# Ground Truthing SHAP – Detailed Report

September 2026


By:

Heather White, MSc, Soils At Guelph

Dr. Inderjot Chahal, University of Guelph

Dr. Jenny Bower, Soil Health Institute

Dr. Laura Van Eerd, University of Guelph


UNIVERSITY OF GUELPH | Soils At Guelph

# Ground Truthing SHAP – Detailed Report

## Contents


Introduction ..... 2

Part 1 ..... 2

What is Soil Health? ..... 2

Why Care About Soil Health? ..... 3

Part 2 ..... 3

Measuring Soil Health in Ontario – A closer look at the SHAP Analytical Indicators ..... 3

Soil Organic Matter – The Heart of Healthy Soil ..... 3

Active Carbon – The Fast Lane of Soil Carbon ..... 4

Respiration – The Window into Soil Microbial Activity ..... 4

Potentially Mineralizable Nitrogen (PMN) – the Soil's Nutrient Power ..... 4

Aggregate Stability – The Foundation of Soil Structure ..... 5

Part 3 ..... 5

The Ground Truthing SHAP Project ..... 5

Project Objectives ..... 5

Recruitment ..... 6

Participant Instructions and Sample Collection ..... 6

Findings ..... 7

Sample Participants, Locations and Production Systems ..... 7

..... 7

Soil Texture ..... 7

Soil Management Practices ..... 8

Soil Health Indicator Results ..... 9

Improving access and value for soil health tests: feedback from participants ..... 13

Summary and Next Steps ..... 14


---

Citing this report: White, H., Chahal, I., Bower, J., and Van Eerd L. 2026. *Ground Truthing SHAP Detailed Report*. Soils At Guelph. September 2026.

## Introduction

Healthy soils are increasingly recognized as a cornerstone of productive and resilient agricultural systems. In 2023, the Ontario Ministry of Agriculture, Food and Agri-business (OMAFA) launched the Soil Health Assessment and Plan (SHAP), which includes an approach to soil health testing based on five analytical indicators:

- Soil Organic Matter (SOM)
- Active Carbon
- Respiration
- Potentially Mineralizable Nitrogen (PMN)
- Aggregate Stability

From 2023 to 2025, Soils at Guelph collaborated with Ontario farmers, advisors, laboratories, and other project partners through the Ground Truthing SHAP Project (The Project) to pilot and validate this approach. This report is meant to communicate findings to those collaborators and other interested parties.

## Part 1

## What is Soil Health?

According to the Canadian Textbook, Digging into Canadian Soils, "*soil health/quality is the capacity of a soil to function within ecosystem and land use boundaries to sustain biological productivity, environmental quality, and plant and animal health*".

In practical terms, soil health is best understood by examining what soil *does* and how it *behaves* rather than trying to define what it *is*. Healthy soils perform essential functions, such as supporting plant growth and biodiversity, supplying nutrients to plants more efficiently, reducing erosion, and regulating climate, temperature and water management.

These functions are influenced by a combination of chemical, physical and biological soil properties (Figure 1). Together, these properties determine how closely to its potential an agricultural soil performs, optimizing agricultural productivity and environmental outcomes.

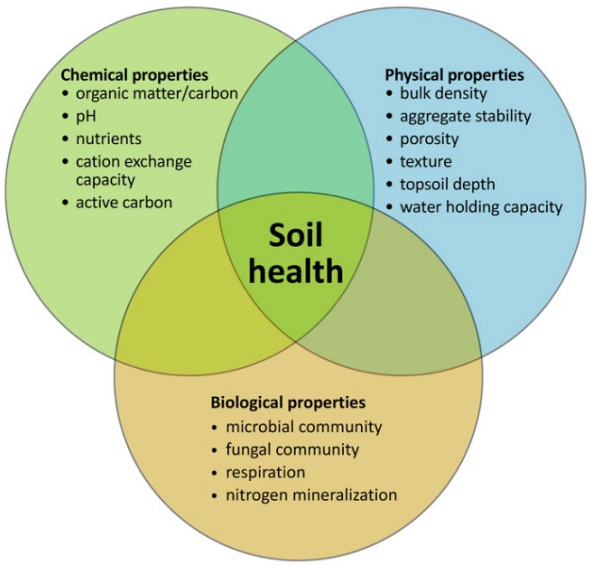



*Figure 1- There are many different factors - chemical, physical and biological - that contribute to a soil's healthy functioning. Source: Ontario Topsoil Sampling Project, 2024.*

## Why Care About Soil Health?

Understanding and tracking soil health helps farmers evaluate the long-term effects of management practices and identify opportunities for continuous improvement. Ontario research shows systems with better soil health, including those with perennials, cover crops, less soil disturbance, and winter wheat, have greater grain yields, require fewer nitrogen inputs, and are more profitable.

