ONFARM

Soil Health Technical Report

March 31, 2024

Prepared by:

SRG SOIL RESOURCE GROUP

OSCIA

Table of Contents

Acknowledgements 1
1.0 Introduction 2
1.1 Program Description 2
1.2 Organizational Structure and Research Sites 2
2.0 Soil Health Research 4
2.1 Overview 4
2.2 Cooperator Field Sites 4
2.3 Data Collection 5
2.4 Soil Health Sampling 7
2.5 Soil Health Data 2023 8
2.6 BMP Case Study 15
2.8 Water Characterization 18
2.9 Summary 19

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 Rural Affairs (OMAFRA) 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 OMAFRA 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 Rural Affairs (OMAFRA) 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 recently 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 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 Rural Affairs (OMAFRA)
- 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 in their respective watersheds.

The ONFARM program is being implemented on working farms across the province in collaboration with partner organizations and cooperating farmers. In the next phase of ONFARM there will be 32 research sites. 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 will be 25 Soil Health sites. 22 of these are being continued and three new sites will be added, including two new sites in northern Ontario. The other seven sites are Edge of Field (EOF) water quality monitoring stations. The location of each ONFARM site is shown in Figure 1.

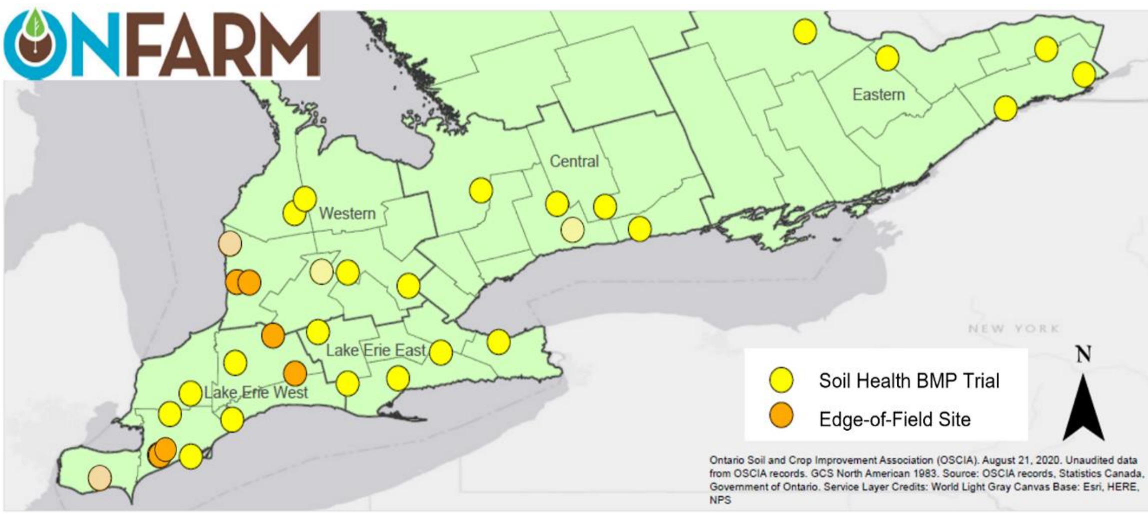


Figure 1. Map of ONFARM sites by type.

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 southern 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.
- BMP impacts on soil health, soil degradation and water holding capacity, and how these parameters ultimately affect crop performance.
- Soil health related BMPs impact on on-farm profitability and return-on-investment.

These sites represent the high variability of soils 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 throughout 2023 at established Edge-of-Field (EOF) and BMP Trial sites. In 2023, there were 6 EOF sites actively managed, and 23 BMP Trial sites with the reduction of 1 site in each of the Western and Central Regions from 2022. The distribution of cash crop farms and livestock farms in the BMP Trial was modified slightly in these regions (Figure 2) from those measured in 2019-22.

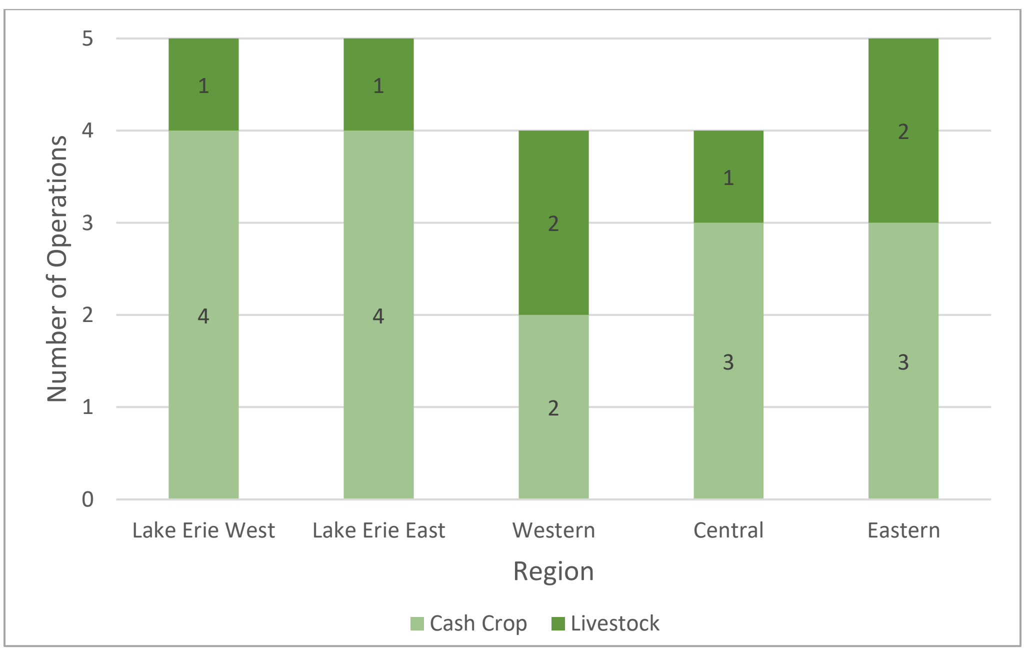


Figure 2. BMP Trial operation type by region in 2023

2.3 Data Collection

The monitoring program and level of data collection was expanded in 2023 with an increase in sampling intensity at the EOF sites to align with the data being collected at the BMP Trial sites. Data collection at all the cooperator sites included soil health indicator and agronomic monitoring activities. The impact of the BMP comparisons at the EOF sites will continue to be monitored as management information is collected for interpretation moving forward. Management of the BMP Trial sites collected annually is reported below.

