ONFARM

Soil Health Technical Report: 2024-2025

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SRG
SOIL RESOURCE GROUP

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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 and yield 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.

1.0 Introduction

1.1 Program Description

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 has been renewed for continuation through 2028. The program's renewal will allow 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 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.

All previous technical reports can be found on the ONFARM Web Page.

1.2 Organizational 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; however, 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 water quality component in their respective PSP watersheds.

The ONFARM program is being implemented on working farms across the province in collaboration with partner organizations and cooperating farmers at the 32 research sites. Each 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 Soil Health BMP Trial sites. Twenty-two of the original 25 sites are being continued and 3 new sites were added in 2024, including two new sites in Northeastern Ontario and one in the Eastern Ontario region. Additionally, there are 7 Edge of Field (EOF) water quality monitoring sites, including one established in 2024. The location of each ONFARM site is shown in Figure 1.

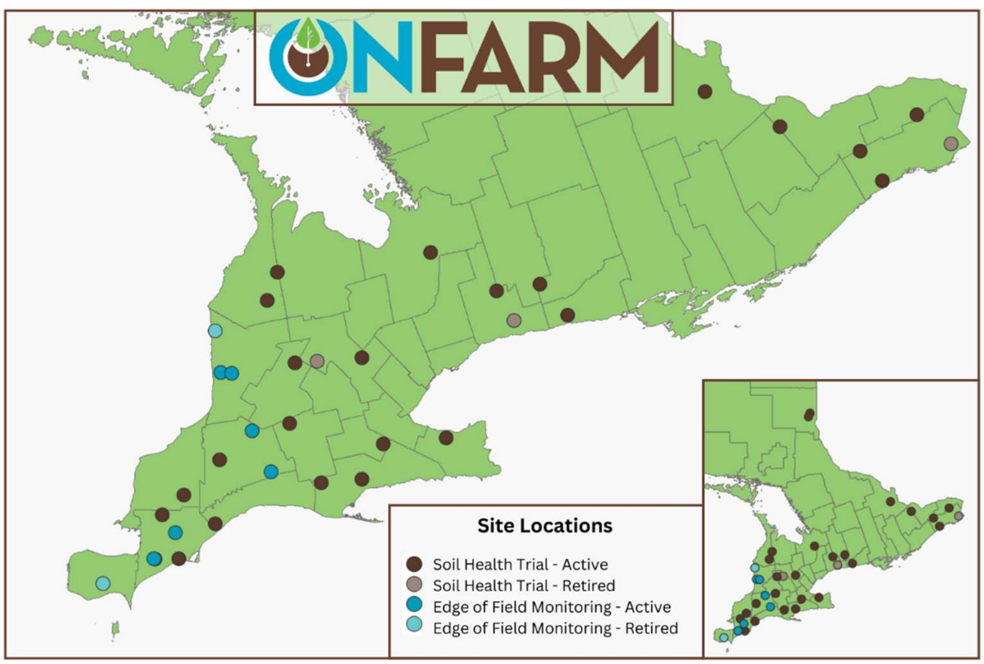

Figure 1. Map of ONFARM sites by type in 2024

2.0 Soil Health Research

2.1 Overview

ONFARM's Soil Health Research and Monitoring component continued investigation at the network of on-farm side-by-side trials across Ontario. The purpose is to better understand and enhance Ontario's agriculture sector's knowledge of:

- The efficacy of soil health related BMPs across the wide variety of Ontario soil types, cropping systems, climatic conditions etc.
- The potential for using novel indicators as a measure of soil health, and recommendations for their adoption in Ontario
- BMP impacts on soil health, soil degradation, and water holding capacity, and how these parameters ultimately affect crop performance and quality.
- Soil health related BMPs impact on on-farm profitability and return-on-investment.

These sites represent the wide range of soil types found across the province and the variability of soils and potential degradation which may be found within a field. The sites capture differences in landscape features at three slope positions of upper, middle and lower that represent predominant soil landscape combinations that may be used for broader regional interpretation.

2.2 Cooperator Field Sites

Soil health investigations continued in 2024 at the Edge-of-Field (EOF) and BMP Trial cooperator field sites. In total, there were 7 EOF sites and 25 BMP Trial sites actively managed. The distribution of grain farms and livestock farms in 2024 in the BMP Trial is shown in Figure 2.

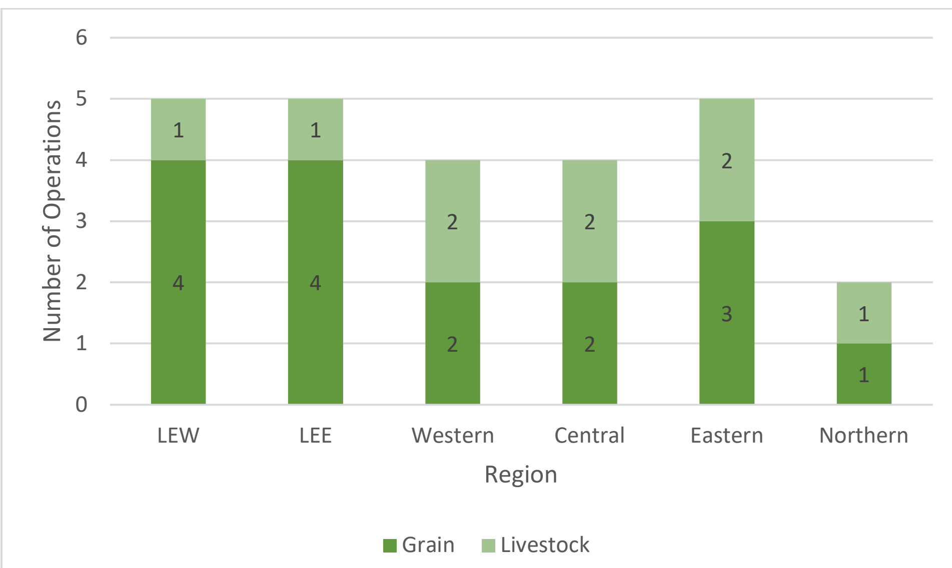

Figure 2. BMP Trial operation type by region in 2024

In 2024, three new BMP sites (one in Eastern Ontario and two in Northeastern Ontario) and one new EOF site in Chatham-Kent area were established. The new BMP site added to the Eastern Region is a grain farm operation with an undulating landscape and coarse loamy soil type. The field site has varying degrees of soil degradation, organic matter and fertility. The BMPs to be implemented at the site are an organic amendment, a cover crop and the combination of both BMPs in establishing three side-by-side BMP treatment field strips and a business-as-usual control treatment strip.

The two new BMP sites in Northeastern Ontario were established in the spring of 2024. Expanding ONFARM research into Northern Ontario allows the inclusion of different climate, soil types, and management systems and consideration of how these regional differences may impact soil health indicators and BMPs. One of the sites is a livestock operation with an undulating to rolling landscape and fine loamy soil types with evidence of soil erosion and varying levels of organic matter. The BMPs first implemented at the site in the fall were an organic amendment, cover crops and the combination of both BMPs to establish three BMP treatment strips and a control treatment strip. The second new site is a grain farm on a gently undulating to level landscape with fine loamy soil type of different drainage types and varying soil erosion and organic matter levels. BMPs were implemented at the site in the fall of different cover crops and different tillage levels along with a control treatment.

The new EOF site is at a beef livestock operation on a nearly level field site with fine loamy soil type with evidence of severe compaction. The BMPs implemented over the site were organic amendment application and minimum tillage. The Lower Thames Valley Conservation Authority (LTVCA) is monitoring water quantity and quality leaving the site.

2.3 Data Collection

Annual data collection at all the cooperator sites included field crop and BMP management information, agronomic monitoring activities, field and laboratory soil health indicator measurements, and field management records. Information from the BMP Trial sites collected annually is reported below.

