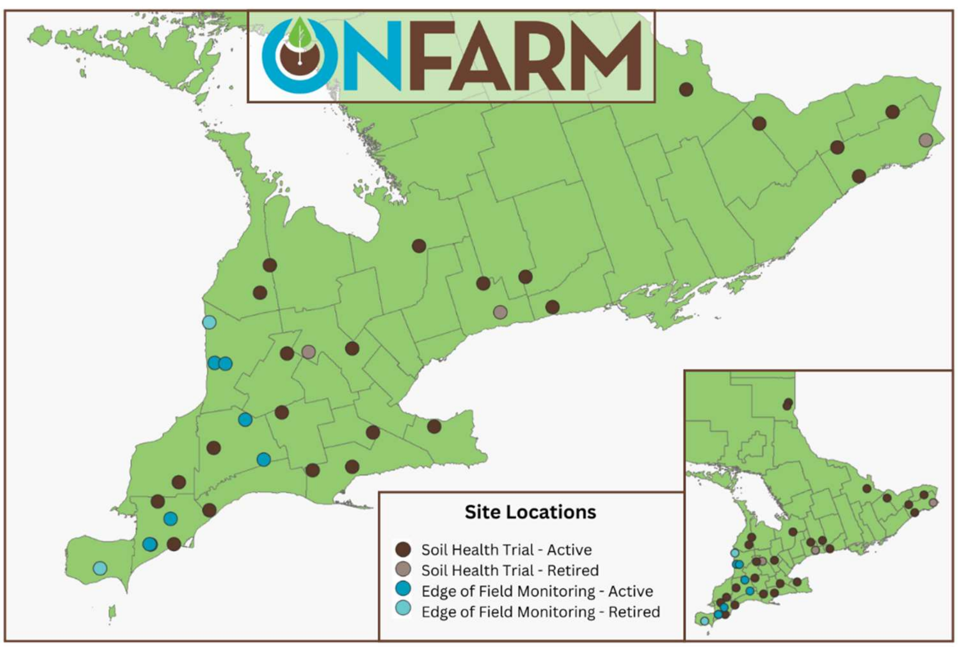

Figure 1. Locations of ONFARM Soil Heath BMP Trials (brown) and Edge-of-Field Sites (blue).

1.2 Edge-of-Field Technical Report Overview

The objective of the Edge-of-Field (EOF) Technical Report is to describe the edge-of-field research sites, summarize lessons learned and layout next steps for the program. Technical reports for ONFARM are released annually as iterative updates on the program's progress. Previous technical reports can be found on the ONFARM Web Page.

2.0 Water Quality Monitoring and Best Management Practices (BMP) Assessments

In the current phase of ONFARM, the water quality monitoring component focuses on evaluating BMP effectiveness at EOF sites. Each site captures tile and/or surface runoff as water exits the field. Together, the sites are being used to evaluate several BMPs, including: cover crops, reduced tillage, nutrient application, and tile drain management.

2.1 Edge-of-Field Site Overview

Collection of data at the EOF scale began at different times, as some monitoring locations were established through other programs and have collected up to a decade of water quality data, whereas other EOF sites were established in either 2016 through Great Lakes Agricultural Stewardship Initiative's (GLASI) or in 2019 directly through ONFARM. Each EOF site and monitoring location collects a variety of monitoring parameters which are detailed in Table 1.

Table 1. Examples of data collected at each EOF location.

Data Collected	Examples
Weather	Rainfall, snowfall, snowpack, temperature
Hydrologic layers	Stream/water body layer, municipal drainage layer (open and closed), tile surface inlet locations, subsurface tile drainage layer
Land management	Non-agricultural land use boundaries, land-based BMP layer (Water and Sediment Control Basins, buffer, etc.), field boundaries, agricultural land use by field
Field/soil characteristics	Soil phosphorus (P) and potassium (K) test, potentially mineralizable nitrogen (N), soil organic matter, soil aggregate stability, bulk density, infiltration
Field activities	Fertilizer application, manure application, tillage, surface residue cover, planting, harvest, crop protection
Water quantity	Overland and tile flow
Water quality	Total suspended solids, total P, dissolved reactive P, total organic P, total N, nitrate-N, ammonia-N, organic-N

Monitoring includes surface runoff flow and water quality, and where possible, subsurface (tile drainage) flow and water quality at most sites. This monitoring is visualized in the conceptual diagram shown in Figure 2. Overland flow patterns were assessed at site establishment to ensure all flow leaving a sub-watershed within the field area was directed through flumes or water control basins. Monitoring the rate of flow and the depth of water allowed for the calculation of discharge at any given time. Similarly, sensors in the tile drain captured tile water levels and/or subsurface flow rates to determine tile discharge volumes. ISCO water samplers were used to collect samples for water quality analysis at regular intervals when triggered by the flow sensorsFigure 4. Visual assessment of variations in water quality following a sampling event, demonstrating baseline (left), rising flow (middle left), peak flow (middle), and descending limb of flow (right).Figure 4. Figure 3 shows the inside of one of the water quality monitoring stations with this equipment in place. Figure 4 shows the visual variation in water quality that occurs across a sampling event at Merlin B, as discharge increases to a peak in the middle of the event, coinciding with the highest turbidity in the samples.

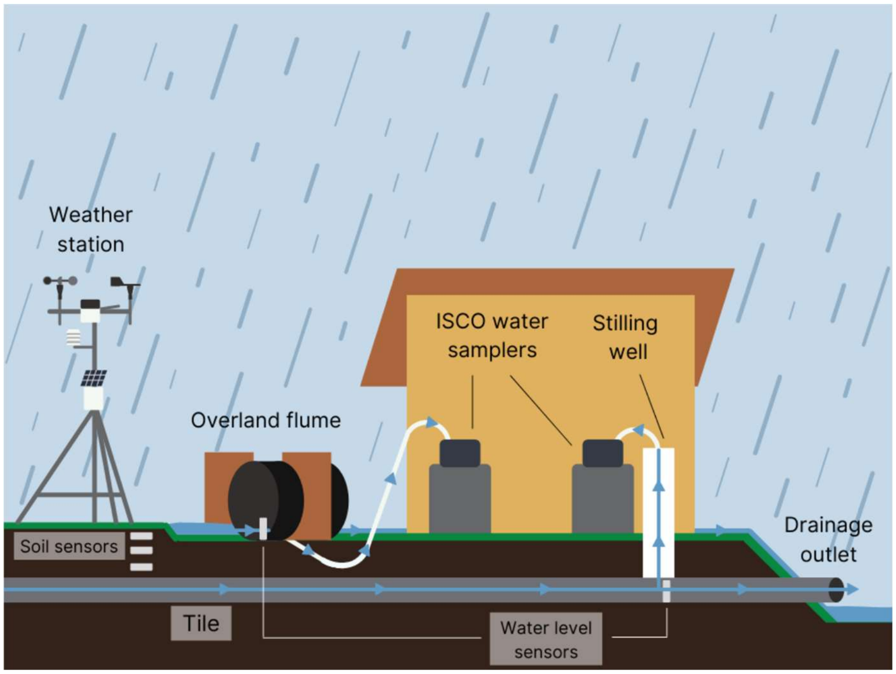

Figure 2. Conceptual diagram of an Edge of Field (EOF) monitoring station. Sensors capture weather, soil, and water level data, and water movement triggers automatic collection of water samples from overland flow or tile drains.

Figure 3. The inside of a water monitoring station established by the Upper Thames River Conservation Authority.

Figure 4. Visual assessment of variations in water quality following a sampling event, demonstrating baseline (left), rising flow (middle left), peak flow (middle), and descending limb of flow (right).

Conservation Authority (CA) staff collected data and entered the results into the Water Information System by Kisters (WISKI) database for long-term storage and analysis. The WISKI database is well suited for time-series data, such as the water discharge, and offers features for quality assurance tracking, and automating water quality calculations, like nutrient loading. Improving ONFARM's integration into WISKI has been a large focus for conservation authority staff in 2024, and has involved various group training sessions to support the adoption of new features and collaborations to bring historical datasets up to date in the database.

Monitoring is being conducted at seven sites, all of which are unique monitoring operations, due in part to the unique nature of drainage pathways and field topographies. As a result, most of the sites are monitored at multiple locations, e.g. two or more fields or sub-basins provide comparable areas for BMP treatments and controls, whereas the Merlin A and B sites are two separate, neighbouring farms that offer a close comparison. Fairview is the only Edge of Field site that could not physically facilitate a spatial comparison for water quality; instead, future analysis will focus on comparisons across time as more water-years' worth of data are collected from the new ONFARM site. **Error! Reference source not found.**provides an overview of the sites, including treatments, flow paths being monitored, and if water quality and quantity are being captured.

There are seven farms where all flow pathways are captured, either separately or in a combined outlet, and can be used to estimate total field discharge, sediment and nutrient losses. There are four fields where both tile and surface pathways are captured independently. These fields can be used to understand the role of different transport pathways. At these sites, field totals, of runoff, sediment and nutrients, are calculated by adding surface and tile totals together. There are three fields where an outlet that combines tile and surface runoff is monitored. Capturing both flow paths is not possible in all fields for various reasons. There are six fields where tile is the only flow path measured, and two where only surface is measured. In addition, surface runoff from an untitled field and a wooded (untiled) area are also captured. In total, tile runoff is monitored at ten fields, and surface runoff at seven fields (not including the woodlot).

Table 2. Summary of edge-of-field sites, treatments, and flow paths.

CA	Site	Treatment	Tile Monitoring	Surface Monitoring	Combined Tile and Surface	Site Total	Water Quality and Quantity?
LTVCA	Merlin A	Conventional	X	X		Addition	Yes
	Merlin B	No-till and cover crop	X	X		Addition	Yes
	Fairview	Manure application	X			Tile Only	Yes
UTRCA	Upper Medway - CD1	Control drainage	X			Tile Only	Yes
	Upper Medway - CD2	Control drainage	X			Tile Only	Yes
	Upper Medway - FD	Free drainage	X			Tile Only	Yes
	North Kettle - EOFN	Cover crop			x	Combined Outlet	Yes
	North Kettle - EOFS	No cover crop			x	Combined Outlet	Yes
ABCA	Gully-DFTEL3	Cover crop		X		Surface Only	Yes
	Gully-DFTEL5	No cover crop		X		Surface Only	Yes
	Gully-DFTILE	Field outlet			x	Combined Outlet	*Quantity Only, Historical Quality Data*
	Huronview Field A	Contour drainage	X	x		Addition	Yes
	Huronview Field B	Pattern drainage	X	x		Addition	Yes
	Huronview Tile 15’	Tile spacing 15’	X			*Tile Only*	*Quantity Only*
	Huronview Tile 30’	Tile spacing 30’	X			*Tile Only*	*Quantity Only*
	Huronview Field D	Untiled field		X		*Surface*	*Quantity Only*
	Huronview Woods	Natural area		X		Surface	Yes

2.3 Edge-of-Field Site Descriptions

2.3.1 Merlin A and B

The two Merlin sites (Merlin A and Merlin B) neighbour each other and are both on clay soils with predominantly flat landscapes. The fields have differing management characteristics which can provide great insight to their effects on water quality (Table).