The BMP Trial site crops were grown under no-till or some form of reduced tillage management. BMPs implemented included cover crops or organic amendments, and combinations of both (Table 1). Differences exist between management practices at each site such as species and blends of cover crops, timing of planting and their termination. Prior to the 2023 cropping season, cover crops were established at 6 sites by the fall of 2022 along with 10 other sites that rotated into a winter wheat crop. Organic amendments that included on-farm manures or off-farm non-agricultural source materials were applied at 4 sites prior to the 2023 crop. The reduction in the use of cover crop and organic amendment BMPs for the 2023 crop was due in part to the large number of fields that had winter wheat immediately following soybean. With the establishment of the restart of a three crop rotation beginning with wheat in 2023, the use of BMPs afterward increased to 14 sites with cover crops and 13 sites with organic amendment applications.

Table 1. ONFARM soil health BMP trial site cropping and BMPs in 2022 and 2023.

Site	Crop 2022	BMPs 2022 (pre 2023 crop)	Crop 2023	BMPs 2023 (pre 2024 crop)
1	Soybeans		Soybeans	
2	Corn	Cover crop	Soybeans	
3	Soybeans	Cover crops, organic amendment	Corn	Organic amendment (spr. 2023)
4	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crops, organic amendment
5	Corn		Soybeans	Cover crop
6	Corn	Cover crops, organic amendment	Soybeans	(winter wheat fall 2023)
7	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crop
8	Adzuki beans		Sunflowers	
9	Soybeans	Cover crop	Corn	Interseeded cover crops
10	Corn	Cover crop, organic amendment	Corn	Cover crop, organic amendment
11	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crop, organic amendment
12	Corn		Soybeans	(winter wheat fall 2023)
13	Spring barley		-	
14	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crop, organic amendment x2
15	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crop, organic amendment
16	Cereal rye		-	
17	Adzuki beans	(winter wheat fall 2022)	Winter wheat	Cover crop, organic amendment
18	Soybeans	(winter wheat fall 2022)	Winter wheat	
19	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crop, organic amendment
20	Oats	Organic amendments	Soybeans	Organic amendment
21	Corn	Interseeded cover crops	Soybeans	Cover crop, organic amendment
22	Soybeans	(winter wheat fall 2022)	Spring wheat	Cover crops
23	Soybeans		Spring wheat	Cover crop, organic amendment
24	Soybeans	(winter wheat fall 2022)	Winter wheat	Cover crop, organic amendment
25	Corn		Adzuki beans	

Cropping and management information continued to be recorded by the cooperator at each field site throughout the 2023 season, including economic data on the cost of inputs for BMP implementation. Data was collected in established record keeping sheets and with follow-up interviews after the season.

The agronomic monitoring program was completed in 2023 at all BMP Trial benchmark sampling locations including hand harvest yield measurement, which was also performed previously throughout the ONFARM sampling seasons. Monitoring of the same agronomic parameters were begun at the EOF sites in 2023 to be continued each year. Soil health samples were taken from the BMP Trial and EOF sites in similar sequence as in prior years through the month of June. Data collected at each BMP and EOF site is summarized in Table 2.

Autoclaved Citrate Extractable (ACE) Protein soil analysis was added in 2022 to the set of soil health indicators (SHI) tested annually. ACE protein analysis, measured from 15cm soil core samples, is a measurement of the amount of "protein-like substances" that are present in the soil organic matter. It represents the level of nitrogen in the soil organic matter and therefore is considered to be an indicator of the SOM quality (Cornell Soil Health Assessment manual, Moebius-Clune et al 2016[1]).

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, fertility; biological - Solvita labile amino nitrogen (SLAN), Solvita CO_2 burst, active carbon (permanganate-oxidizable carbon or POxC), potentially mineralizable nitrogen, 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 cost-benefit analysis at the BMP Trial cooperator sites

2.4 Soil Health Sampling

The benchmark sampling georeferenced locations established at each site in 2019 based on 3 distinct soil landscape positions across each of the side-by-side BMP treatment strips continue to be monitored and sampled annually. Composite soil samples are collected in triplicate from three separate areas ('trillium' design) within a 2m radius around each benchmark. The field plot design (Figure 3) allows for the statistical comparison of the benchmark results for three areas of analysis:

- relationship between soil landscape position and SHI
- impact of different BMPs on SHI
- interaction effect of both landscape and BMP on SHI

The numbers of soil samples collected for SHI analysis, as well as hand harvest yield samples, across the ONFARM study in 2023 were:

- 6 EOF cooperator sites represented by 12 treatment field areas with 3 soil landscape zones and 3 benchmark location triplicates that total 108 samples, and

[1] Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M Kurtz, D.W. Wolfe, and G.S. Abawi, 2016. Comprehensive Assessment of Soil Health – The Cornell Framework, Edition 3.2, Cornell University, Geneva, NY.

- 23 BMP trial cooperator sites of 91 treatments and 3 soil zone benchmarks and 3 triplicates that total 819 samples.