The BMP Trial sites were selected for their ongoing management under no-till or some form of reduced tillage. Project BMPs of interest to cooperators to investigate include cover crops or organic amendments, and combinations of both (Table 1). Management of the BMPs at each site therefore differs between practices such as cover crop seeding rates and establishment methods, species and blends of cover crops, timing of planting and termination. Prior to the 2024 cropping season, cover crops were established at 12 sites by the fall of 2023. Organic amendments that included manure (generated both on and off-farm) or non-agricultural source materials were applied at 10 sites prior to the 2024 crop. The large number of sites that were able to implement a BMP prior to the 2024 cropping season was due to many sites having grown wheat in 2023, that allowed time in the late summer and fall to plant a cover crop and/or apply an organic amendment.

Table 1. ONFARM soil health BMP trial site cropping and BMPs in 2023 and 2024.

Site	Crop 2023	BMPs 2023 (pre 2024 crop)	Crop 2024	BMPs 2024 (pre 2025 crop)
1	Soybeans	(winter wheat fall 2023)	Winter Wheat	Cover crop
2	Soybeans		Corn	
3	Corn		Corn	Cover crop
4	Winter wheat	Cover crop, organic amendment	Sorghum-Sudangrass	Cover crop
5	Soybeans	Cover crop	Corn	Cover crop
6	Soybeans	(winter wheat fall 2023)	Winter Wheat	Cover crop, organic amendment x2
7	Winter wheat	Cover crop	Corn	Cover crop
8	Sunflowers		Corn	Cover crop (interseeded, post-harvest)
9	Corn	Interseeded cover crop	Soybeans	
10	Corn		Corn	Cover crop
11	Winter wheat	Cover crop, organic amendment	Corn	
12	Soybeans	(winter wheat fall 2023)	Winter Wheat	Cover crop, organic amendment
14	Winter wheat	Cover crop, organic amendment x2	Corn Silage	Cover crop, organic amendment
15	Winter wheat	Cover crop, organic amendment	Corn	
17	Winter wheat	Cover crop, organic amendment	Corn	
18	Winter wheat		Corn	
19	Winter wheat	Cover crop, organic amendment	Corn	
20	Soybeans	Organic amendment	Corn	Interseeded cover crop
21	Soybeans	Cover crop, organic amendment	Spring Canola	Organic amendment
23	Spring wheat	Cover crop, organic amendment	Corn Silage	Organic amendment
24	Winter wheat	Cover crop, organic amendment	Corn	Cover crop
25	Adzuki beans	(winter wheat fall 2023)	Winter Wheat	
26	-		Soybeans	(winter wheat fall 2024)
27	-		Oats	Organic amendment
28	-		Dry Peas	Cover crop

The annual agronomic monitoring program was initiated in the spring and continued through harvest time at all BMP Trial and EOF site benchmark sampling locations in 2024. Soil health samples and field measurements were taken from all the BMP Trial and EOF sites in similar sequence as in prior years from late May through end of June.

Cropping and management information continued to be recorded by the cooperator at each field site throughout the 2024 season, including economic data on the cost of inputs for BMP implementation. Economic information will be used for future ONFARM field profitability mapping investigation.

Cooperator data was collected in established record keeping sheets and from follow-up interviews after the season. Data collected over the 2024 season at each BMP and EOF site is summarized in Table 2.

Table 2. Annual data collection program at each ONFARM BMP and EOF location

Data Collected	
Treatment data	• Baseline/control (check) treatment specifications • Tillage and planting equipment changes – reduced tillage management • Crop/cover crop – species, rates, timing, control • Addition of organic amendments – type, source, characteristics (physical/chemical), calibrated rates, application method, timing
Benchmark data	Soil health tests: physical - bulk density, wet aggregate stability; chemical - Soil Organic Matter (SOM), fertility; biological - Solvita Labile Amino Nitrogen (SLAN), Solvita CO2 burst (respiration), Active Carbon (or permanganate-oxidizable carbon (AC or POxC)), Potentially Mineralizable Nitrogen (PMN), Autoclave-Citrate Extractable (ACE) protein
Agronomic data	Emergence and stand population, soil temperature, soil moisture, pest and disease pressure, nutrient deficiencies and toxicities, crop yield, cover crop biomass and/or crop residue
Economic data	BMP implementation costs, other field management costs, and crop yield

2.4 Soil Health Sampling

The georeferenced benchmark sampling locations established at each site in year 1 based on three distinct soil landscape positions across each of the side-by-side BMP treatment strips continue to be monitored and sampled annually. For the new BMP and EOF sites in 2024, georeferenced benchmark sampling locations were selected and sampled according to the established project protocols. Composite soil samples were collected in triplicate from three separate areas (a 'trillium' design) within a 2 m radius around each benchmark. The field plot design (Figure 3) allows for the statistical comparison of the benchmark results for three groups of analysis:

- influence of soil landscape position on soil health indicators (SHI)
- impact of different BMPs on SHI
- interaction effect of both landscape and BMP on SHI

The numbers of soil samples collected in 2024 for SHI analysis, as well as hand harvest yield samples, across the ONFARM study were:

- 7 EOF cooperator sites represented by 13 treatment field areas with 3 soil landscape zones with 3 benchmark location triplicates that total 117 samples, and
- 25 BMP trial cooperator sites of 99 treatments with 3 soil landscape zones with 3 benchmark location triplicates that total 891 samples.

The investigation initiated in 2023 to further assess soil health with the characterization of soil water availability at the monitoring sites continued in 2024. Soil core sampling for available water holding capacity (AWHC) analysis was completed in the fall of 2024 at two BMP Trial sites and one EOF site. In collaboration with the University of Guelph and the OSCIA, results of the analysis and these activities will be reported separately.

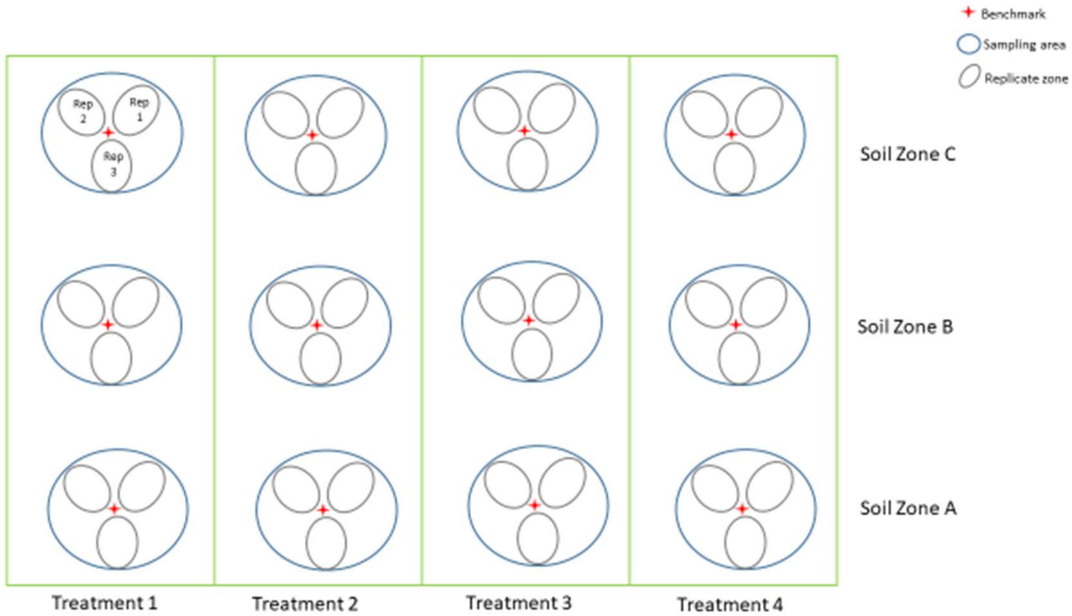

Figure 3. Conceptual sampling design at benchmark location of field treatment and soil zone/landscape position (upper, mid, lower) location

2.5 Soil Health Data Analysis 2024

Results of the 2024 laboratory analysis of soil health indicators at the BMP Trial sites continued to find significant variability within and between sites and, as in previous years, reflected the wide range of values of the various tests and range of site conditions. The SHI levels measured from the triplicate sampling zones immediately surrounding an individual benchmark at a site differed between tests in the level of variability. The overall variability of each SHI in each year and of the project to date were close to or below 10% (Table 3). The significant shift in variability in the Solvita CO2 burst and SLAN from 2023 compared to 2024 is likely due to changes in laboratory equipment in 2023.