## Part 2

## Measuring Soil Health in Ontario – A closer look at the SHAP Analytical Indicators

Because soil health reflects many interacting physical, chemical and biological processes, it cannot be measured directly using a single test. Instead, soil health assessments rely on *indicators* to provide insight into how well the soil ecosystem is functioning. SHAP's 5-analytical indicators were selected to capture important aspects of soil biological, physical and chemical functioning.

Additionally, effective soil health indicators should ideally:

- Reflect meaningful soil functions
- Respond to management practices
- Be scientifically defensible
- Be applicable across diverse agricultural contexts
- Be practical and affordable to measure.

## Soil Organic Matter – The Heart of Healthy Soil

Soil organic matter (SOM) is composed of both living and dead plant materials. It feeds soil life and helps soil store nutrients, store water and resist erosion. SOM is composed of roughly 58% organic carbon, and 42% other organic components, such as oxygen, hydrogen and nitrogen.

Typical range of SOM in Ontario farmland is: 1% to >8% organic matter. Muck soils will have much higher SOM levels.

SOM will impact soil physical, biological and chemical functions.

The laboratory method used to measure SOM in the Project was Loss on Ignition @425°C, where SOM is estimated from the weight lost from a soil sample after "burning off" the OM in a hot oven.

## Active Carbon – The Fast Lane of Soil Carbon

Active Carbon is the portion of soil organic carbon that most available to microbes. It is a helpful indicator **because levels respond more quickly to management** changes, signaling future soil health trends more rapidly than, soil organic matter, for example.

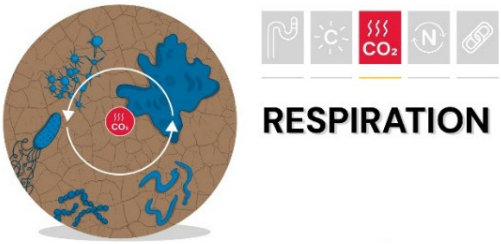
Typical range of Active Carbon in Ontario farmland is between 120 to 1000 mg per kg of soil.

Active Carbon is a measure of soil biological functioning.

The laboratory method used to measure Active Carbon in the Project was Potassium Permanganate Reaction Absorbance @550 nm. In this test the soil is mixed in a solution that reacts with readily available (active) carbon. The resulting colour change in the solution is then measured using a spectrometer at a wavelength of 550 nm. The readings from the spectrometer are used to calculate the concentration of Active Carbon in the soil sample.

## Respiration – The Window into Soil Microbial Activity

As soil microbes go about their life in the soil, they respire, or "breath". Many – like humans- respire and release carbon dioxide. Measuring the release of carbon-dioxide from the soil can help understand how active and healthy soil biology is.




Since soil microbes play an important role in releasing nutrients for crop growth and building stable soil structure, measuring their respiration activity is an indicator of microbial – and thus soil- health.

Typical range for soil respiration in Ontario farmland is between 0.254 to 2.0 mg of $CO_2$-C per kg of soil.

Soil respiration is a measure of soil biological functioning.

The laboratory method used to measure soil respiration in the Project was 4-day Rewetted Alkaline Trap. In this test, an air-dried soil sample is rewetted to "wake up" the microbial community. As the microbes begin feeding and growing again, they respire and release carbon dioxide ($CO_2$). Those levels are measured and reported as soil respiration.

## Potentially Mineralizable Nitrogen (PMN) – the Soil's Nutrient Power

Recalling that SOM contains organic nitrogen (N), the PMN test measures how much soil organic-N is stored in the SOM, could be available for plant use if released by soil microbes.

Understanding a soil's PMN can help guide and optimize fertilizer application rates.

Typical range for soil PMN in Ontario farmland is between 0.1 to 35 *u*g of N per g of soil.

Soil PMN levels are a measure of soil biological activity driving soil fertility/chemistry.