Table 3. Field and management characteristics at the Merlin A and Merlin B sites.

Site	Field Size	Management Practices
Merlin A	50 Acres	Conventional tillage and no cover cropping
Merlin B	90 Acres	No-till and cover cropping

Consistant monitoring set ups are used for each site (Figure 5). Each site contains two tile sampling locations, one flume for surface runoff, and one well depth monitoring site. There is some variation in the equipment used to measure depth, velocity, and flow (Table).

Table 4. Plots and equipment present at Merlin A and Merlin B.

	Merlin A		**Merlin B**	
Type of Sites	Site ID Name	Equipment	Site ID Name	Equipment
Tile Sites	Plot 2	1 ISCO 6712 sampler 1 Hach AV9000 Area Velocity Analyzer Module and submerged AV sensor 1 HOBO U20 water level logger in tile, 1 HOBO Barometric logger	Plot 1	1 ISCO 6712 sampler 1 Blue Siren AV sensor (eco siren model) 1 HOBO U20 water level logger in tile
	Plot 3	1 ISCO 6712 sampler, 1 Hach FL902 logger with HACH Flo-Tote 3 AV sensor (Issues with sensor - Not reliable AV data), 1 U20 level logger in tile	Plot 2	1 ISCO 6712 sampler 1 ISCO 750 Area Velocity Flow Module and AV sensor 1 HOBO U20 water level logger
Surface Flume Sites		1 ISCO 6712 sampler 1 HOBO U20 water level logger in flume	Plot 4	1 ISCO 6712 sampler - at flume for surface water samples 1 HOBO U20 water level logger in flume
Well Monitoring Sites		1 HOBO U20 water level logger in groundwater well		1 HOBO U20 water level logger in groundwater well

Figure 5. Merlin A's flume (right) capturing surface flow entering the municipal drain, with the permanent ISCO enclosure to the left.

2.3.2 Fairview

The Fairview site is located approximately 30 kilometers east of the Merlin A and B sites or 15 kilometers east of Chatham. The field is 100 acres, has high soil phosphorus levels, poorly drained soils, and drains into the Thames River. The Fairview site was previously used to test phosphorus absorbent materials and contains two tanks, and an inflow and outflow ISCOs (Figure 6).

Figure 6. Fairview site containing an inflow permanent ISCO enclosure with solar panel [Right], first tank [Right Middle], second tank [Left Middle], and outflow permanent ISCO enclosure with solar panel [Left].

Currently, only the inflow ISCO is being used to concentrate the study on the quality and quantity of tile runoff from a swine manure applicated field (Table 5). This site allows for the assessment of how organic amendments can affect soil health, and biological, chemical and structural indicators. The equipment at this site is similar to the equipment at the Merlin A & B sites for tile monitoring. There is no well or flume monitoring at this site.

Table 5. Equipment located at the Fairview site.

Type of Site	Fairview
Inflow Tile Site	1 ISCO 6712 sampler 1 Blue Siren AV sensor (eco siren model) 1 ZL6 with a hydrosensor 1 uMetos 300 Weather Station 1 Sentek Triscan 120 CM Soil Probe (Salinity, temperature, soil moisture)

Recent improvements to the site include the installation of a ZL6 data logger and hydrosensor. The hydrosensor autocorrects for barometric pressure, which is more efficient than downloading two loggers and adjusting the data periodically. The ZL6 logger provides telemetry so that water levels can be monitored remotely.

2.3.3 Gully

Gully EOF (DFTILE EOF) was established in 2012 by ABCA. The overall catchment is 18 ha and is monitored at the tile outlet. This larger catchment is further divided into sub-basins within the field, and is monitored at three WASCOB sites (DFTEL2, DFTEL3 and DFTEL5) with drainage areas between three and five ha (Figure 7). ABCA has used the data from these established sites to understand the relationship between vegetative cover and residue on runoff generation. Since 2017, vertical till and no-till practices have replaced more conventional tillage practices. In ONFARM, the site is used to monitor the impact of cover crops, by establishing cover/no cover plots utilizing the WASCoBs as monitoring points.

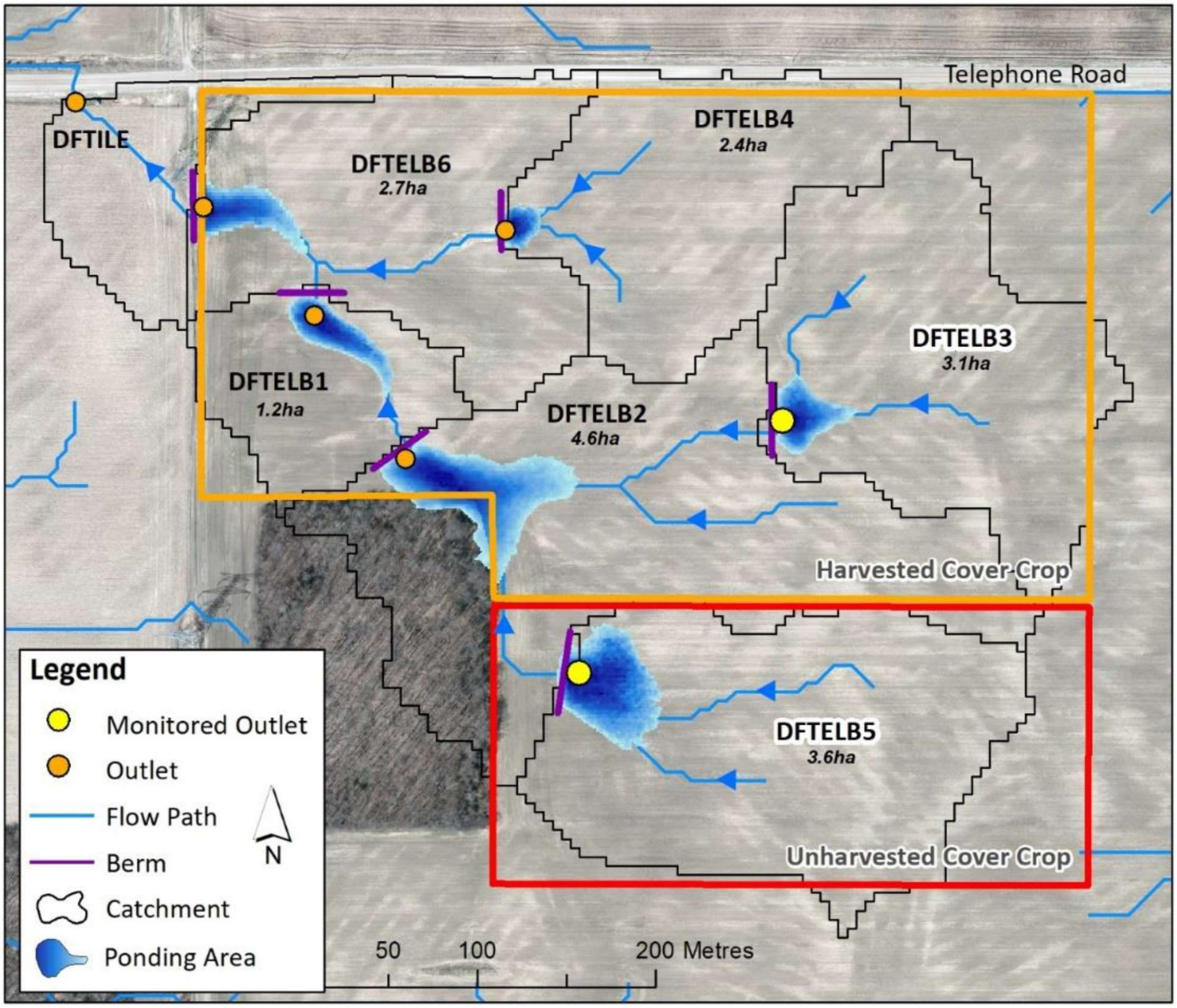

Figure 7. Map of Gully EOF (DFTILE EOF) site in the Gully Creek watershed. WASCoBs 2, 3, 5, were monitored for water quality from sub-basins within the field, and the tile outlet (top left) was monitored for water leaving the entire field.

2.3.4 Huronview

The Huronview Demonstration Farm is actively farmed by the Huron County Soil and Crop Improvement Association to demonstrate agricultural BMPs (particularly to inform management of tile drainage and its impact on water quality). The site has two permanent subsurface water quality monitoring stations located in Field A and Field B (Figure). There are four treatments of water management being measured: i) no drainage; ii) wetland treatment of tile water; iii) systematic drainage (with a side comparison of 15' and 30' spacing); and, iv) contour drainage with control structures in the lateral lines.