Table 3. Variability of SHI test results from 5 years across BMP sites as % Coefficient of Variability (%CV)

Year	Soil Organic Matter (SOM)	Active Carbon (AC)	Solvita CO_2 Burst	ACE Protein (ACE)	Solvita Labile Amino Nitrogen (SLAN)	Potentially Mineralizable Nitrogen (PMN)	Aggregate Stability (AS)	Surface Bulk Density (BD)	Surface Soil Moisture
2020	6.9%	11.0%	5.6%	-	15.8%	36.6%	8.7%	6.2%	12.7%
2021	8.0%	8.1%	4.3%	-	11.5%	-	-	6.7%	11.4%
2022	6.0%	6.4%	5.3%	6.1%	15.3%	18.0%	5.0%	5.8%	9.0%
2023	6.2%	9.7%	24.1%	6.7%	13.4%	18.4%	7.3%	5.3%	11.3%
2024	6.4%	6.0%	4.1%	6.3%	4.4%	24.3%	3.8%	5.4%	6.2%
Overall	6.6%	8.3%	8.7%	6.3%	12.0%	24.2%	6.2%	5.8%	10.1%

To determine how well the different SHIs relate to the relatively stable SOM indicator, correlation analysis was conducted again in 2024. Across all the BMP sites, there were only a few strong correlations found between SOM and a SHI (Table 4). Active carbon and ACE protein continued to be highly correlated to SOM with increased SOM levels predicting increased AC and ACE protein levels. SLAN was moderately correlated to SOM in 2024, but the variability within the triplicate measurements of SLAN around a benchmark has been higher in previous years and further investigation of year-to-year variability is ongoing.

Table 4. Spearman or Pearson correlation coefficient for SH Indicators from all BMP site samples in 2024

	SOM	AC	Solvita CO_2	SLAN	PMN	AS	BD	
SOM								
AC	***0.73521***							
Solvita CO_2	0.49209	0.4402						
SLAN	*0.66754*	***0.75796***	0.42544					
PMN	0.29675	0.1753	0.44431	0.3332				
AS	0.31318	0.32216	0.23731	0.41776	0.00484			
BD	-0.41776	-0.44191	-0.37034	-0.37236	-0.19067	-0.06036		
ACE	***0.70214***	***0.70065***	0.38061	***0.70559***	0.27596	0.28167	-0.39612	

*Correlation coefficient > 0.7 (in green italics) is considered a strong correlation

Tracking the variability and correlations of the SHIs is being used to better understand how responsive each indicator is for detecting change in the soil over time. Soil health indicators observed in 2024 that have relatively low sampling variability and high correlation levels with SOM are AC and ACE protein. As in 2023, these indicators were the focus of further analysis. The figures below illustrate how stable AC (Figure 4) and ACE protein (Figure 5) have been over the last 3 years compared to PMN (Figure 6) which is more scattered and appears to shift between years, possibly in response to the differences in soil moisture and temperature conditions or crop in the period preceding soil health sampling.