The laboratory method used to measure PMN in the Project was the 7-day Anerobic @37°C KCL Extraction $NH_4$-N. This method tracks the amount of ammonium-N released by soil microbial activity over a 7-day period to estimate the soil's organic nitrogen levels.

## Aggregate Stability – The Foundation of Soil Structure

Soil particles naturally bind together to form aggregates, which are the building blocks of soil structure. Aggregate Stability measures of how well these soil aggregates remain intact when exposed to water, which means that soils with stable aggregates are better able to resist erosion, crusting, and compaction, while supporting growth and helping plants cope with wet and dry conditions.

Typical range for soil Aggregate Stability in Ontario farmland is between 65 and 98%.

Soil Aggregate Stability is a measure of soil physical conditions and structure.

The laboratory method used to measure Aggregate Stability in the Project was Modified Yoder Sieving, 30 strokes/min (4cm stroke). This method places aggregates on a sieve, which is moved through water at 30 strokes/min with a 4 cm stroke length. The percentage of aggregates that remain intact after the sieving process are considered stable.

## Part 3

## The Ground Truthing SHAP Project

## Project Objectives

The Ground Truthing SHAP Project (the Project) aimed to:

- Build capacity within Ontario with soil health testing by having 1000 soil test voluntarily submitted by farmers and advisors and analyzed by a commercial laboratory.
- Improve how soil health indicator measurements are translated into meaningful soil health scores and ratings.

- Better understand how soil management practices relate to soil health.

## Recruitment

During 2023 to 2025, Ontario farmers and advisors were recruited to participate in the Project by various methods, including announcements on the noon Farm Radio reports, distribution of "coupon" fliers (see figure 2) at sector events and through social media, and invitations to all participants of OMAFA's Topsoil Sampling Project[1].

*Figure 2- Recruitment flyer for the Ground Truthing SHAP project.*

## Participant Instructions and Sample Collection

Once registered, participants were sent the 1-2-3-4 steps of participation:

1- Complete the SHAP Management Tool: This web-based app was used to gather information from farmers and advisors about the cropping and soil management history of the field being sampled, as well as to identify the reason behind choosing a sample location.

2- Complete the SHAP IN Field Tool: This web-based app was used by farmers and advisors to create a geo-referenced record of the soil sample location. This was to help researchers identify slope characteristics of the sample location and could be used by farmers in the future to re-sample from the same location.

3- Take soil sample following Ground Truthing SHAP 4-step protocol:
   - Chose a point in the field to sample based on a goal or curiosity.
   - Use a soil probe (or shovel) to take 15-20 samples from a 3m (10 foot) radius 15 cm (6") deep. Put soil in a clean bucket, remove debris and rocks, then mix but don't pulverize.
   - Put a 500ml (2 cup) sample into at sealable container/bag. Label and store in a cool place.
   - Mark location using the GPS tool (see step #2). Then deliver cool to the lab.

[1] Ontario Ministry of Agriculture, Food, and Agribusiness (OMAFA) (2024) Ontario Topsoil Sampling Project 2024. Ontario Ministry of Agriculture, Food and Agribusiness. https://www.ontario.ca/page/ontario-topsoil-sampling-project-2024

4- Send to the lab: The lab that was used in this study was The University of Guelph's Agriculture and Food Laboratory, located in Guelph, Ontario.

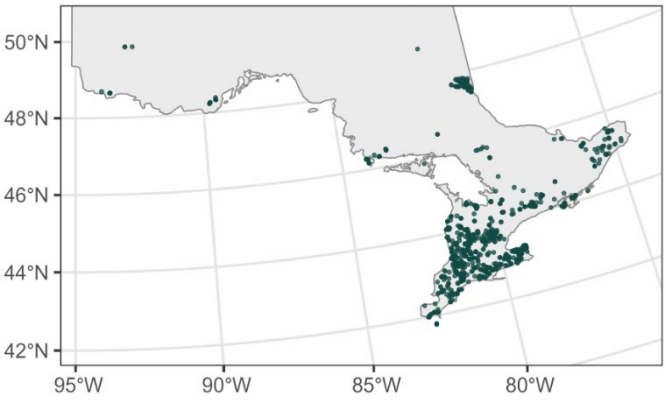
To date, we developed a brochure, *Making Sense of Soil Health Analytical Indicators*, and factsheet, *Measuring Soil Health in Canada: Why Soil Health Testing is NOT Standardized Yet* to support step 3 of the process. The documents also help to address some of the feedback we obtained from project participants through email correspondence and during in-depth conversations.