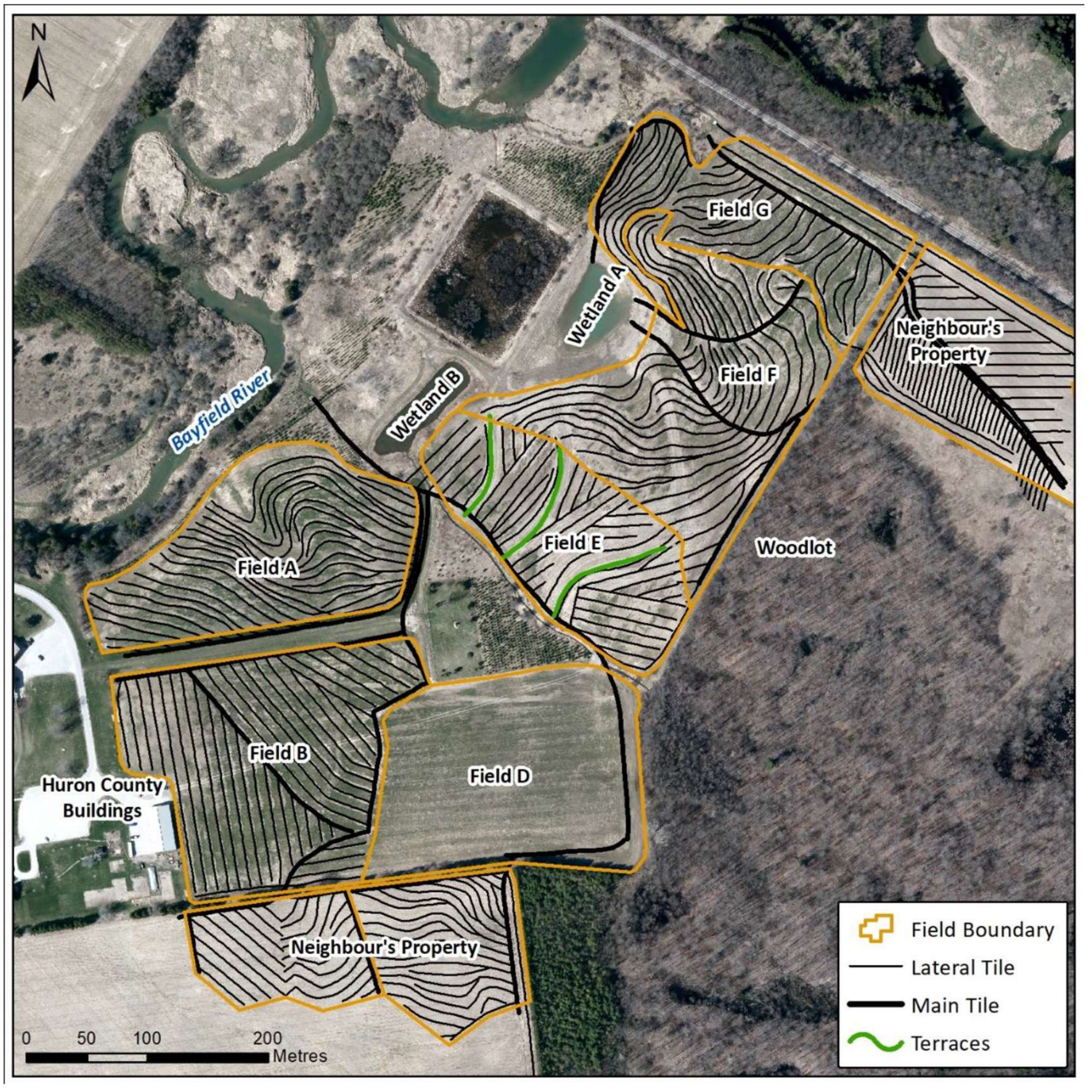

Figure 8. The Huronview Demonstration Farm, shown by field and drainage sub-basins with the various tile drain setups.

2.3.5 Upper Medway

Within the Upper Medway Creek subwatershed, data will be captured from a unique EOF site that has been monitored since 2015 by Agriculture Agri-Food Canada (AAFC) to compare controlled tile drains as a management practice. At the Controlled Drainage Site, tile runoff is sampled from two controlled drainage plots and one free drainage plot (Figure). There is an opportunity to demonstrate and compare the effects of stacking of BMPs in the future, such as the impact of cover crops and controlled drainage.

Figure 9. Upper Medway EOF Site.

2.3.6 North Kettle

In the North Kettle Creek subwatershed, an EOF station was constructed at a T-shaped berm that separates two distinct catchments in the field (Figure 10). Each side of the berm also has a separate surface inlet and tile outlet, allowing for different treatments to occur on either side. The North catchment serves as the experimental side, with a cover crop planted each fall, while the South catchment provides the control where no cover crop is planted (Figure 11).

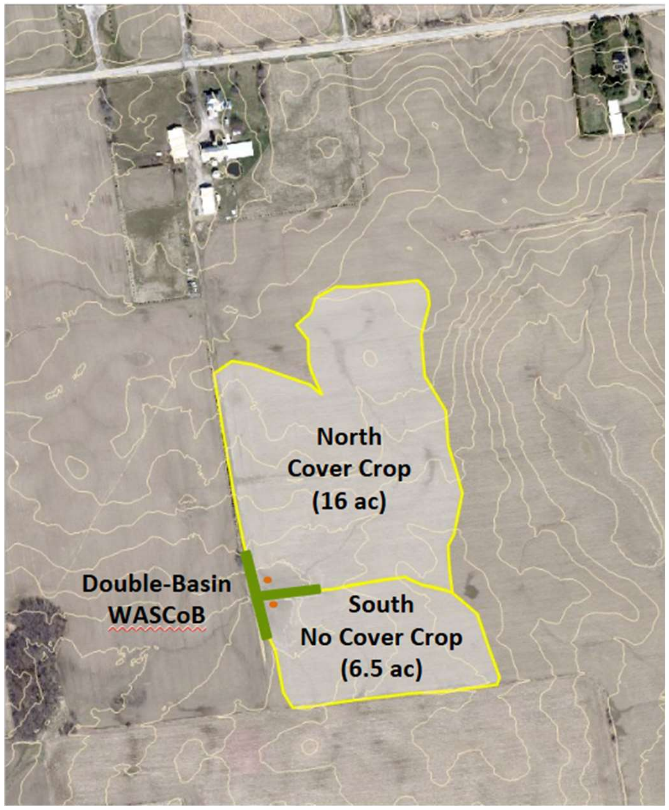

Figure 6. Site map showing the layout at the North Kettle EOF.

Figure 11. Photo of T-shaped berm separating the two monitored catchments at the North Kettle EOF.

3.0 Water Quality Results and Discussion

3.1 Impacts of Cover Crop Catch Quality on Water Quality

Cover crops have been seeded as a BMP at the North Kettle EOF site for several years, however, as a management practice, the impact on water quality has shown limited effects compared to the control side because of poor stand establishment. Because of the site's rotation between sweet corn and soybeans, the opportunity for seeding cover crops is later in the fall than normal for the typical cover crop seeded in Ontario, i.e. in August after winter wheat harvest, which has limited biomass development through the late fall period. However, in the fall of 2023, a good catch of oats was established that maintained consistent ground cover into the spring of 2024 after being winterkilled. Analysis of several large runoff events in 2024 now allows for the comparison of water quality parameters between the north (cover cropped) field, and the south (control) field, between these events and other large historical events when the two fields had very similar conditions.

Table 6 shows a breakdown of the timing, precipitation received, and runoff for five events, of which the last three occurred in March 2024 with a strong cover crop stand, and Table 7 shows water quality parameters calculated for the same events. The first, starting March 26, 2021, occurred when a cereal cover crop had been planted; however, the rye did not develop well and provided little more ground cover than the soybean residue in the control (Figure 12). This event provides a strong comparison as it occurred at the same time of year, and followed similar levels of snow melt through February. However, discharge levels were lower compared to the three events in 2024 (approximately half to four times less discharge occurred). The second event occurred Sept 21, 2021, when both sides of the field still had a standing crop of sweet corn present. This September event is unique in having the largest volume of discharge to leave either side of the field of all five events (an immense storm followed a long dry period), and for having a large amount of living biomass on both sides, shown in Figure 13. Hydrographs generated for each field (Figure 14) show how tile flow quickly reached maximum capacity, i.e. the periods of flat horizontal lines, for which continued for several days and led to surface water ponding near the tile inlet.

Figure 12. Poor establishment of a cover crop on the right field compared to soybean residue on the left field in November 2020 (left photo) and March 2021 (right) prior to a rain event.

Figure 73. A rain event occurring in September 2021 on growing sweetcorn. The high precipitation led to standing water in field, and the highest level of discharge from the five selected events.

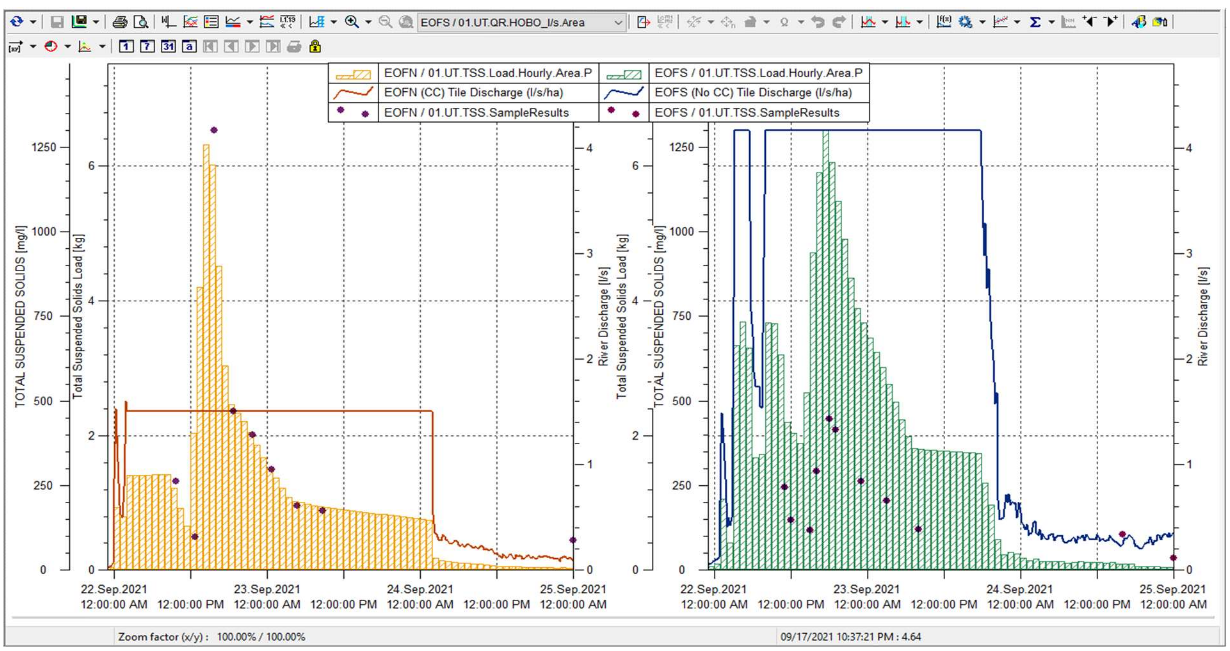

Figure 14. Hydrographs from the Sept 2021 event showing the responses in both sides of the field for water discharge (line), measured TSS concentrations (dots), and calculated TSS load (bars).