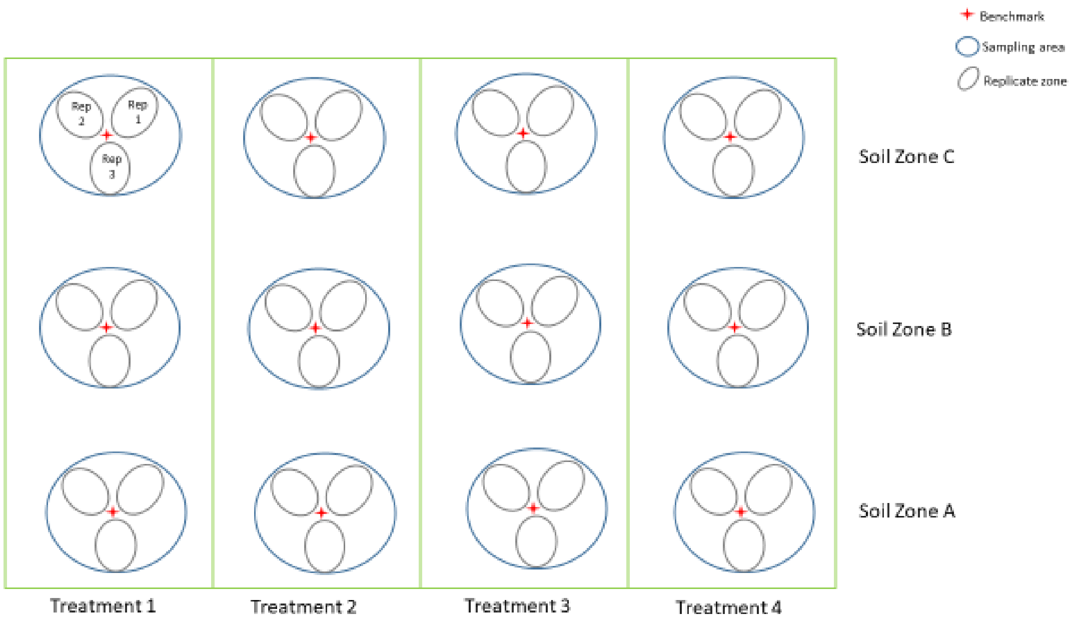


Figure 3. Conceptual sampling design at benchmark location of field treatment and soil zone/landscape position (upper, mid, lower) location

2.5 Soil Health Data 2023

Results of the 2023 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. The SHI tests measured in 2023 from the 3 areas or triplicate sampling immediately surrounding an individual benchmark differed between tests in the level of variability (Table 3). Overall in 2023, the range of variability at all of the benchmark locations expressed as coefficient of variation was lowest for bulk density (5.3%) followed by organic matter (6.1%) up to the higher results of PMN (18.2%) and the Solvita CO_2 burst test (24.5%). The significant shift in variability in the Solvita CO_2 burst in 2023 compared to the previous three years is currently being investigated.

Table 3. Variability of 2023 SHI test results across all BMP sites as CV levels

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
6.1%	9.7%	24.5%	6.7%	13.4%	18.2%	7.2%	5.3%	11.3%

To determine how well the different SHIs relate to the more stable SHI of soil organic matter, correlation analysis was conducted again in 2023. Across all the BMP sites, there were only a few strong correlations found between SOM and a SHI (Table 4). The ACE protein test had the strongest correlation to SOM with higher SOM levels predicting higher ACE protein levels. This would generally be expected as ACE protein is a measurement of the nitrogen portion of SOM. SLAN was also strongly correlated to SOM in 2023, but the variability within the triplicate measurement around a benchmark was higher 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 2023

	SOM	AC	Solvita CO_2	SLAN	PMN	AS	BD	ACE
SOM								
AC	0.57873							
Solvita CO_2	0.30368	0.47719						
SLAN	**0.73679***	0.67446	0.47732					
PMN	0.21393	0.22673	0.14405	0.24090				
AS	0.25311	0.32917	0.35131	0.28184	-0.0388			
BD	-0.39540	-0.38286	-0.05075	-0.46169	0.01810	0.0257		
ACE	**0.78416**	0.52478	0.26159	**0.70393**	0.25584	0.26331	-0.40971	

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

Tracking the variability and correlations of the SHIs is being used to provide a better understanding of how useful the measurement is in detecting change in the soil over time. Soil health indicators observed in 2023 to have relatively low sampling variability and higher correlation levels with organic matter, active carbon and ACE protein, were the focus of further analysis. When comparing the sample distribution, the simple linear regression of organic matter with active carbon, r^2=0.38, is not as well related as with ACE protein with an r^2=0.63 (Figure 4 and below).

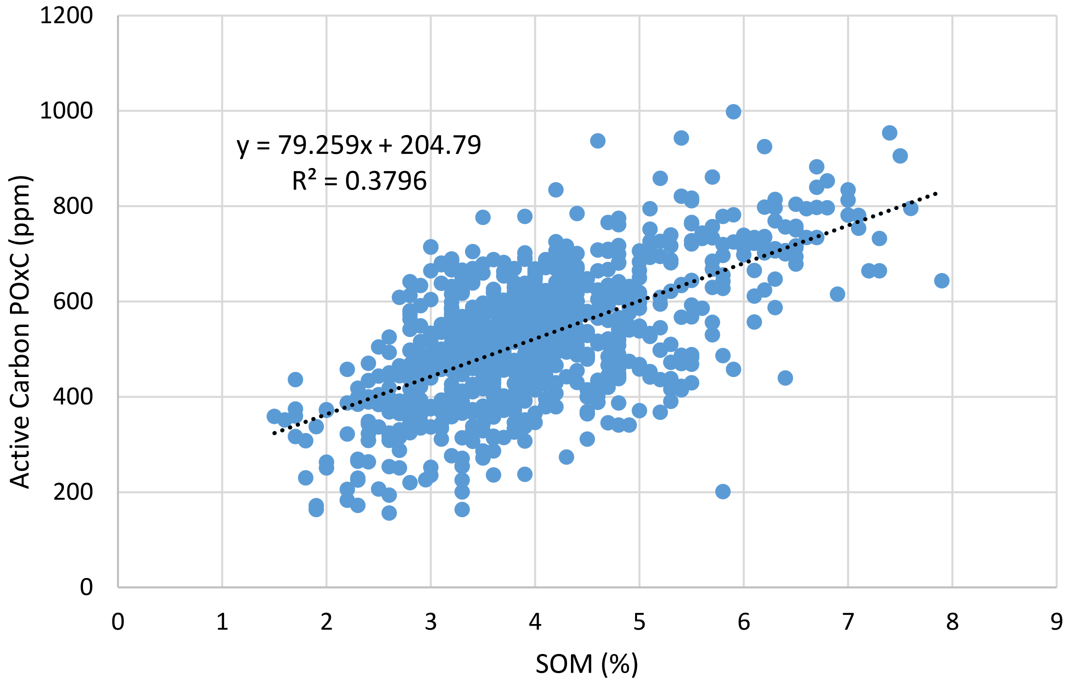


Figure 4. Regression analysis of organic matter and active carbon values from all samples