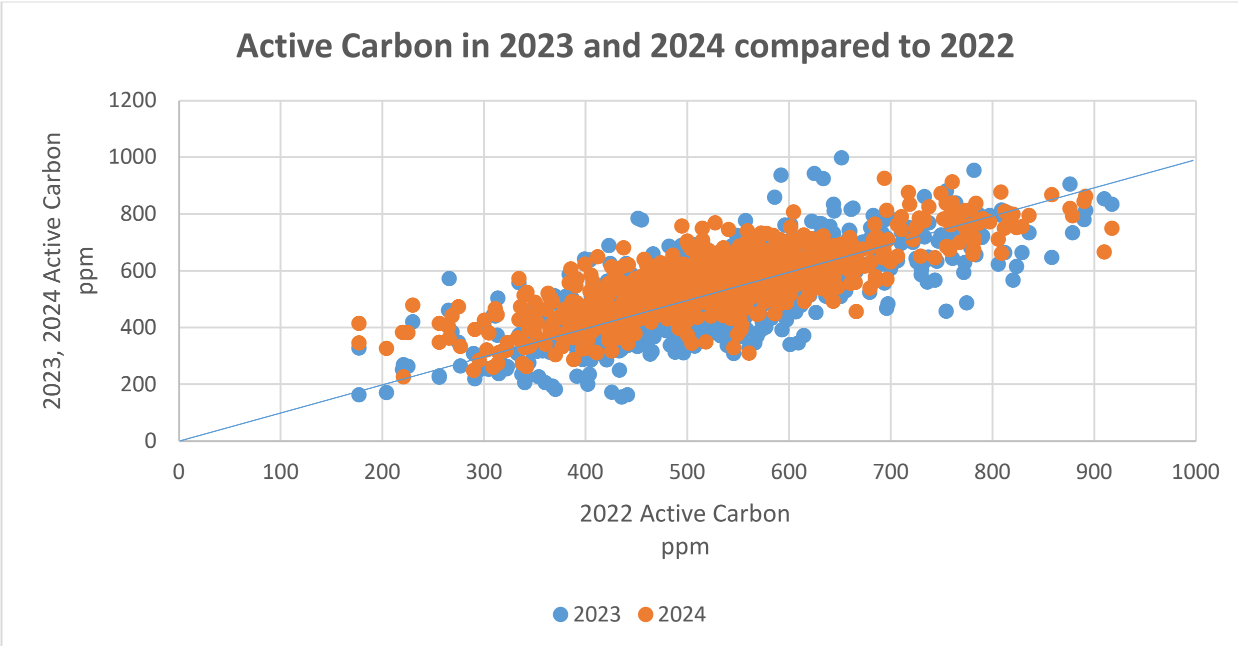

Figure 4. Active Carbon at all sites in 2023 and 2024 compared to 2022

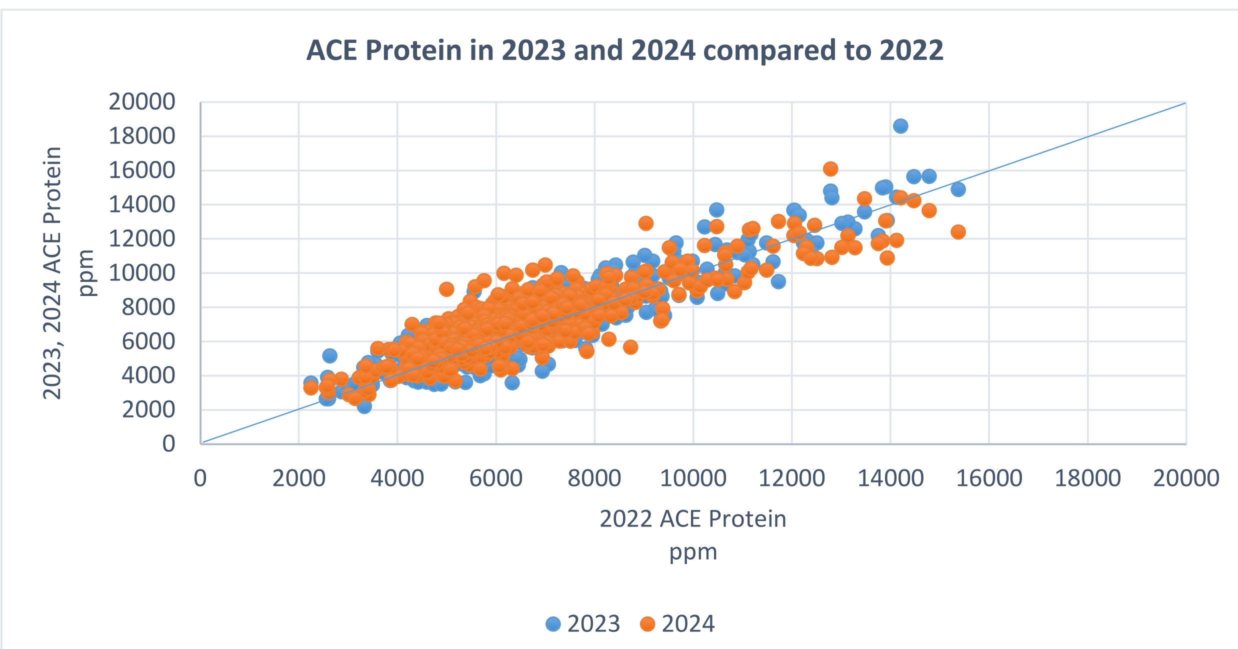

Figure 5. ACE protein at all sites in 2023 and 2024 compared to 2022

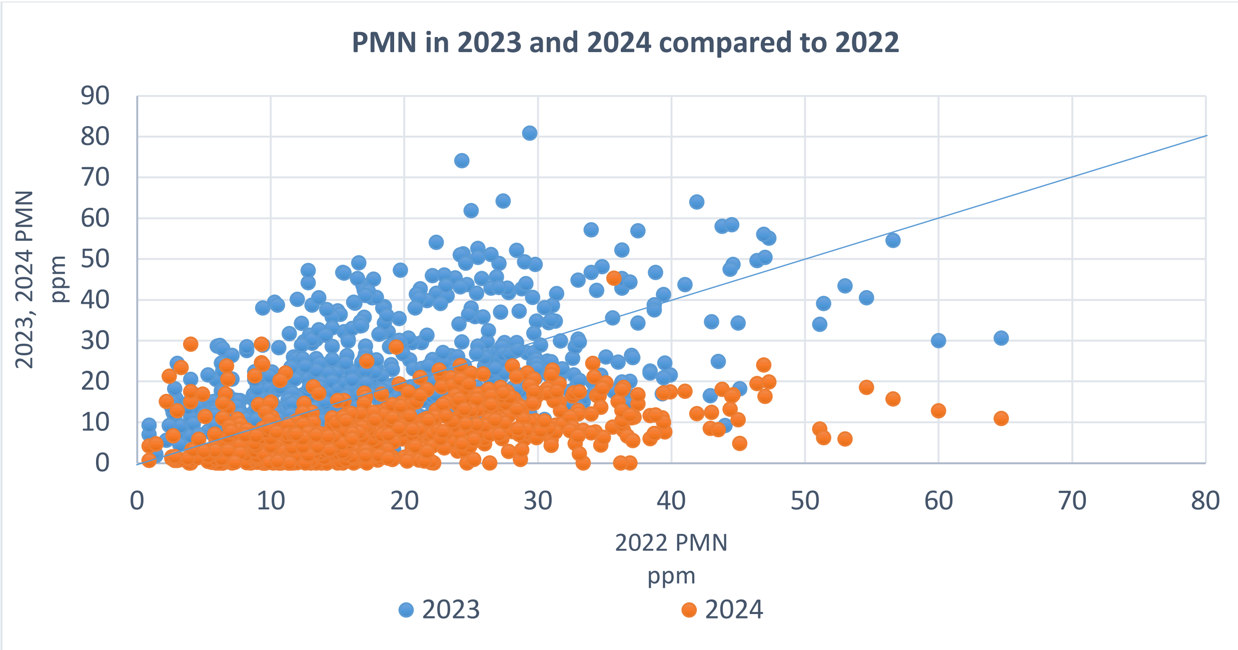

Figure 6: PMN at all sites in 2023 and 2024 compared to 2022

Initial investigation of SHI results from 2024, analyzed for differences between landscape position and BMP treatment across the sites, generally found similar findings to previous years where differences were largely site specific. Clear differences continue to be shown when comparing the three distinct soil landscape positions, with inconsistent differences observed with the influence of BMP treatment. Specifically, the lower landscape positions have higher SHI values for SOM, AC, and ACE protein on average across most of the BMP sites. Lower SHI values have been observed at many of the BMP site benchmarks affected by tillage erosion, topsoil loss and subsequent soil degradation at the middle and upper landscape positions. Figures 7, 8, and 9 illustrate the effect of landscape position on SHIs at the new Site 26 in 2024, which was again a finding across most sites in 2024.

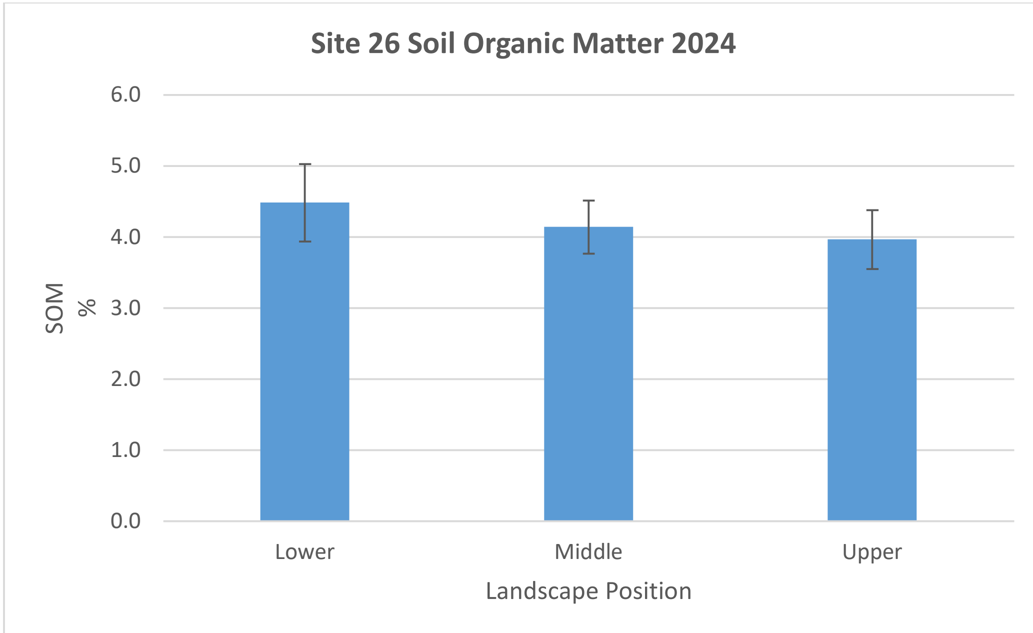

Figure 7: Site 26 Soil Organic Matter average and standard deviation across landscape position in 2024