Table 6. Hydrological event characteristics for five events captured by field from the Kettle Creek Edge of Field Site

Field	Treatment	Event Type	Event Date	Field area (ha)	Discharge (L)	Discharge (mm)	Precipitation (mm)	Runoff Index
North	CC	Poor catch	2021-03-26	5.7	254,890	4.50	25.00	0.18
South	Control	Poor catch	2021-03-26	2.4	239,708	9.87	25.00	0.39
North	CC	Sweet corn	2021-09-21	5.7	1,601,063	28.26	90.00	0.31
South	Control	Sweet corn	2021-09-21	2.4	1,521,883	62.68	90.00	0.70
North	CC	Good catch	2024-03-09	5.7	963,677	17.01	30.00	0.57
South	Control	Good catch	2024-03-09	2.4	670,450	27.61	30.00	0.92
North	CC	Good catch	2024-03-14	5.7	448,254	7.91	17.00	0.47
South	Control	Good catch	2024-03-14	2.4	328,578	13.53	17.00	0.80
North	CC	Good catch	2024-03-26	5.7	549,470	9.70	19.00	0.51
South	Control	Good catch	2024-03-26	2.4	402,316	16.57	19.00	0.87

The three events occurring with a strong oat cover crop catch (shown in Figure 15) occurred close together, from March 9-11, March 14-16, and March 26-28. Precipitation at these events ranged from 17 to 30 mm, comparable to the poor catch event (March 2021) at 25 mm, and well below the event in sweet corn at 90 mm. Table 8 shows a comparison between the two fields for various parameters as a ratio of CC field value : control field value; e.g. when nutrient loads are lower, the cover crop field is performing well, when values are close to one the two fields are consistent, and when values are greater than one the cover crop field is performing worse. For the two events which occurred when the two fields had limited differences (the poor catch and sweetcorn), it was expected that ratios would be close to one for each parameter, which was not the case. The two sides demonstrated large differences in hydrologic response; for example, while the total discharge in L from each side was similar in these events, based on the difference in contributing area, the control area moved around twice as much water off the field. The calculated runoff index shows that the cover crop field held 70-80% of the rainwater during these events, and approximately half of the rainwater during the good cover crop catch period. This water holding may be related to history of cover cropping – despite the aboveground biomass having limited growth in the past, the presence of cover crop roots may still have had an impact on soil health to support this. Further investigation of water retention using pressure plate analysis has been started at this site to better understand this site in future program years. In contrast, in the presence of a good catch, the cover crop field exported a higher proportion of precipitation as runoff, in the range of 50-60% of the precipitation. While still maintaining a lower runoff index than the control field, the absolute values for discharge were higher.

Table 7. Water quality parameters calculated for five events captured by field from the Kettle Creek Edge of Field Site.

Field	Treatment	Event Type	Event Date	TSS FWMC (mg/L)	TP FWMC (mg/L)	DRP FWMC (mg/L)	TSS Load (kg/ha)	TP Load (kg/ha)	DRP Load (kg/ha)	PP Load (kg/ha)
North	CC	Poor catch	2021-03-26	768.76	1.92	0.16	34.58	0.09	0.01	0.08
South	Control	Poor catch	2021-03-26	363.32	1.50	0.08	35.87	0.15	0.01	0.14
North	CC	Sweet corn	2021-09-21	307.43	1.24	0.23	86.87	0.35	0.07	0.28
South	Control	Sweet corn	2021-09-21	165.52	0.91	0.18	103.75	0.57	0.12	0.46
North	CC	Good catch	2024-03-09	210.40	1.35	0.47	35.79	0.23	0.08	0.15
South	Control	Good catch	2024-03-09	867.49	2.07	0.15	239.54	0.57	0.04	0.53
North	CC	Good catch	2024-03-14	143.85	1.32	0.36	11.38	0.10	0.03	0.08
South	Control	Good catch	2024-03-14	492.82	1.46	0.09	66.69	0.20	0.01	0.19
North	CC	Good catch	2024-03-26	241.34	1.15	0.33	23.40	0.11	0.03	0.08
South	Control	Good catch	2024-03-26	714.49	1.99	0.07	118.39	0.33	0.01	0.32

Figure 15. Photos taken in January of 2024 showing conditions on the no-cover field (left) and oat cover crop (right) prior to the series of rain events that would occur in March 2024.

Comparisons between water quality parameters between the fields are shown in Table 7; starting with total suspended sediment (TSS), the fields lost similar loads on a per hectare basis during the first two events, which was expected. TSS showed one of the largest improvements driven by the cover crop BMP, reducing over 80% of TSS export compared to the control. It is notable that this reduction occurred at the same time as the runoff index was increased on these fields, which may be attributed to the presence of cover crop improving the infiltration of water to the tile, without an increase in overland flow. Because the monitoring setup at this site is only capable of monitoring the combined surface and tile water, we are unable to validate that assumption at this time. However, changes in dissolved reactive phosphorus (DRP), measured as ortho-phosphate, were oppositely affected by the cover crop's presence, which is consistent with other findings from other research programs, and is in agreement with the expectation of increased DRP through tile runoff occurring with decreased surface runoff.

Table 8. Ratios of each hydrologic and water quality parameter of values measured or calculated from the cover cropped field: the control field from the Kettle Edge of Field site for the five selected events.

Event Type	Event Date	Discharge (L)	Discharge (mm)	Runoff Index	TSS FWMC (mg/L)	TP FWMC (mg/L)	DRP FWMC (mg/L)	TSS (kg/ha)	TP (kg/ha)	DRP (kg/ha)	PP (kg/ha)
Bad catch	2021-03-26	1.06	0.46	0.46	2.12	1.28	1.88	0.96	0.58	0.86	0.57
Sweet corn	2021-09-21	1.05	0.45	0.45	1.86	1.35	1.26	0.84	0.61	0.57	0.62
Good catch	2024-03-09	1.44	0.62	0.62	0.24	0.65	3.13	0.15	0.40	1.93	0.28
Good catch	2024-03-14	1.36	0.58	0.58	0.29	0.90	3.91	0.17	0.53	2.29	0.41
Good catch	2024-03-26	1.37	0.59	0.59	0.34	0.58	4.39	0.20	0.34	2.57	0.25

Shown in Table 8, DRP was the only water quality parameter calculated to increase with the presence of cover crops, losing 2 to 2.5 times more DRP compared to the control. While unfortunate to see a management practice we hope functions to improve water quality, these results alone should not dissuade the use of cover crops, but should still be considered in the larger context of using cover crops amongst a suite of BMPs. While 2.5 more DRP is a large effect, it should be considered in comparison with the magnitude of the losses, the relative value of DRP loss from the first two events, and holistically with the impacts on total phosphorus (TP) and particulate phosphorus (PP) as well.

The specific magnitude of DRP loss, shown in Table 8, was low (below 0.01 to 0.03 kg/ha) during several events – both during the poor catch and during two of the good catch events, so while the percent difference or ratio between these events was large, the actual change was relatively small. Compared to the loads lost during the larger precipitation events, which saw up to 0.12 kg/ha of DRP lost, the increase of 0.02 kg/ha is less impactful on the whole system. Additionally, the largest loss of DRP from the cover crop field was 0.08 kg/ha, still less than what was lost from the control field when sweetcorn was growing.

Relative to other forms of phosphorus, DRP was consistently a smaller contributor (ranging from 4 to 35%) than PP (ranging from 65 to 96%) to the amount of TP lost from either field (shown in Table 9). The portion of DRP increased from near equivalency in the first two events, up 5-7 times greater from the cover crop field vs the control when a good catch of cover crop was in place. However, the ratio of PP from the cover cropped field to the control field was much lower in all cases where there was a good catch present. Of these three events, the greater precipitation received March 9 still increased PP to a level of 0.15 kg/ha from the consistently lower level of 0.08 kg/ha observed at the other two events; in comparison, the control field saw a larger increase up to 0.53 kg/ha. Controlling this larger pool of PP, and therefore the TP load more effectively, shows the benefit of cover cropping despite the trade-off with DRP.

Table 9. Loads of water quality parameters exported during the five selected events, and the proportion of total phosphorus lost as either dissolved reactive phosphorus or particulate phosphorus.

Field	Treatment	Event Type	Event Date	TP (kg/ha)	DRP (kg/ha)	PP (kg/ha)	% DRP	% PP
EOFN	CC	Bad catch	2021-03-26	0.09	0.01	0.08	8	92
EOFS	Control	Bad catch	2021-03-26	0.15	0.01	0.14	6	94
EOFN	CC	Sweet corn	2021-09-21	0.35	0.07	0.28	19	81
EOFS	Control	Sweet corn	2021-09-21	0.57	0.12	0.46	20	80
EOFN	CC	Good catch	2024-03-09	0.23	0.08	0.15	35	65
EOFS	Control	Good catch	2024-03-09	0.57	0.04	0.53	7	93
EOFN	CC	Good catch	2024-03-14	0.10	0.03	0.08	27	73
EOFS	Control	Good catch	2024-03-14	0.20	0.01	0.19	6	94
EOFN	CC	Good catch	2024-03-26	0.11	0.03	0.08	29	71
EOFS	Control	Good catch	2024-03-26	0.33	0.01	0.32	4	96

3.2 Comparison of winter field conditions that hold precipitation or generate runoff

While comparisons can be made between nutrient loads within or across events to understand the impact of a BMP on runoff, its also important to consider cases where that comparison cannot be made – where the difference in field management prevents runoff from occurring in one area but not the other. At the Gully site, precipitation events have been tracked from 2011 to 2024 to determine whether flow was captured at the B3 or B5 monitoring stations (Figure 6 shows the location of these subfield areas); both areas of the field have historically been seeded with cover crops, but the cover grown over B3 has been harvested for forage in the fall, leaving less residue cover over the non-growing season.

Rain events occurring from October 1 to April 30 have been delineated based on having a minimum rainfall of 10 mm or more, and events have been considered distinct when separated by a minimum of 12 hr between precipitation falling. Table 10 shows the precipitation events that occurred by year, the type of soil cover or residue, and the number of runoff events from either field. In total, 170 rain events were recorded over this period, ranging from 10-22 per year. Less than half of all rain events generated runoff from either section of the field.

The greatest proportion of events generating runoff occurred when the field had only soybean residue providing ground cover, with up to 90% of rain events generating runoff from the B5 subbasin. This is not unexpected, as soybeans provide less residue than other crops like corn or wheat, and it is readily broken down by winter weather conditions. However, of the years with soybean residue, one year of events, 2019-2020, the B5 field did have a much lower proportion of events generating runoff, having only 20% of events which generated runoff. This may be due to drier conditions over that winter. With only 10 rain events occurring, it was the smallest number of all years and likely had less events occurring in sequence when antecedent soil moisture was high, allowing for more infiltration and water holding. However, results from 2023-2024 do somewhat disagree with this trend – despite being the second year in a row of growing soybeans and the field receiving a normal amount of precipitation events, the proportion of runoff generating events was quite low at 26% from B5. This may reflect the long-term impact of BMP implementation there, as B3 still had a greater proportion of events generating runoff, at 42% of the 19 events.