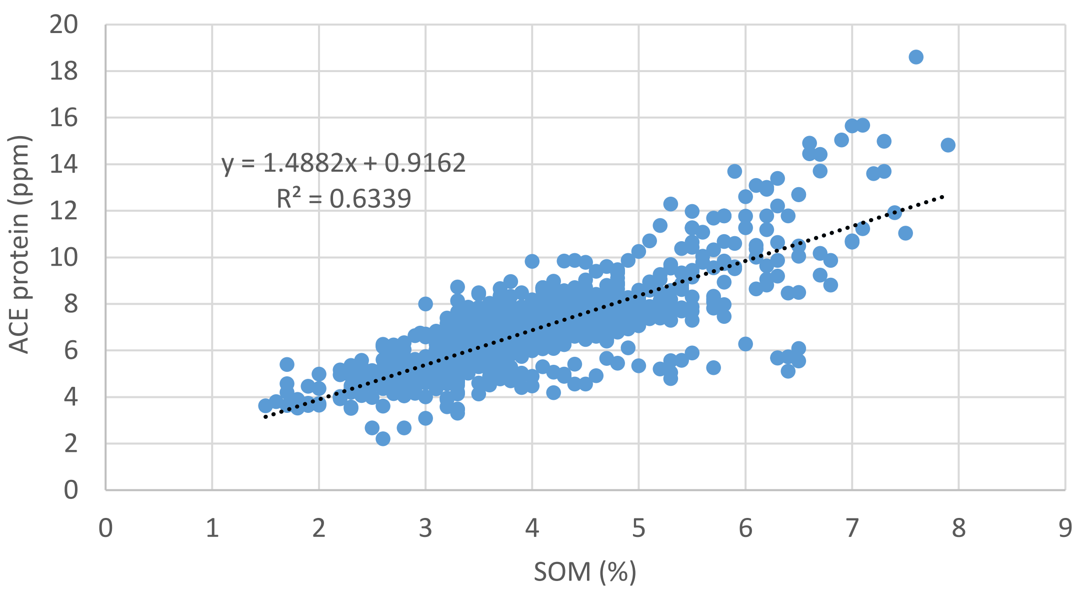


Figure 5. Regression analysis of organic matter and ACE protein values from all samples

Investigation of soil health indicator results from 2023 were analyzed for differences between landscape position and BMP treatment differences across the sites and generally found similar findings to previous years where differences were largely site specific. Clear differences continue to be shown when comparing the 3 distinct soil landscape positions, with inconsistent differences observed in BMP treatment influence.

The 2023 SHI data was analyzed using a multivariate ANOVA analysis 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 on the SHI was determined. Differences of a BMP treatment from the control treatment were reported as a BMP treatment effect, and differences between the lower landscape position and the more degraded middle and upper slope positions was considered a landscape position effect.

Landscape position effect has been observed at some sites in 2023 as the factor most affecting SHI levels. Specifically, the lower landscape position has corresponded with higher measured values for SOM, AC, and ACE protein on average across all the BMP sites (Figure 6). A reduction in SHI levels has 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.