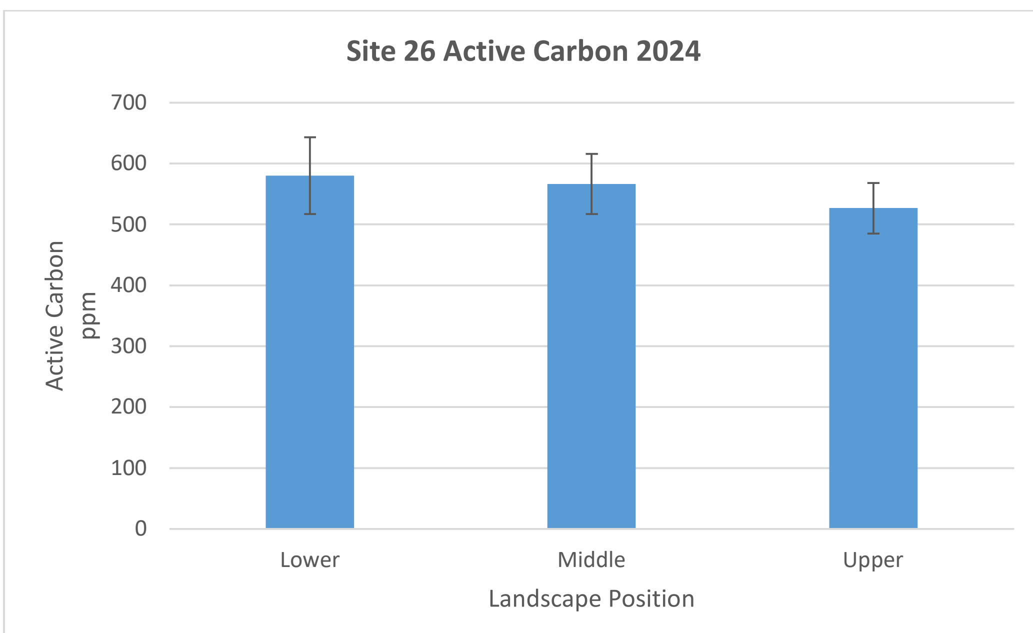

Figure 8: Site 26 Active Carbon average and standard deviation across landscape position in 2024

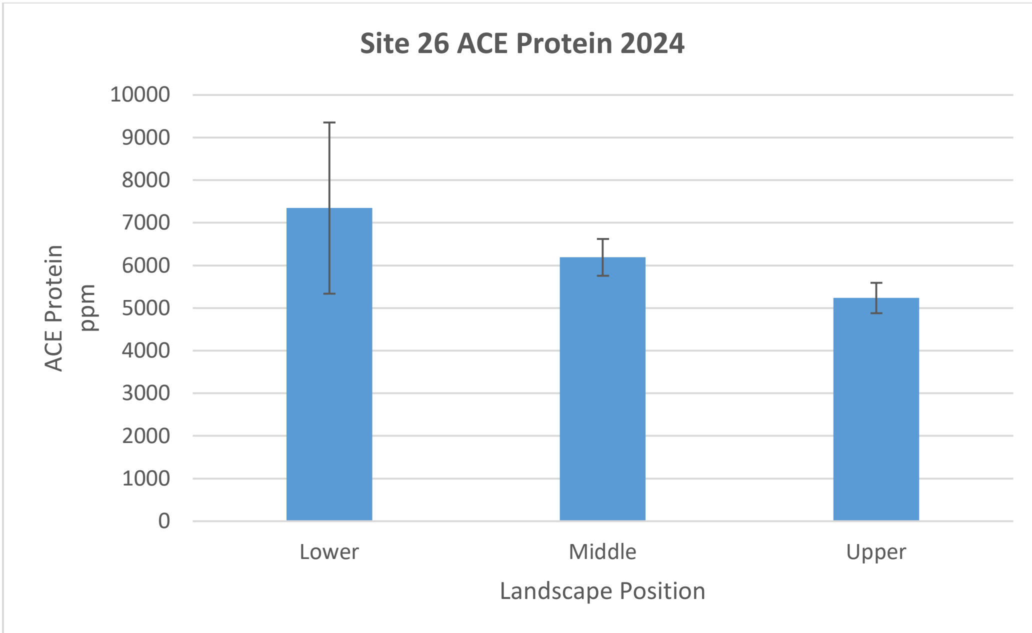

Figure 9: Site 26 ACE protein average and standard deviation across landscape position in 2024

The influence of landscape position continued to impact SHI measurements across all sites in 2024 for AC, ACE protein, Solvita CO_2 and SLAN (Figure 10, 11, 12, and 13; note that, for clarity, data from Site 21 with very high organic soils is not included in these graphs). The findings from year to year found the lower landscapes typically have higher SOM which often relate to higher SHIs. The opposite occurs at the upper landscape positions across sites where SOM levels are lower and is often associated with observed soil loss and degradation.

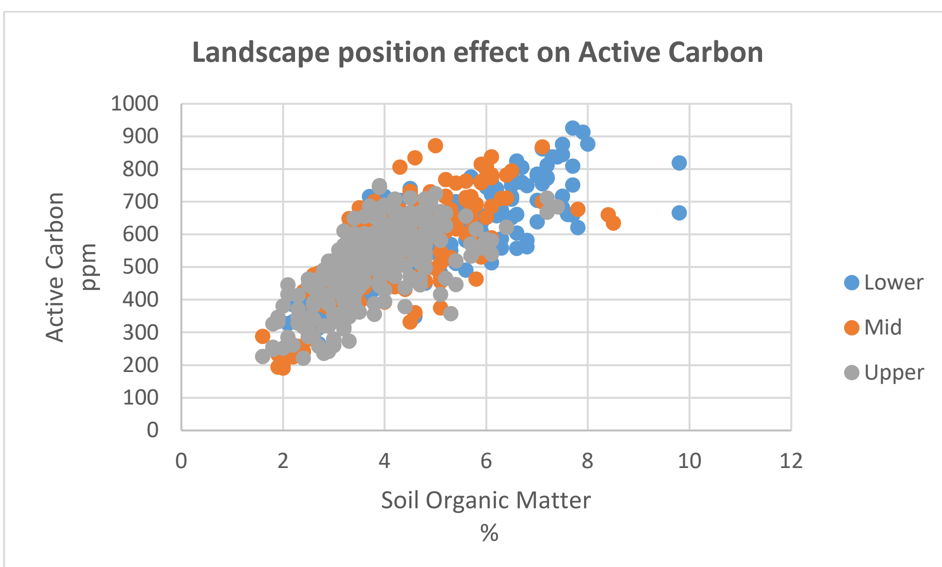

Figure 10: Active Carbon measurements vs Soil Organic Matter at each benchmark across 24 sites in 2024

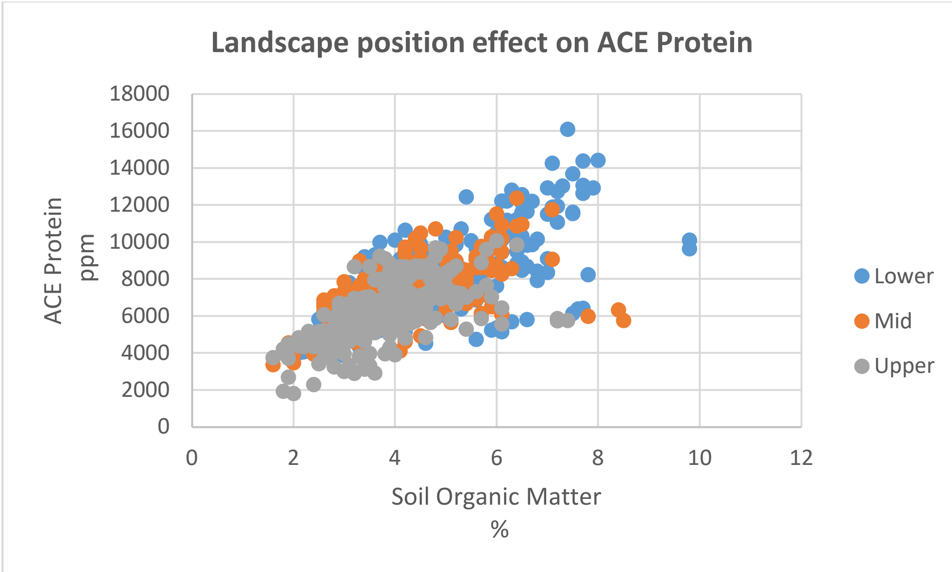

Figure 11: ACE protein measurements vs Soil Organic Matter at each benchmark across 24 sites in 2024