The best performing years for holding back runoff happened when oat cover crops were grown. From both subbasins, the proportion of runoff generating events was only 10-30%, which indicates cover crops can be successful at keeping water on fields, and preventing nutrient loss, as phosphorus export into surface water only occurs when runoff does, and the majority of TP loss occur through overland runoff. Corn residue appears to be a middle ground between the poor cover of soybeans, and the stronger cover of growing cover crop, with proportions ranging from 30-60%.

In the years 2016-17 and 2020-21, differences in the subbasins exist because of BMP implementation, i.e. the harvesting of cover crops in B3, but not in B5. In 2016-17, this led to no differences in the proportion of events generating runoff; both had it occur in 4 of 15 events. However, in 2020-2021, runoff only occurred in 1 of 13 events in the unharvested section, but 4 of 13 in the harvested area. The harvested oats appear to still be providing a good amount of residue to hold back water, compared to other crop residues, but the biomass of an unharvested cover crop has shown the strongest benefits.

Table 10. Non-growing season rain events monitored at the Gully EOF site, and the number of these rain events which generated runoff captured at either the B3 or B5 subbasin berms.

Year	Ground cover type	Total events	Events at B3	Events at B5
2014-15	Soybean residue	15	9	9
2015-16	Soybean residue	21	10	19
2016-17	Oat cover crop Oct, then no cover	15	4	4
2017-18	Corn residue	20	12	10
2018-19	Soybean residue	22	12	13
2019-20	Soybean residue	10	4	2
2020-21	Oat cover crop	13	4	1
2021-22	Corn residue	20	13	7
2022-23	Soybean residue	15	5	5
2023-24	Soybean residue	19	8	5

3.3 Preliminary results for the impact of cover crops, fertilizer application timing, and tillage on nitrogen loss and crop productivity

At the Huronview site, many types of BMPs have been implemented over the past few years because the site serves as a demonstration farm for the local Huron Soil and Crop Improvement Association. As such, the impact of different practices can be compared year to year. Figures 16-18. shows the distribution of water quality parameter concentrations in all water samples collected during the non-growing seasons from fall of 2019 to the spring of 2024. The results from Figure 16 show one year where nitrate concentrations were consistently lower, in 2021-2022. In this case there are several potential factors affecting these concentrations, the first being the use of the multi-species cover crop mix, and the second, the lack of fertilization in the fall of 2021 (which has been the standard practice across other years), and the third, variability in weather between the five winters.

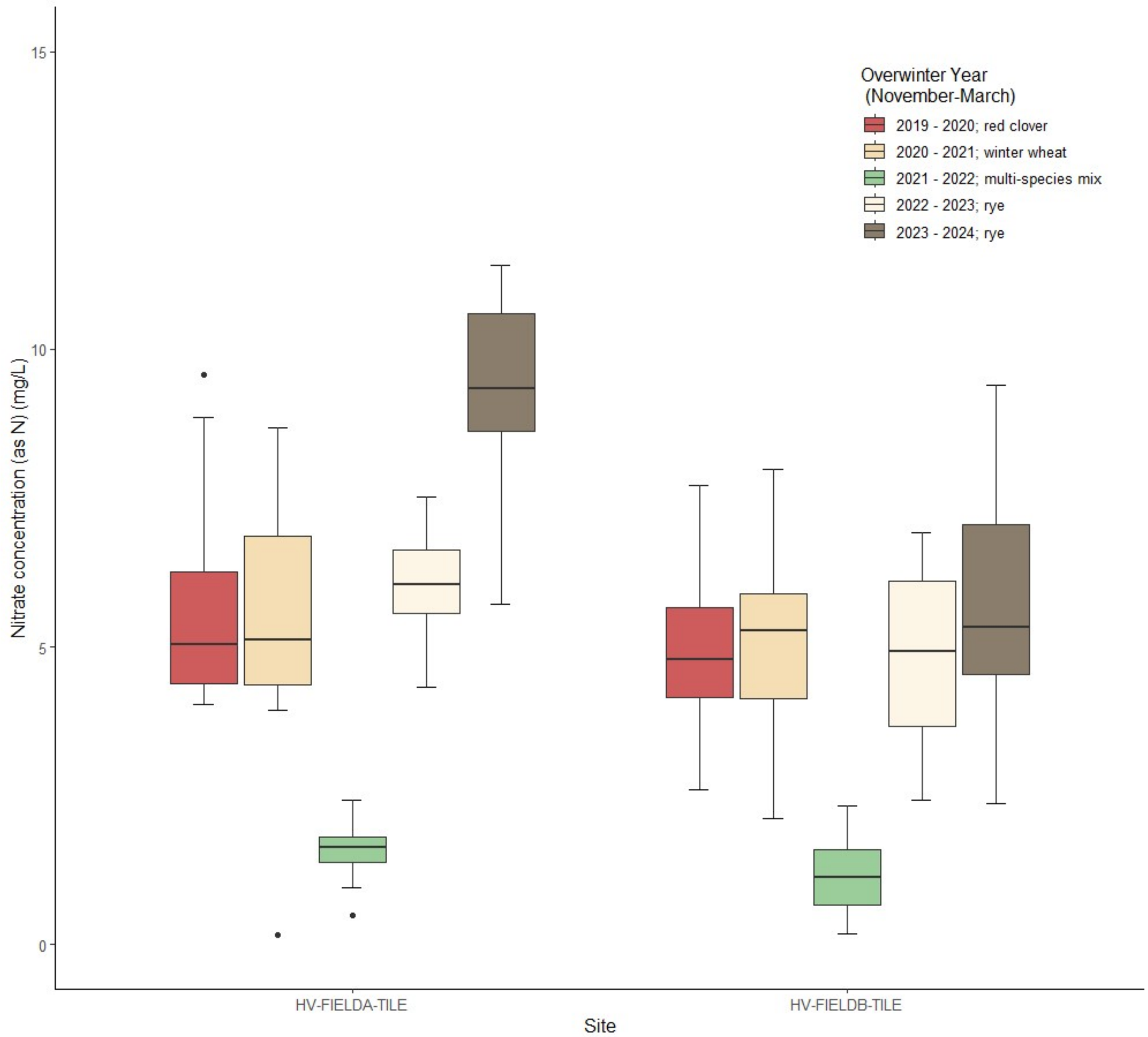

Figure 16. Distribution of nitrate-N concentrations from all water quality samples collected from tile flow event that occurred over-winter from two fields at the Huronview EOF Site. Colours represent the growing crop or cover crop during the sampling year.

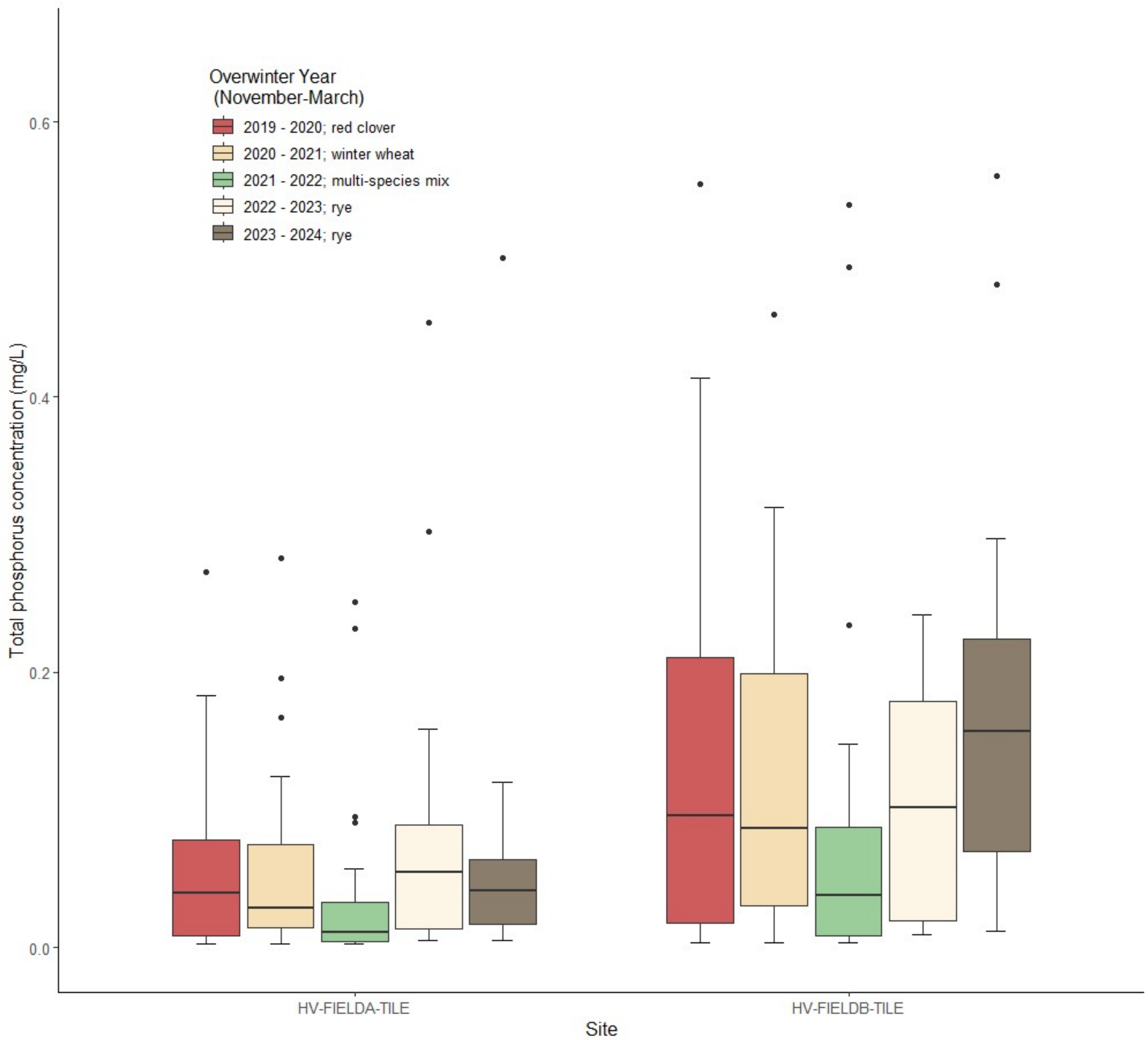

Figure 17. Distribution of total phosphorus concentrations from all water quality samples collected from tile flow event that occurred over-winter from two fields at the Huronview EOF Site. Colours represent the growing crop or cover crop during the sampling year.