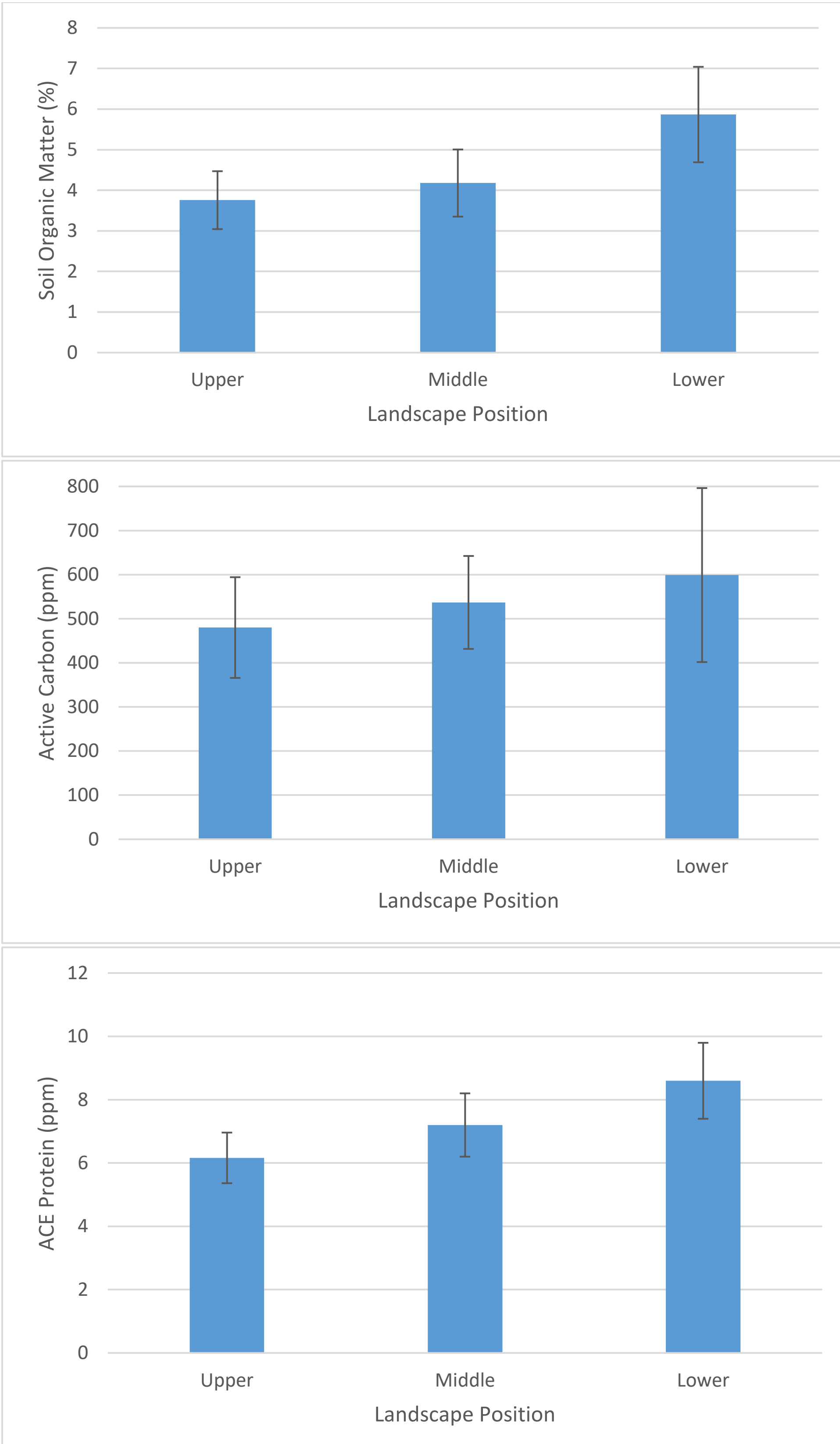
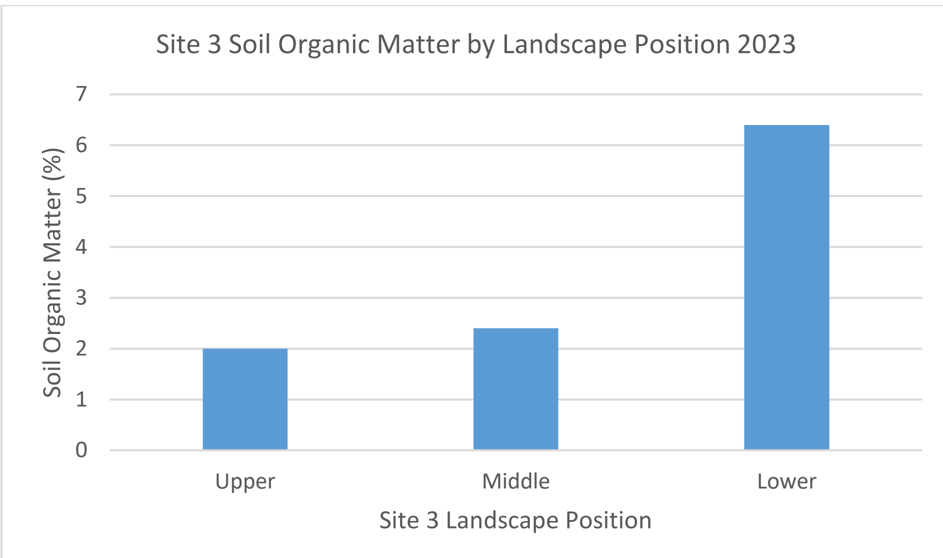
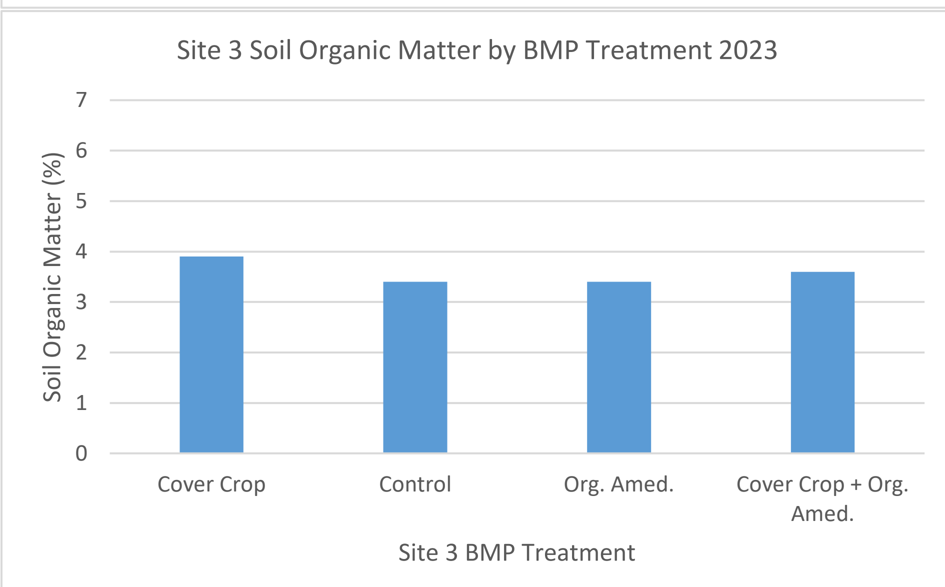


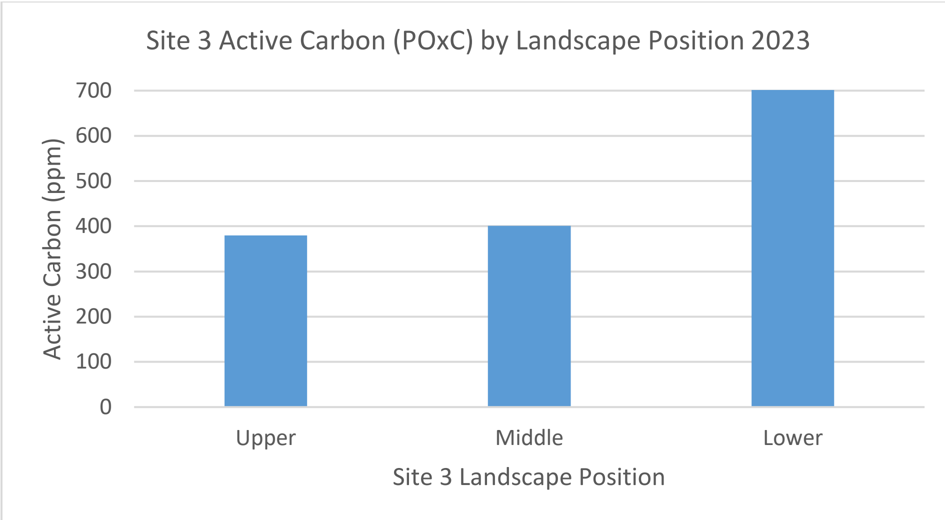
Figure 6. Average SOM, AC, ACE protein soil health indicator values in 2023 by landscape position