## Findings

### Sample Participants, Locations and Production Systems

Over the three years of the project, 331 farmers and advisors sent in a total of 1033 soil samples for soil health analysis, ranging from 1 to 30 samples per farm, 1 or 2 samples per field. The samples came from all agricultural regions in Ontario (Map 1). The soil samples could also be grouped into six different cropping systems, Grains (n=598), Grains + Forages (n=119), Forages (n=126), Vegetables (n=123), Vineyards (n=127), and Orchards (n=94) (Figure 3).

*Map 1 – Ontario map showing the geo-referenced locations of the soil samples taken and submitted to the Ground Truthing SHAP project, 2023-2025.*



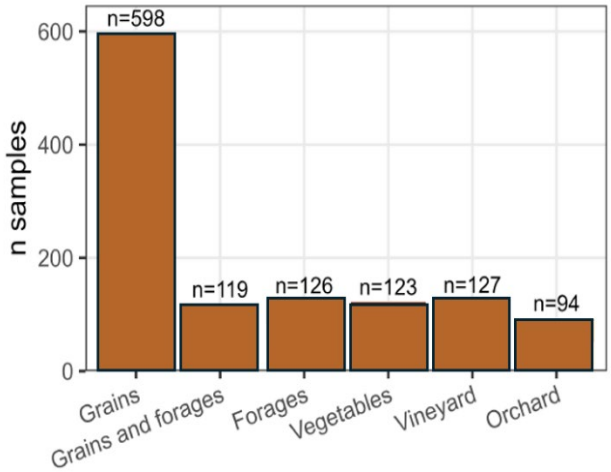




*Figure 3- Production systems of the Ontario operations that participated in the Ground Truthing SHAP Project, 2023-2025. Figure shows that the majority of the soil samples came from Grain Production Systems.*

### Soil Texture

Soil texture describes the relative amounts of coarse sand, medium-sized silt, and fine clay particles in a soil. Because texture can influence soil health measurements independently of management practices, it was important to consider texture when assessing soil health indicators.

Canadian soil texture classes are divided up into categories (fine, medium, coarse) based on the proportion of sand, silt and clay in a soil sample (Figure 4). The different production systems in the study (reference = Pasture + Perennial (Forage) Systems, Annual = Grain, Forage, Vegetable Systems; Horticulture = Orchard + Vineyard) were distributed across texture groups (Figure 5).

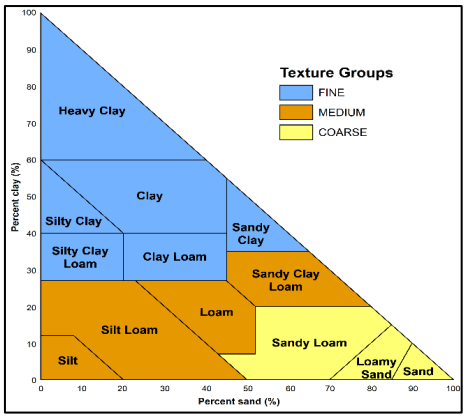



*Figure 4 – The Canadian soil texture triangle, which classifies soils according to their sand, silt, and clay content and groups them into coarse-, medium-, and fine-textured categories.*

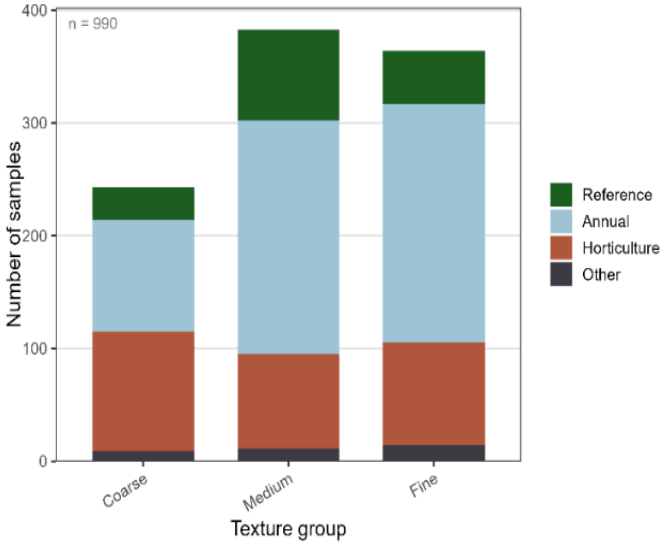



*Figure 5 - Soil sample distribution among texture groups by production systems.*