While Figures 17 and 18 show that both TSS and TP concentrations were lower in 2021, indicating potentially an impact from the stand of cover crop limiting runoff, both parameters still had concentration ranges that substantially overlapped ranges from all other years. Therefore, it appears the absence of fertilizer application that fall had a large contribution to the nitrate concentrations. This suggests that the cover crops was not be able to scavenge and hold back all fall applied nitrogen until spring, and waiting until spring to apply fertilizer may be a better option for supporting water quality outcomes where it is not agronomically essential, for example, applying starter fertilizer with winter wheat. The more moderate impact on TP may reflect the impact of legacy phosphorus on yearly TP losses, such that not having mono-ammonium phosphate (MAP) applied resulted in a lower magnitude of loss, phosphorus already in the soil continued to move with runoff. As a more mobile nutrient, nitrogen would have a lower legacy impact, and therefore, a stronger drop-off in concentrations in a year without fall fertilizer application.

These results as presented are only preliminary findings – the Huronview site was recently updated with a modern mag-meter for measuring tile discharge. As more tile-flow events are monitored, data collected from that instrument will be used to pair these concentration data points with the event hydrology, to calculate flow weighted mean concentrations and nutrient loads. Also, BMP management at Huronview will repeat previous BMPs, like multi-species cover crops as the rotation continues, providing more insight into the BMP's impact here.

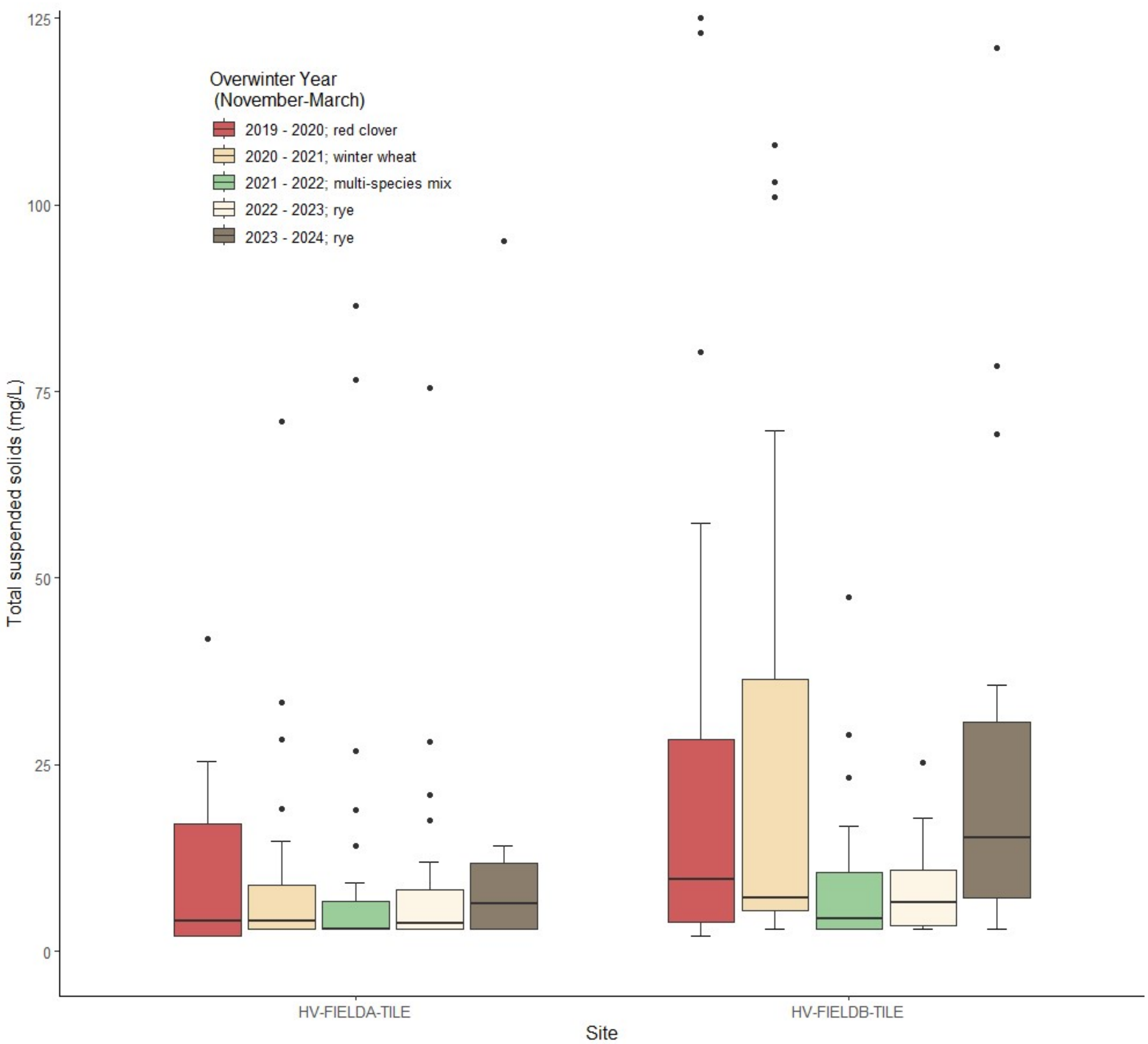

Figure 18. Distribution of total suspended solids concentrations from all water quality samples collected from tile flow event that occurred over-winter from two fields at the Huronview EOF Site. Colours represent the growing crop or cover crop during the sampling year.

Outside of the water quality perspective, the management of the multi-species cover crop has provided insight into the impact of cover crop management on the next soybean crop. That year in particular, the crop developed a substantial amount of biomass through the spring, such that planting conditions were challenging. Huronview farm operators intended to plant green as a learning opportunity and demonstration of the practice. Specifically, separate fields compared the practice of roller-crimping before no-till planting (Field A; Figure 19) against spraying for crop termination before strip tilling (Field G; Figure 20). Strip tillage successfully managed the thick cover crop stand in Field G, resulting in the expected soybean yields for the field, at over 50 bu/ac. However, roller-crimping did not enable successful no-till planting; the field had to be sprayed weeks later, and soybeans were replanted. This resulted in a yield hit of around 20 bu/ac from the expected yield.

This demonstrates the need to consider BMP choices based on a whole system approach, to ensure that BMP implementation continues to have an overall positive impact on water quality, other environmental factors, and the economic sustainability of the farm operation. In this case, choosing to implement a form of reduced tillage to continue managing cover crops is a more balanced outcome compared to dropping cover crops out of the rotation to enable strictly no-till management. As demonstrated above in Section 3.1 through the increased DRP loads from cover crops, and shown here with a yield impact from planting green, management practices we refer to as “best” or “beneficial” may at times introduce unexpected negative consequences – but it is only through continued, long-term implementation that ONFARM cooperators and researchers are learning how to minimize these effects for new adoptees.

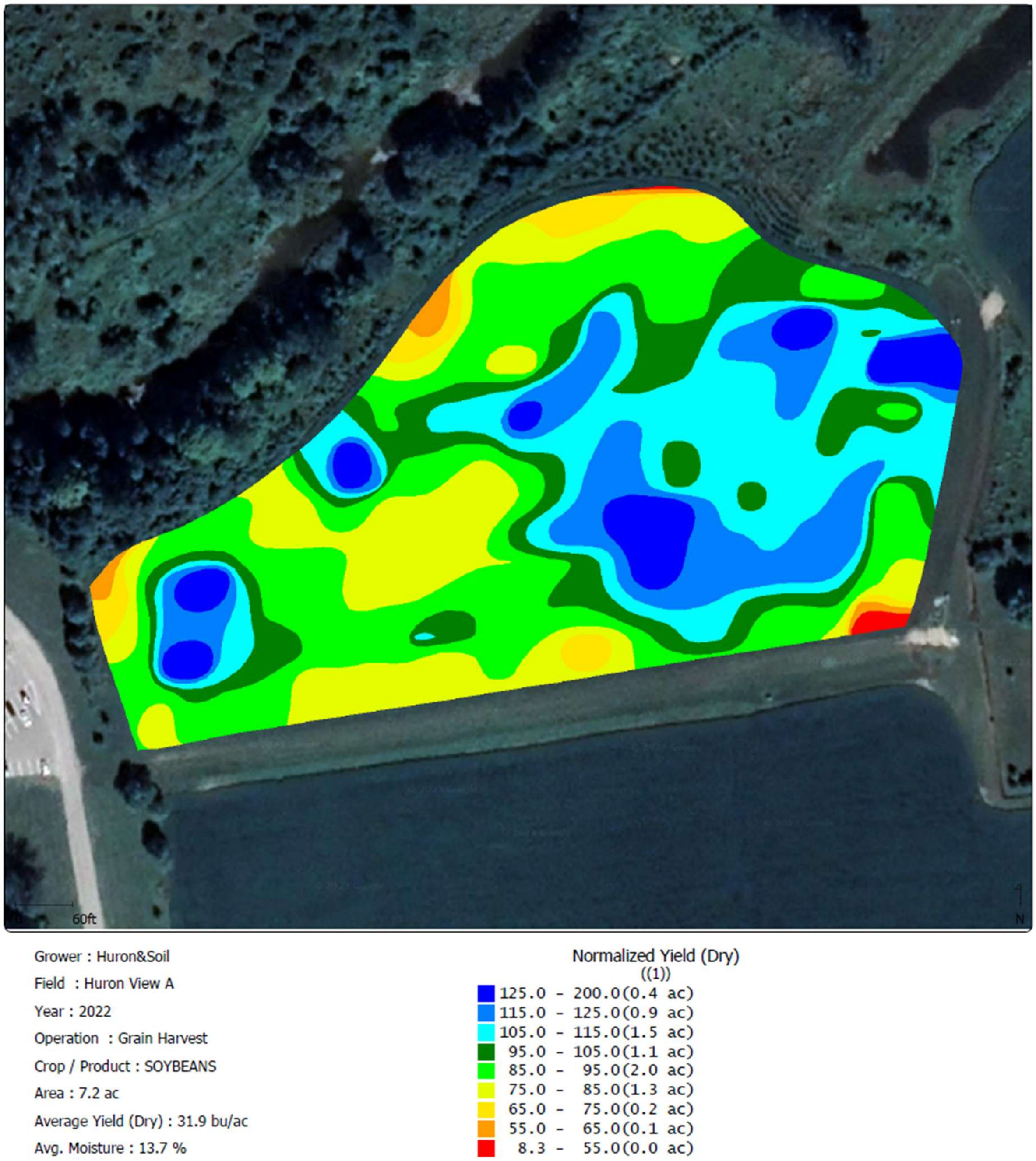

Figure 19. Crop yield from the Huronview EOF Site Field A from soybeans grown in 2022. Beans were planted after a sizeable mixed-species cover crop was grown. The cover crop was terminated via roller-crimper in spring and beans were initially planted without tillage. The field was sprayed weeks later and replanted.