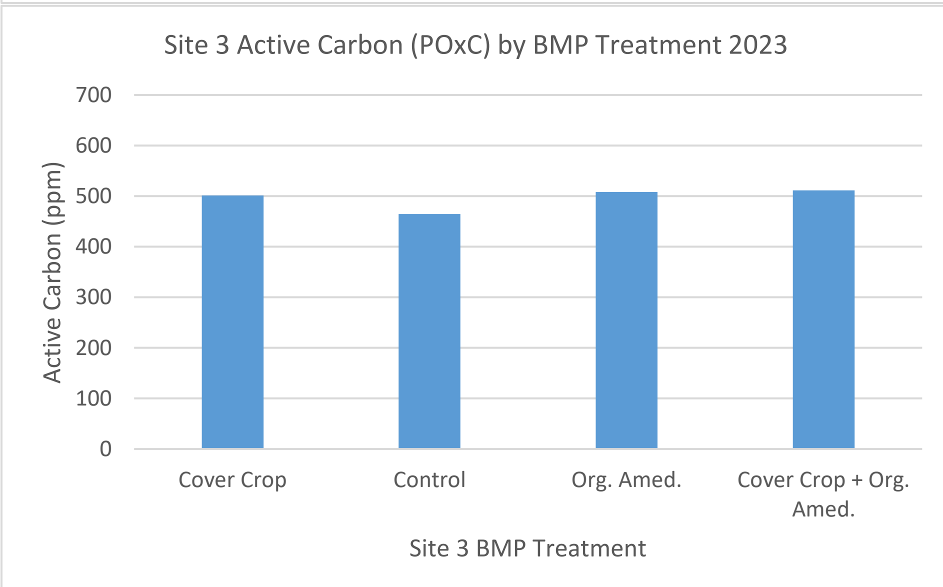
The influence of landscape position on SHI measurement has likely limited the ability to determine a BMP effect on SHI values over an entire treatment field strip situated to span predominant landscape positions. Results in 2023 from SOM, AC, or ACE protein measurements across all sites indicated there were no instances where a BMP treatment strip was different from the control treatment strip.

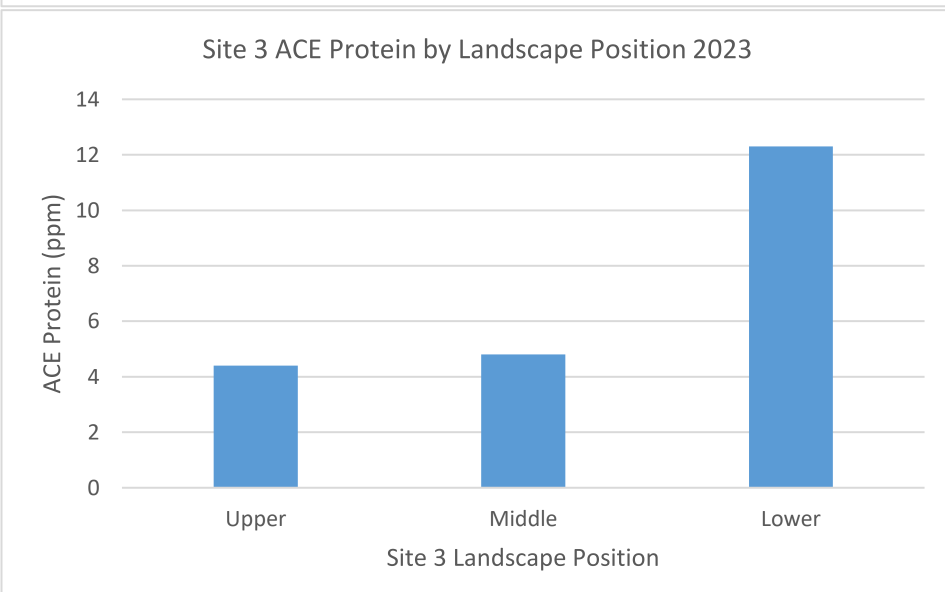
To illustrate the influence of landscape position on SHIs within BMP treatment strips, the SOM, AC, and ACE protein results from 2023 at Site 3 are presented in Figure 7. The level of organic matter at the upper landscape position is less than half the lower position where there is an area of depleted organic soil at the site. BMP treatment measurements that are combined over a strip are not statistically different between treatments due to the dominant effect of the lower landscape position values across the treatments. A similar observation occurs in the AC and ACE protein measurements that are statistically different between landscape positions but there is no statistical difference between the BMP treatments.






Site 3 Active Carbon (POxC) by Landscape Position 2023
Active Carbon (ppm)
700
600
500
400
300
200
100
0
Upper
Middle
Lower
Site 3 Landscape Position


Site 3 Active Carbon (POxC) by BMP Treatment 2023
Active Carbon (ppm)
700
600
500
400
300
200
100
0
Cover Crop
Control
Org. Amed.
Cover Crop + Org. Amed.
Site 3 BMP Treatment


Site 3 ACE Protein by Landscape Position 2023
ACE Protein (ppm)
14
12
10
8
6
4
2
0
Upper
Middle
Lower
Site 3 Landscape Position