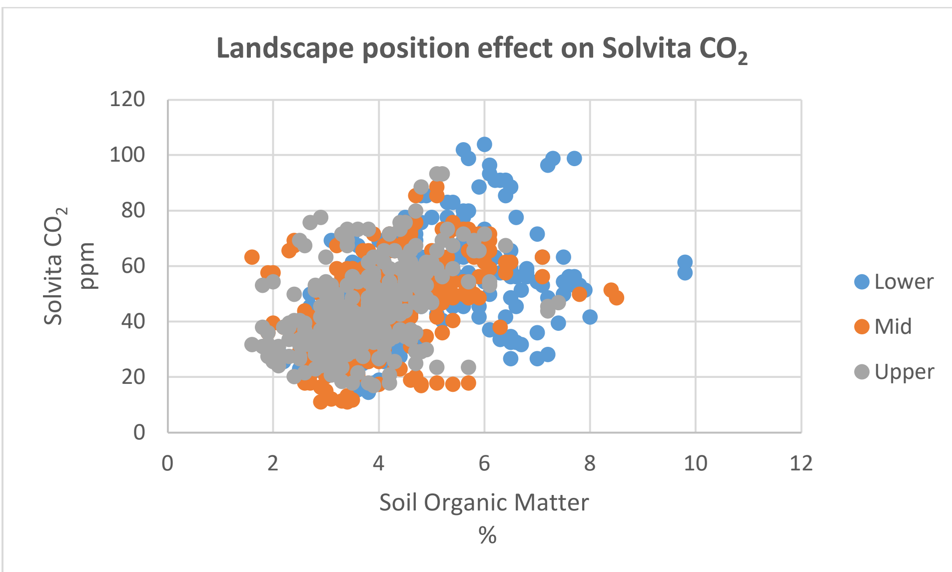

Figure 12: Solvita CO_2 measurements vs Soil Organic Matter at each benchmark across 24 sites in 2024

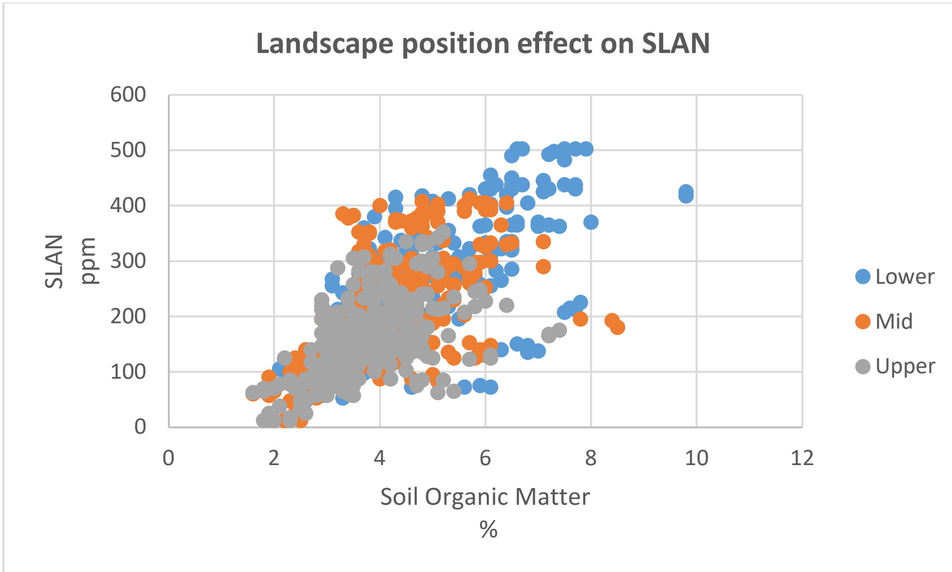

Figure 13: SLAN measurements vs Soil Organic Matter at each benchmark across 24 sites in 2024

As shown above, the influence of landscape position on SHI measurement is a strong and dominant factor. To measure a significant BMP treatment strip effect, it would require a large impact on SHIs over an entire treatment strip that spans the 3 contrasting landscape positions. Results from all the 2024 data for SOM, AC, or ACE protein indicated there were no instances where a BMP treatment strip overall was statistically different from the control treatment strip. Given the strong influence of landscape, BMP treatments were compared across similar landscape zones rather than comparing treatments across all 3 landscape positions.

To compare data at a landscape zone level, a multivariate ANOVA analysis is completed each year with the baseline 2020 site data being considered as a covariate within the analysis. The BMP treatment effect, landscape position effect, or the interaction effect of the influence of the two factors together (landscape x treatment) on each SHI is determined. A BMP treatment that is significantly different from the control treatment is reported as a BMP treatment effect, and differences between the lower landscape position and the potentially more degraded middle and upper slope positions is considered a landscape position effect. The interaction effect, or differences between individual benchmarks across the site, that is being analyzed in this study are the differences between the same landscape position within a treatment versus the same landscape position within the control (i.e. benchmark 1A vs benchmark 2A in Figure 3, assuming 2A is in the control strip).

There was a notable increase in 2024 in the frequency of significant statistical differences at the individual benchmark scale, which considers the influence of BMP treatment and landscape position together as the interaction. Investigation of benchmark differences between the BMP treatments and the control indicated BMP treatment effects occurred more often at one landscape position over another within the field. To illustrate some of the benchmark effects observed in 2024, a case study from Site 6 is presented below.

2.6 BMP Case Study

Site specific discussion of the 2024 results considers the field plot of Site 6 and the treatment effects of its BMP management history over the last 5 years of ONFARM. Site 6 is a dairy livestock operation located on a coarse loamy soil in ONFARM's Lake Erie East region of Ontario, near Woodstock. The site has had a crop rotation of winter wheat - silage corn - grain corn - soybeans - winter wheat from 2020 to 2024. BMP treatments applied in each crop year by the cooperator included seeding cover crops and applying two types of organic amendment to compare with the non-BMP control treatment (Table 5). Site 6 has had frequent and intense BMP implementation, with rates of amendment applications between 2900-4200 Imp.gal/ac (3500-5000 US gal/ac), and cover crops generating up to 2.1 t/ac of biomass (Figure 14). Cover crops were harvested and used for livestock feed.

Table 5. ONFARM BMP trial design and history of Site 6

Year and Crop	Treatment 1 Organic Amendment 1 (OA)	Treatment 2 Organic Amendment 2 (OA)	Treatment 3 Organic Amendment 2 + Cover Crop (OA+CC)	Treatment 4 Control	Treatment 5 Cover Crop (CC)
2020 Winter wheat	Manure OA (fall)	Digestate OA (fall)	Digestate OA + Oats CC (fall)	none	Oats CC (fall)
2021 Silage Corn	Manure OA (spring)	Digestate OA (spring)	Digestate OA + Rye CC (fall)	none	Rye CC (fall)
2022 Corn	Manure OA (spring)	Digestate OA (spring)	Digestate OA (spring)	none	No BMP
2023 Soybean	No BMP (winter wheat)	No BMP (winter wheat)	No BMP (winter wheat)	none	No BMP (winter wheat)
2024 Winter Wheat	Manure OA (fall)	Digestate OA (fall)	Digestate OA (spring) + Rye CC (fall)	none	Oats CC (fall)

Figure 14. BMP treatment photos at Site 6 of: a) liquid digestate application and cover crop; b) post winter wheat cover crop; c) and cover crop harvest for feed.