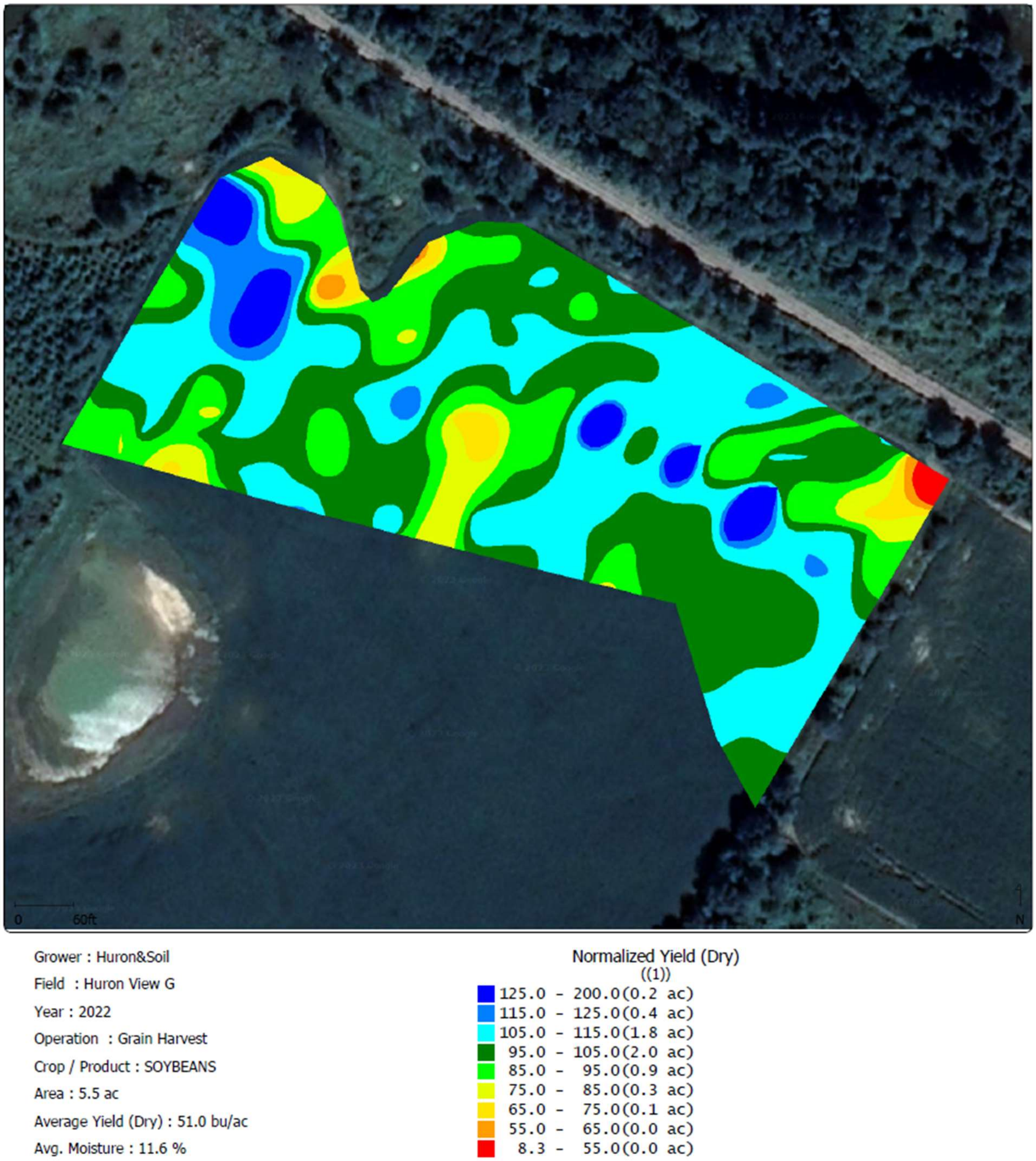

Figure 20. Crop yield from the Huronview EOF Site Field G from soybeans grown in 2022. Beans were planted after a sizeable mixed-species cover crop was grown. The cover crop was sprayed in the spring and strip tilled prior to planting.

3.4 Water quality trends following nutrient application at Fairview

As a newer ONFARM Edge-of-Field monitoring site, Fairview has a shorter record of water quality history to look back on, unlike sites like Kettle and Gully described in sections 3.1 and 3.2, where the multi-season records are enabling more comparable years for analysis. As well, Fairview has the challenge of not being physically able to apply and monitor paired treatment effects on water quality. But what can be evaluated here is the impact of field management practices on runoff events over time, and the wet summer of 2024 produced more runoff events than is typical for the growing season (shown in Figure 21). Previous ONFARM Water Quality Technical reports have identified the non-growing season as the predominant time for nutrient loss, however, periods of heavy precipitation can regardless of time of year, drive large losses.

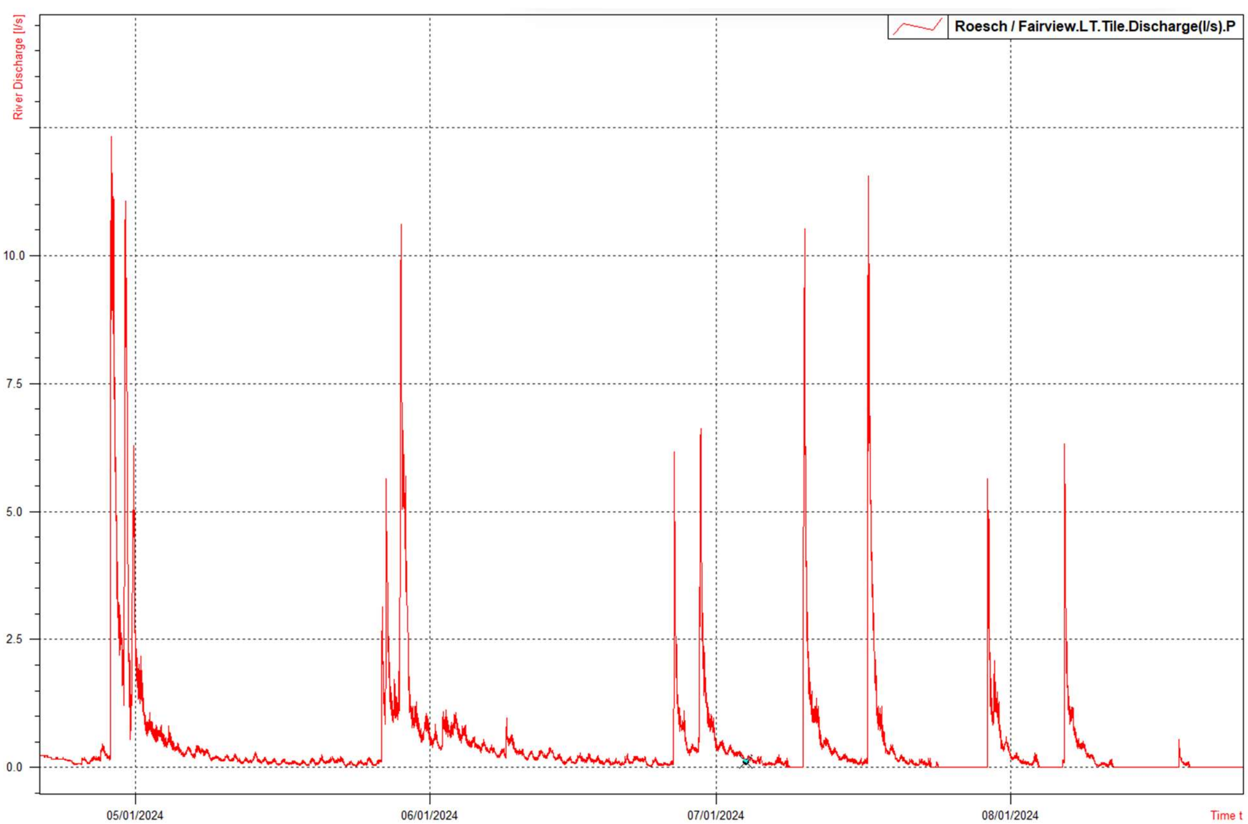

Figure 21. Continuous monitoring of tile discharge in L/s from the Fairview site in the summer of 2024.

Tile monitoring captured four runoff events (an event shown in Figure 21 at the end of May was missed by equipment failure) which occurred: April 10-17, June 26-29, July 10-16, and Aug 6-11. The April event captured conditions prior to the planting of white beans (June 20) which was preceded by a nitrogen fertilizer broadcast (urea at 70 lbs/ac) and an organic amendment (liquid hog manure at 4000 gal/ac) which were both incorporated in early June. Therefore, the three events following the nutrient application show its impact, and give insight into how long that supply of nutrients may continue to be exported into the surface water system.

It is notable that of the four events detailed in Table 11, the pre-app event in April had the greatest amount of discharge at 715,000 L, while the first event after application had the lowest at 201,000 L. Not unexpectedly, the greatest amount of discharge did not lead to the highest losses of phosphorus and suspended sediment (TP shown in Figure 22), which occurred during the events after the application (TP from June 26 shown in Figure 23). It is clear from the second and third events that the impact of nutrient application lead to an increase in loads, even with the implementation of incorporation as a BMP. The biggest impacts were on TSS and TP, driven mostly by the increase in PP rather than DRP. Both TSS and TP had their greatest losses during the third event; confirming the impact of fertilizer application was not immediately dismissed by the first flush, and has the potential to be long lasting. However, this may be related to the size of the second event being quite small in comparison to events one and three and therefore not substantial enough to move the nutrients that were available. By the third event in August, nutrient loads were lower across all parameters even compared to the first pre-application event, confirming the application of nutrients would not continue affecting loads longer into the growing season.