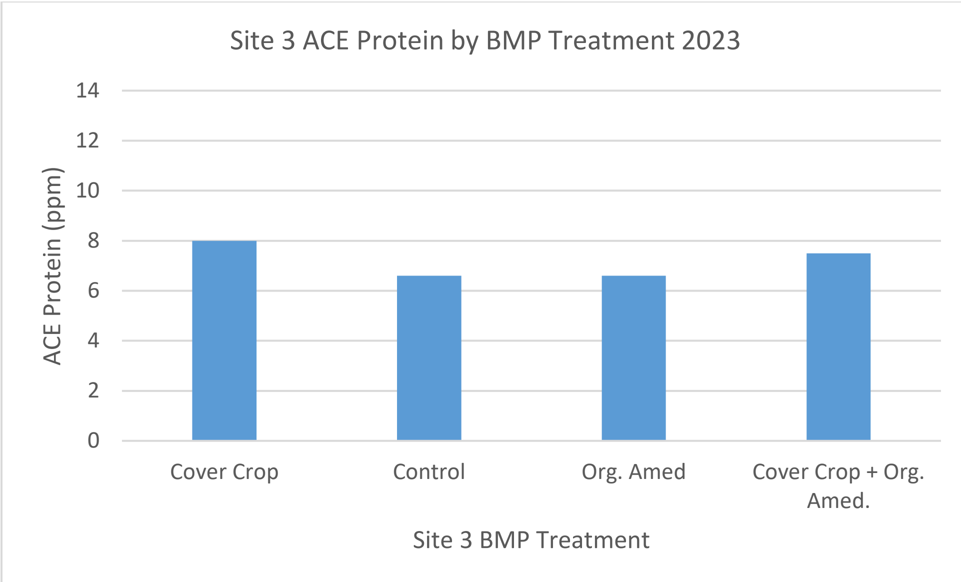


Figure 7. Site 3 SHI average values of SOM, AC, ACE protein by landscape position and by BMP treatment 2023

Significant statistical results of BMP effect were observed at the individual benchmark scale, which considers the influence of BMP treatment and landscape position together as the interaction. These findings indicated the influence of a BMP treatment occurring more often at one landscape position over another within the field. To illustrate the influence of BMP treatment at a site, a case study from Site 20 is presented to highlight some findings in 2023.

2.6 BMP Case Study

The 2023 results from Site 20 consider the site conditions and BMP management history over the last four years of ONFARM. Site 20 is located on a coarse loamy soil in Central Ontario. The site has had a crop rotation over the ONFARM study of corn-soybean-oats-soybean from 2020 to 2023. BMP treatments applied in each crop year by the cooperator included various cover crop and organic amendment applications to compare with the non-BMP control treatment (Table 5).

Table 5. ONFARM BMP trial design and history of Site 20

Year	Treatment 1	Treatment 2	Treatment 3	Treatment 4
2020 Corn	Organic Amendment (OA)	Organic Amendment + Cover Crop (OA+CC)	Cover Crop (CC)	Control (CTL)
2021 Soybean	Liquid biosolid – spring 2021	Cover crop (interseeded) in fall 2020 + Liquid biosolid in spring 2021 (OA+CC)	Multi species cover crop (interseeded) in fall 2020 (CC)	None
2022 Oats	Mushroom compost – fall 2021	Single species cover crop + Mushroom compost – fall 2021	Single species cover crop – fall 2021	None
2023 Soybean	Solid compost – spring 2023	Solid compost – spring 2023		None

Figure 8. BMP treatment photos at Site 20 of liquid biosolid application, interseeding cover crop into soybeans, and cover crop and organic amendment

The addition of some BMP treatments over time was found to have an impact on soil health indicators measured in 2023. SHI values of SOM, AC and ACE protein were observed to be statistically higher than the control treatment where organic amendment applications had occurred without or with a cover crop addition at some of the landscape positions (Table 6). There was not a statistical difference in SHI measurements from the control for just the cover crop treatment alone at any landscape position. Furthermore, the BMP effect of an increase in SHI was evident at the middle and upper positions but did not show an effect at the lower position. At the more severely degraded upper landscape position , only SOM was greater with the organic amendment treatment 1 but not in treatment 2 that included the same organic amendment applications but with some cover crop additions. However, the middle position benchmark locations had higher levels of ACE protein at both the organic amendment treatments 1 and 2, as well as higher levels of SOM and AC in treatment 2 where there were additional cover crop additions.

Table 6. Significant increase in soil health indicator values by BMP treatment and by landscape position at the benchmark level at Site 20 in 2023

Landscape Position	Treatment 1 OA	Treatment 2 OA+CC	Treatment 3 CC	Treatment 4 CTL
Lower				
Middle	ACE	SOM, AC, ACE		
Upper	SOM			

The results of higher levels of SHIs, particularly at the middle landscape position, suggest that at this site by year 4 of the study, the BMP treatments with the greater addition of organic carbon and organic nitrogen may have had the effect of increasing the measurable level of soil organic carbon and organic nitrogen. A greater level of SOM was measured in the organic amendment treatments compared to the levels of SOM in the control. This was not expected in this short period of time and may be due to the frequent additions of organic matter at this site. Indicators such as AC and ACE will continue to be measured to determine if changes in soil health can be detected sooner and more consistently.

2.7 Yield Monitoring

Along with the annual monitoring of soil health indicators, crop monitoring and yield measurement has been completed at all benchmark locations. Over the 4 years of the project, yield reductions may correspond to areas of soil degradation though it is often not a reliable measure of soil health as observed from site to site. Overall, correlation analysis of yield with any of the SHIs across the sites was again poor in 2023 (Table 7).

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

	SOM	Active C	Solvita CO_2	SLAN	PMN	AggStab	BD	ACE
Yield	-0.14883	0.0032	-0.00915	-0.06640	0.06919	-0.15449	-0.00071	-0.11351

Annual crop productivity potential can be significantly influenced by genetics, crop inputs, and soil moisture surplus or deficit. One example in 2023 is at Site 24 where the AC was measured to be significantly different by landscape position (orange being considered a low AC rating and dark green is considered a very high rating - Cornell Soil Health Assessment), yet the winter wheat yield between positions was not statistically different (range 72-79 bu/ac) (Figure 9). Crop genetics and inputs likely contributed to supporting yields in areas of the field where SHI measurements were considered low to moderate.