The addition of frequent and intense BMP treatments over time was found to have an impact on SHI measured in 2024. SHI values that have generally shown more stability from year to year (SOM, AC and ACE protein) were observed to be statistically higher in 2024 in strips where organic amendment applications had occurred (with or without the cover crop) than in the control treatment. This effect was observed at all three landscape positions (Table 6). At the more severely degraded upper landscape position, there were fewer SHIs differences, and no statistical differences in SHI measurements found from the control for the cover crop treatment or for the cover crop and organic amendment treatment. The statistically higher SHIs of the middle and lower landscape positions could suggest that by year 5 of the study at this site, the BMP treatments with greater additions of organic carbon and nitrogen may have had a greater effect on increasing the soil organic carbon and organic nitrogen. More time may be required to see measurable changes at the upper landscape position due to greater soil degradation conditions.

Table 6. Significant increase in soil health indicator values by BMP treatment and by landscape position at the benchmark level at Site 6 in 2024

	Treatment 1 OA1	Treatment 2 OA2	Treatment 3 OA2+CC	Treatment 4 Control	Treatment 5 CC
Lower	SOM, ACE	SOM, ACE	SOM, ACE		SOM
Mid	SOM, AC, ACE	AC	ACE		SOM, ACE
Upper	AC, ACE	AC			

Differences determined at the benchmark scale is the level of evaluation most appropriate for assessing treatment effect and is often the level that the statistical analysis requires based on the results of the statistical model. However, tracking changes in the SHI levels of a treatment from year to year also provides insight into whether indicators are increasing steadily over time with BMP implementation at the field scale given that crop and weather conditions are often different. Comparing AC over time at Site 6 shows fluctuations in AC across the treatments strips from year to year (Figures 15). However, the general trend over time shows AC in the OA and OA+CC treatments gradually increasing (particularly OA2 and OA+CC), likely due to the greater input of readily available carbon with frequent and intense BMPs. The control treatment strip without the addition of carbon-based treatments appears not to be increasing in AC. A similar trend is observed in the ACE protein test over the three years it has been measured, whereby the control treatment has the lowest measured ACE protein level while the treatments with OA additions generally have the highest level (Figure 16).

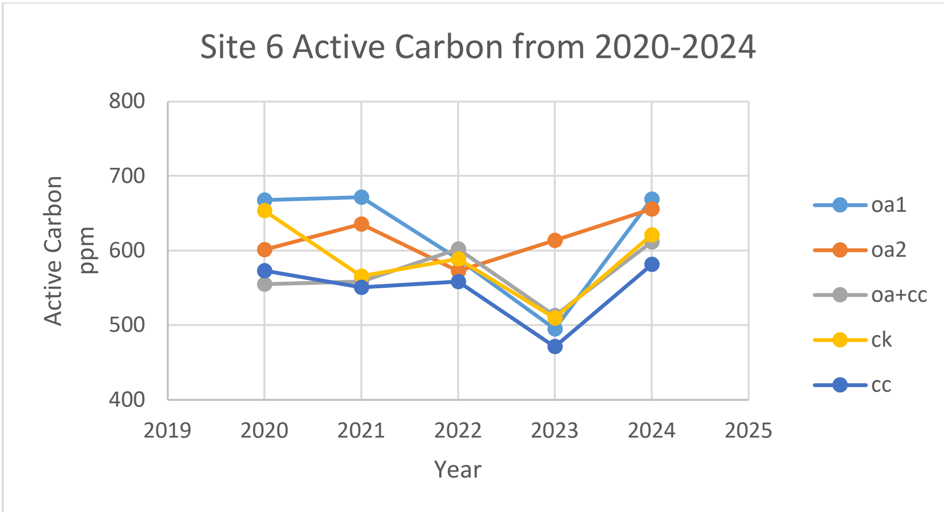

Figure 15: Active Carbon measurements in the treatment strips from 2020-2024 at Site 6

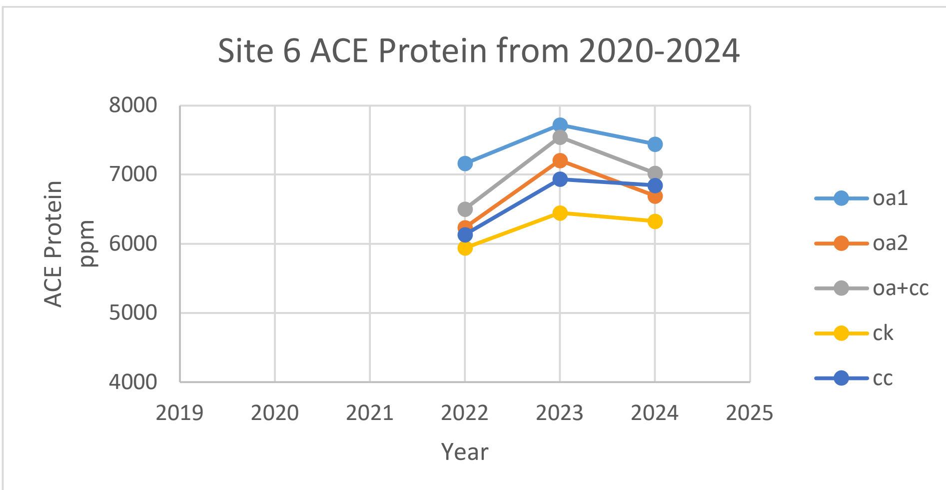

Figure 16: ACE Protein measurements in the treatment strips from 2020-2024 at Site 6

2.7 Yield Monitoring

Along with the annual monitoring of soil health indicators, crop monitoring and yield measurements were completed at all benchmark locations to compare treatments. Over the five years of the project, yield reductions often correspond to areas of soil degradation; however, it is often not a reliable measure of soil health year to year across the network of sites. Overall, correlations of yield with any of the SHIs across the sites are poor at <0.4 and often negative (Table 7).

Table 7. Spearman or Pearson correlation coefficient for yield at all sites (n=819) from 2020-2024

Yield	SOM	Active C	Solvita CO_2	SLAN	PMN	AggStab	BD	ACE
2020	-0.04033	-0.08157	-0.10733	-0.06708	-0.0296	-0.03877	-0.09351	nd
2021	-0.11845	-0.06939	-0.03372	0.02318	nd	nd	0.1118	nd
2022	0.09245	0.07523	-0.21934	0.08146	-0.0059	-0.16307	-0.2049	0.13336
2023	-0.14883	0.0032	-0.00915	-0.06640	0.06919	-0.15449	-0.00071	-0.11351
2024	-0.20078	-0.00764	-0.39654	0.03576	-0.27597	-0.05232	0.21047	-0.0793

Annual crop productivity potential can be significantly influenced by genetics, crop inputs, and available soil moisture. In 2024, early season moisture conditions were higher than previous years at many sites. There continued to be adequate moisture throughout the growing season which often lowered water stress at the upper more degraded landscapes resulting in lower yield differences between the landscape positions compared to other years. As an example, annual yield differences by landscape position are shown for Site 11 in Figures 17, 18, and 19.