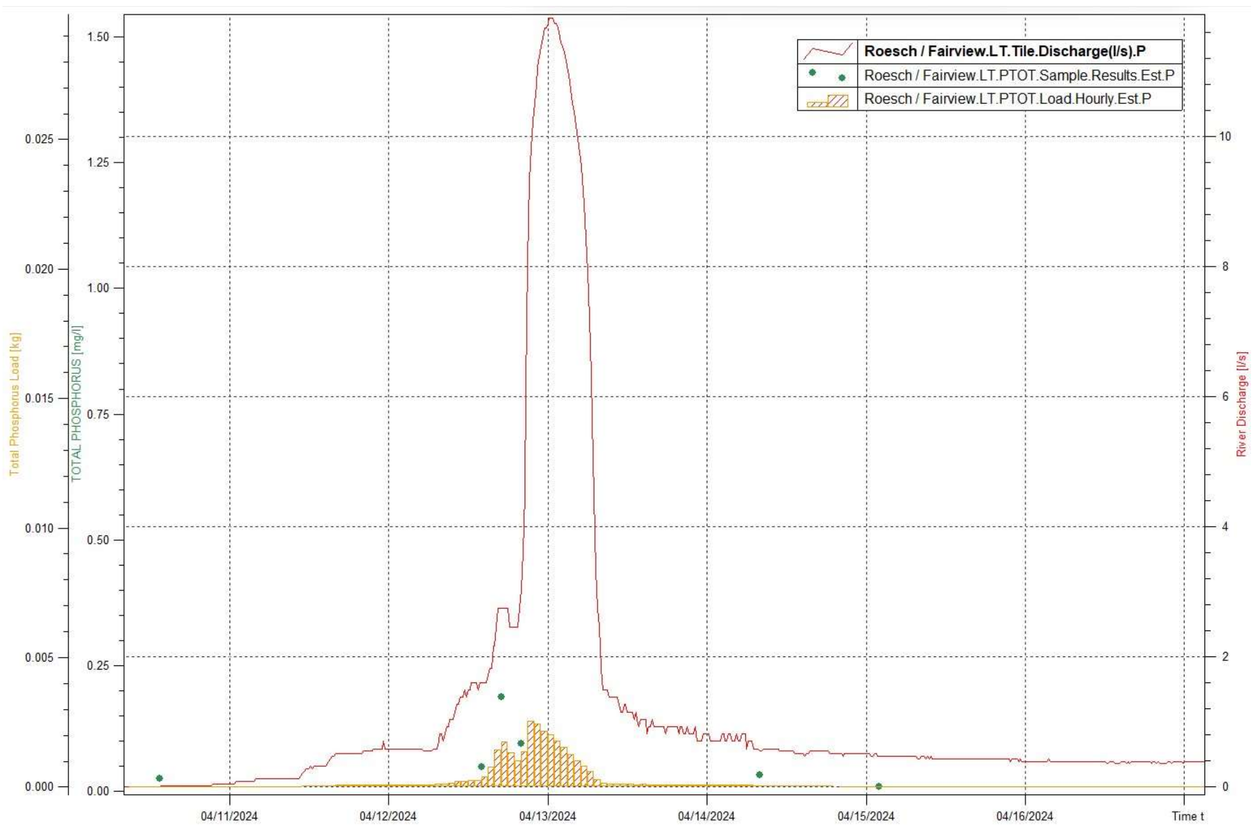

Figure 82. Tile discharge, measured total phosphorus (TP) concentrations, and calculated TP loads from Fairview's tile April 2024.

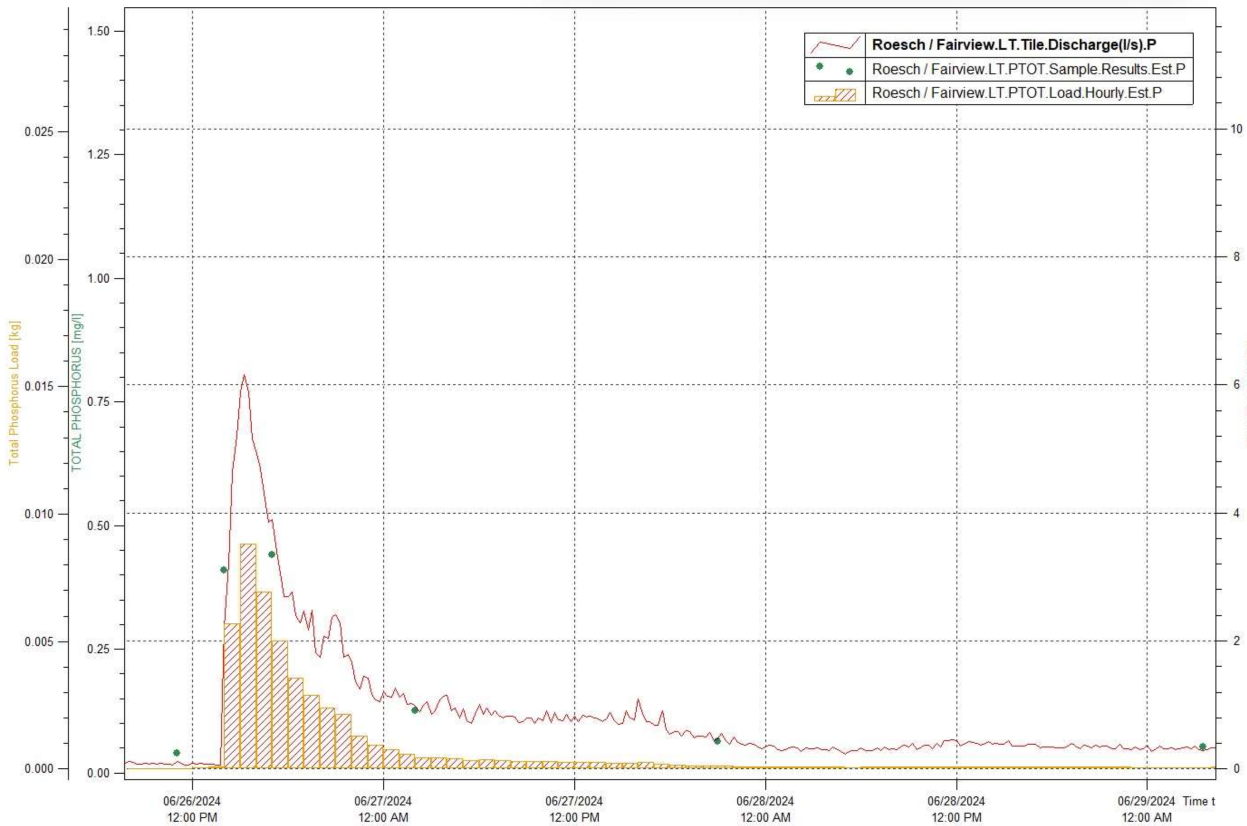

Figure 93. Tile discharge, measured total phosphorus (TP) concentrations, and calculated TP loads from Fairview's tile June 2024.

The loss of phosphorus being driven more by particulates than the dissolved reactive fraction combined with high losses of TSS suggest that loading may have been driven by other field conditions at this time. The limited increase in DRP at the second event is not unexpected; there was no phosphorus included in the fertilizer and much of the phosphorus applied in manure would have been held in the organic fraction. Instead, it appears sediment losses may have increased from the soil disturbance of incorporating the fertilizer and the minimal ground cover provided by the young beans which struggled to establish in with spring ponding occurring. However, this is not to suggest that incorporating was the wrong management choice – it is far more likely that nutrient losses would have been greater that way, an example of this impact can be seen in the 2022 ONFARM Water Quality Technical Report from monitoring at the retired Garvey Glenn EOF site when manure was spread shortly before a rain event.

Table 11. Water quality parameters loads from four events captured at Fairview in 2024.

Field	Event Start	Discharge (L)	TSS (kg/ha)	TP (kg/ha)	DRP (kg/ha)	PP (kg/ha)
Fairview	2024-04-10	714,850	0.50	0.0031	0.0013	0.0018
Fairview	2024-06-26	201,717	1.05	0.0048	0.0013	0.0035
Fairview	2024-07-10	440,309	1.30	0.0050	0.0021	0.0029
Fairview	2024-08-06	249,901	0.43	0.0017	0.0006	0.0011

These results demonstrate the potential for specific times of year to act as hot moments for nutrient loss, in this case following spring nutrient application on bare soils. Acknowledging that good management was followed by applying nutrients at the right time (shortly before planting) and in the right place by incorporating, and there was still nutrient loss through tiles shows how important it is to continue developing BMPs that supports this sensitive time of year, i.e. maintaining greater levels of soil residue until the crop developed and timing nutrient application as close to planting as is feasible. Transitioning to new technology that enables manure application in-crop rather than strictly pre-plant may avoid the opportunity for nutrient losses during these wet, unprotected spring periods. Additionally, it should be recognized that application of organic amendments is an important management practice for supporting soil health and more broadly, environmental sustainability in agriculture, despite the challenges managing their application with improving water quality. Capturing future runoff events at this field will contribute to our understanding of the impact of fertilizer and manure management on nutrient loads, and how these events occurring in the growing season compare in magnitude to runoff in the non-growing season.

4. Next Steps

4.1 Lake Erie Enhanced Analysis of Agricultural Practices

On February 4, 2025, OSCIA announced the launch of the Lake Erie Enhanced Analysis of Agricultural Practices (LEEAAP) research program. Funded by the Canada Water Agency’s Great Lakes Freshwater Ecosystem Initiative’s Lake Erie Substream, the four-year program will support enhanced data analysis of data collected from ONFARM and GLASI, and will establish a standardized framework for water quality data management and analysis to support water quality specialists and conservation industry professionals. Results will be mobilized through LEEAAP and ONFARM to continue supporting Ontario farmers with current knowledge on implementing agricultural BMPs.

5.0 Conclusion

The long-term implementation of ONFARM monitoring at these edge-of-field sites is enabling our researchers to look back at a range of historical conditions, and we are now beginning to analyse trends appearing over time and between similar parts of each farm’s rotation. Capturing this variety of cropping information, weather, water movement, and water quality data is enabling further insights into the impacts of best management practices (BMPs) on water quality parameters.

Results have shown the impact cover crops can have on these sites, by holding back water from rain and preventing surface runoff, and by greatly reducing the amount of total suspended sediment (TSS) and total phosphorus (TP) carried off fields when runoff does occur. However, results have also been clear that cover crops are not a simple or guaranteed solution for managing water quality concerns. A poor cover crop catch can provide limited benefits for reducing TSS, and conversely, a strong catch can increase the amount of dissolved reactive phosphorus (DRP) despite the TP reduction. As well, cover crops may cause management issues in the spring that may not work with preferred tillage or planting plans. Springtime is also a period where field management can have a substantial impact on nutrient loss as fertilizer applications and tillage leave a field susceptible to nutrient loss before the crop stand develops, and future BMPs should be considered to minimize this risk.

ONFARM cooperators continue to manage these challenges as they occur, continue building our collective understanding of the best practices and implementation methods to support environmental benefits and agronomic success together. To stay up-to-date on ONFARM activities, and to view other technical reports on soil health trials and reports from previous years, please visit the ONFARM Web Page.