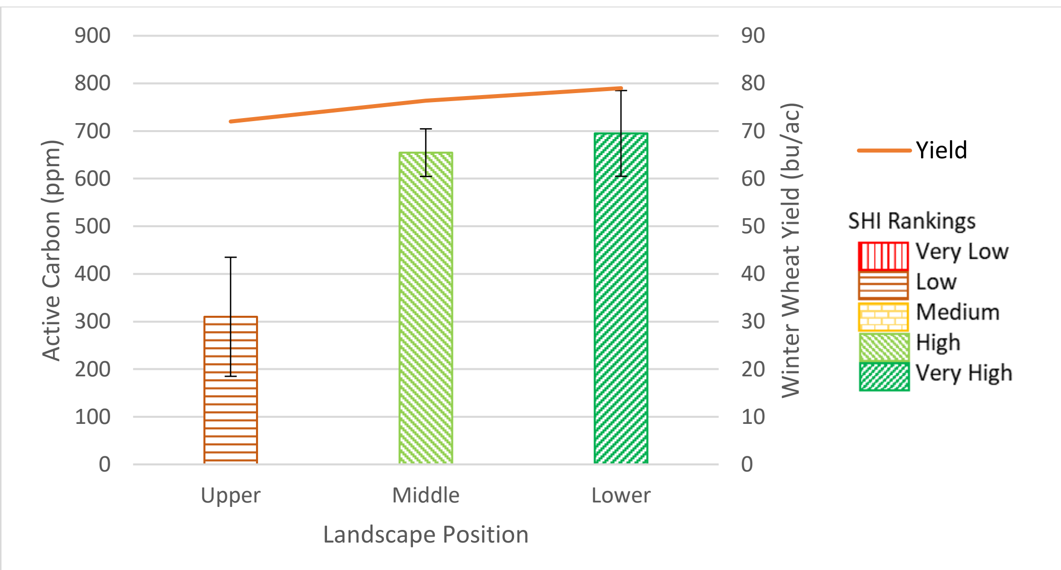


Figure 9. Active carbon and yield average levels by landscape position at Site 24 in 2023

Conversely, there are a number of sites where SHI measurements were not statistically different between landscape positions but the yields were significantly different. As an example in 2023, the AC levels measured at the landscape positions at Site 12 were not statistically different and rated as medium (yellow) for the sandy soil type (Cornell Soil Health Assessment) (Figure 10). However, the soybean yield results, as with other crops at the site over the study, were low at the middle and upper landscape position

(37 bu/ac) very likely due to several factors that were limiting yield, such as low pH and lack of timely moisture from severe tillage erosion and soil profile degradation at the mid to upper position.

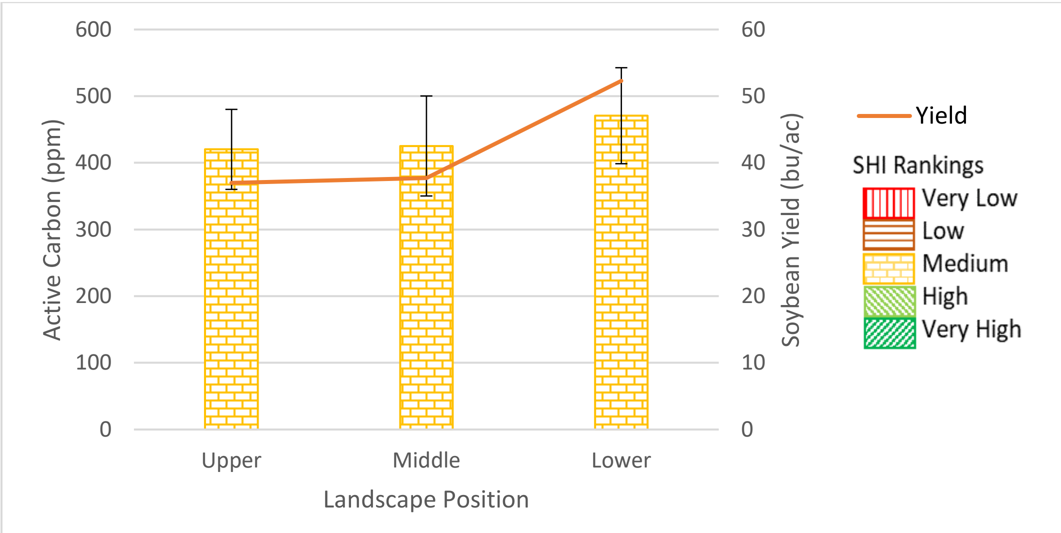


Figure 10. Active carbon and yield average levels by landscape position at Site 12 in 2023

At Site 12 and several other instances, lower yields were measured but the SHI measurements were not rated as low. Often the likely limiting factor for crop yield performance was a lack of moisture. A goal of improved soil health that improves crop yield would be to reduce variability and increase resiliency. The measurement of a soil's ability to better hold moisture would be an additional indicator of soil health.

2.8 Water Characterization

There is an increasing concern that soil moisture extremes may become more common with a changing climate, and runoff risk is an important program component. In response to this increasing concern, ONFARM has initiated additional investigation to characterize soil water availability at the monitoring sites. Available water holding capacity (AWHC) was selected as a new measurement for the study and is led by the University of Guelph. A pilot sampling program by The Soil Resource Group began in the fall of 2023 at two EOF sites and one BMP Trial site. Replicated soil cores taken around benchmark locations at two depths of the topsoil layer (Figure 11) will be analyzed for AWHC in 2024. Further analysis of the impact of BMPs will be assessed using this indicator at all sites by the end of the program.

Figure 11. Field sampling for available water holding capacity fall 2023

2.9 Summary

Soil health investigations continued at established BMP Trial sites. To further the understanding of the connections among crop production, soil health and soil water dynamics, and water quality, the intensity of soil health sampling at the EOF sites was increased in 2023 and will be continued throughout ONFARM.

Results of the 2023 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. ACE Protein soil analysis, which was added to the set of soil health indicators tested annually in 2022, had less variability than other parameters and was strongly correlated with SOM.

At the site scale, landscape position continues to show a strong influence on SHI, while BMP influence is inconsistent. BMP influence is more evident at the benchmark scale, which compares the influence of a landscape position and a BMP treatment over time. The BMP case study illustrated that, after four years, the influence of the type and amount of BMPs may be statistically significant at key landscape positions. Overall, the results demonstrate the need for continued monitoring of the ONFARM cooperator sites to further improve the understanding of the impact of BMPs and indicator variability.

Yield 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. Often the likely limiting factor for crop yield performance was a lack of moisture at critical times. Improved soil health may not increase yields, but it could lead to reduced variability and increased resiliency by increasing available water. To gain further understanding of in-field water dynamics, available water holding capacity was selected as a new measurement for study.

To stay up-to-date on ONFARM activities and to view past reports please visit the ONFARM Web Page.