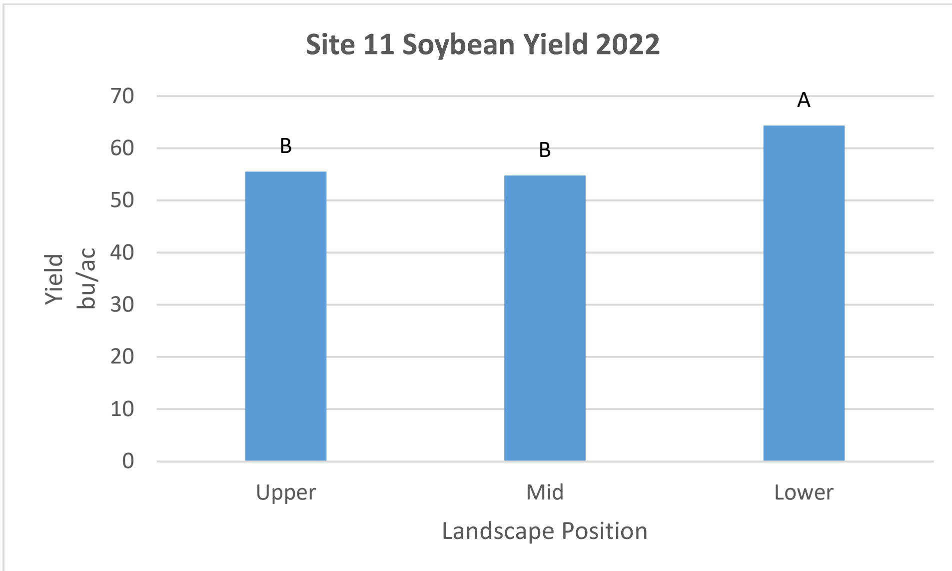

Figure 17: Site 11 soybean yield by landscape position 2022

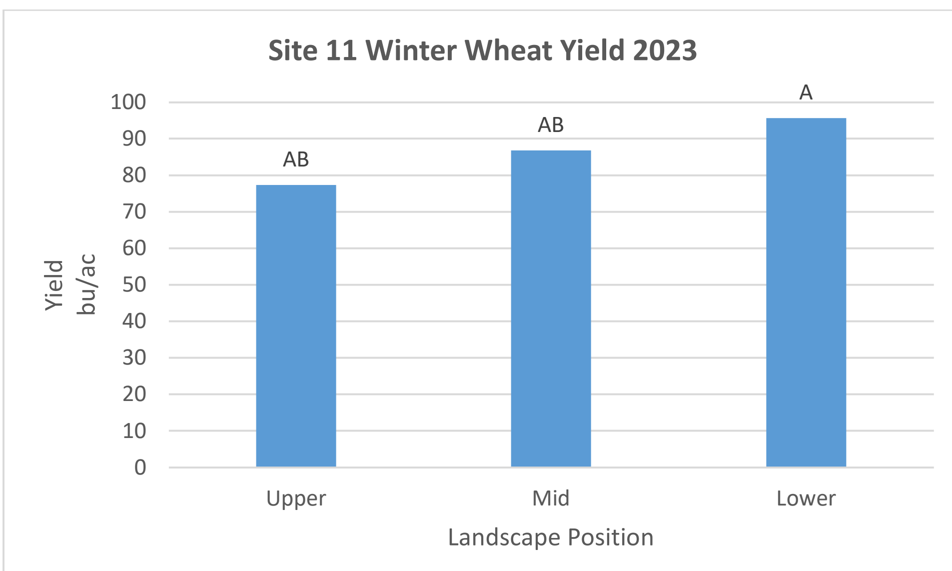

Figure 18: Site 11 winter wheat yield by landscape position 2023

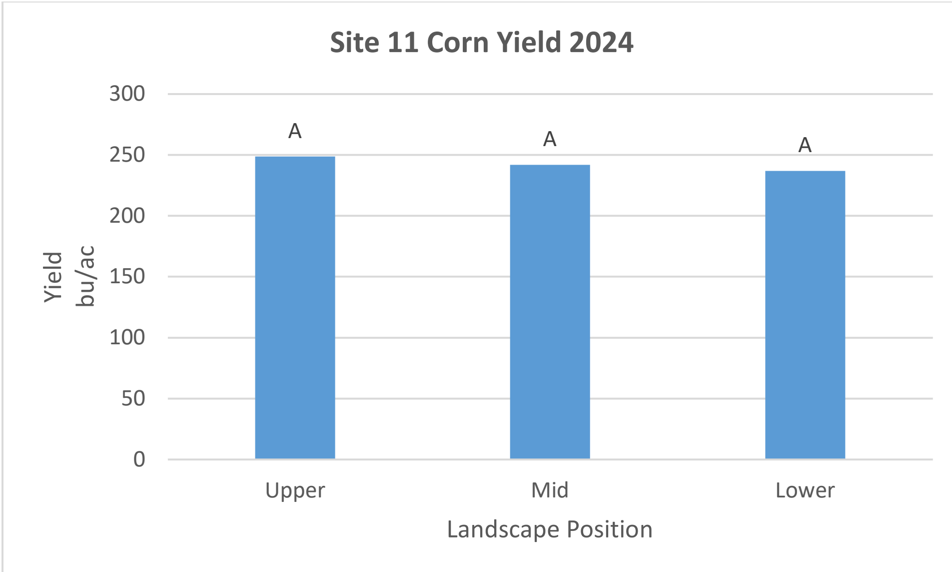

Figure 19: Site 11 corn yield by landscape position 2024

In previous years (2022 and 2023), the yield values at Site 11 were statistically and/or numerically higher in the lower landscape compared to the upper landscape areas. The 2024 crop yield was not statistically different across positions and the upper landscape area had the higher average yield. Yield differences were often not observed in 2024 at a number of sloping sites. Excessive early season moisture conditions resulting in poor plant stands at the lower landscape position (Figure 20a) contributed at some sites, as well as sufficient moisture conditions throughout the season at the upper landscape position (Figure 20b) where plants would typically suffer from moisture stress (Figure 20c). Relating yield results in 2024 with lower-than-normal landscape position differences, to SHI levels with significant landscape position differences helps to explain the poor correlation levels with yield. Furthermore, investigation of treatment and position interaction at individual benchmarks also proved insignificant for measured yield levels, even though there were significant SHI interactions for treatment and landscape position.

Figure 20: Moisture influence on crop growth: a) 2024 Site 7 lower position crop damage in foreground; b) 2024 Site 12 upper position full crop mid-June; c) 2022 Site 12 upper position stunted crop mid-June.

3.0 Summary

Soil health investigations continued at established and new BMP Trial and EOF sites in 2024. To further characterize regional differences between crop and soil management practices, soil health and soil water dynamics, and water quality, two more Northeastern BMP Trial sites and one EOF site (supported by LTVCA) were established in 2024 for a total of 25 BMP Trial and 7 EOF cooperator sites.

Results of the 2024 laboratory analysis of soil health indicators at the BMP Trial sites found significant variability within and between sites and, as in previous years, reflected the wide range of values of the various tests and range of site conditions. Active carbon (AC) and ACE protein soil analysis continue to have the most stability, least variability, and best correlation with SOM. In 2024, PMN values continued to be more variable than other SHIs. Early sampled sites had many PMN values below detection limits likely due to excessive soil moisture conditions in advance of sampling. The high variability and year to year changes in the range of PMN values present challenges to employ this indicator for determining changes in soil health over time.

At the site scale, landscape position continues to show a strong influence on SHIs, while some BMP treatment strips at a few sites appear to have SHI levels trending higher over time. In 2024, a BMP influence on SHIs was more evident at the individual benchmark scale than a treatment strip comparison. Within a site, the BMP case study illustrated that positive treatment differences in SHIs were more often observed with more years of BMP adoption with greater carbon input including organic amendment than with cover crops alone. The SHI differences were also observed more often at lower and mid slope areas than the upper position. The effect of BMPs may require longer term additions to influence SHI levels at these more degraded upper landscape positions. Further investigation of the ONFARM cooperator sites will continue to consider which BMPs and BMP combinations work best, how long before the impact can be measured, and how the extent of degradation has an influence to further the understanding of the impact of BMPs on soil health.

The influence of soil health on yield has not been clear. Yield measured annually has not been a reliable indicator of soil health observed from site to site. Part of the reason for this is that annual crop productivity potential can be significantly influenced by genetics, crop inputs, and soil moisture surplus or deficit. In 2024, there were fewer instances where yields were different between landscape positions, likely due to adequate season-long soil moisture conditions, including the more degraded upper landscape positions. Improved soil health may not consistently result in increased yields but could over time lead to reduced variability in yields and increased crop resiliency by better maintaining available water over the season. To gain a further understanding of in-field water dynamics, available water holding capacity investigations continued at another 2 BMP Trial and 1 EOF sites in 2024.

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