## Soil Management Practices

Using the SHAP Management Tool (see above), Project participants provided information about their field's cropping history and soil management practices. The soil management practices considered included:

1. Compaction Reduction Strategies. Participants were asked to select the strategy that best described their strategies, including, none used, avoidance of wet soil traffic or use of flotation tires, inflation pressure LT 15, central tire inflation systems, permanent tramlines, or controlled traffic.
2. Use of Cover Crops. Participants were asked if they used them, and if yes, were asked for cover crop mix (single, low mix or >3 mix), frequency of use, and typical termination method.
3. Use of Organic Amendments. Participants were asked if the amendments were solid or liquid, and where also asked about the timing and frequency of application.
4. Reduced Tillage Intensity. Participants were asked to describe tillage intensity by indicating tillage type, timing and frequency.
5. Cropping history. Participants indicated current crop and production history of last 3 years as well as whether there had been perennials within the system in the last 12 years.
6. Residue Removal. Participant were asked to indicate the frequency of residue removal in the last 4 years.

Soil samples were grouped according to the level of soil care practice use within the field, few (0-1 practices; n = 241), some (2-3 practices; n = 379), and many (4-6 practices; n = 213). Soil care practices include: compaction reduction strategies, good crop rotation, use of cover crops, use of organic amendments, reduced tillage intensity, use of perennials and pasture, minimal residue removal. Fields with a history of perennials or pasture – and therefore minimally disturbed - were considered reference conditions (n = 175) (see figure 6).

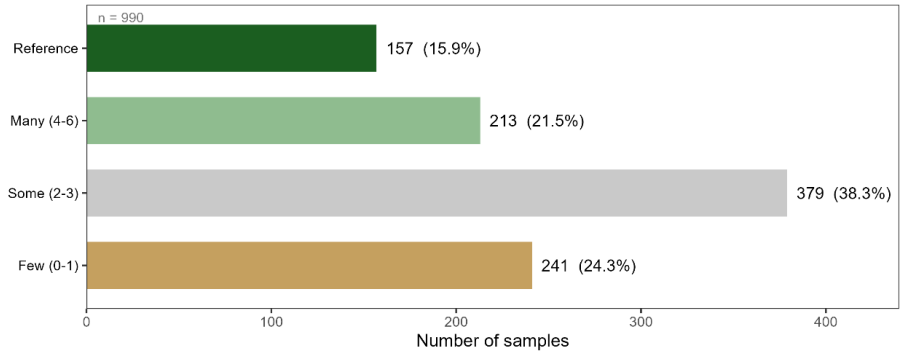



*Figure 6 - Soil samples grouped according to the level of soil care practices "stacked" within the field.*

## Soil Health Indicator Results

Throughout this next section, box-and-whisker plots are used to illustrate how soil management practices influence soil health indicator values within the dataset. These plots provide a concise visual summary of the data distribution, including the median (the vertical line within the coloured box), variability (the middle 50% of observations is contained within the coloured box), overall range (indicated by the horizonal "whiskers"), and potential outliers (shown as dots). This makes it possible to compare differences among management groups while also showing the degree of variation within each group.

The letter (a, b, or c) shown at the far right of each box-and-whisker plot helps identify statistically significant differences among groups. If two groups have different letters, their values are significantly different.

At the top of each graph are the results from the reference sites. For comparison, results are also shown for sites with many (4-6) and few (0-1) soil care practices. Sites with some (2-3) soil care practices are not shown because their values generally fell between those of the many and few practice groups.

## Soil Organic Matter, Active Carbon, Respiration

The results clearly show that as the number of soil care practices increases, levels of soil organic matter, active carbon, and soil respiration also tend to increase (Figures 7, 8 and 9). Soil organic

matter and soil respiration differed significantly among all three management categories (Figures 7 and 9). For active carbon, the reference sites and sites with many soil care practices had similar values, but both were significantly higher than sites with few soil care practices (Figure 8).

These findings also demonstrate the value of benchmarking individual soil test results against a larger database. For example, soil organic matter values of 4% occurred in all soil care practice categories (Figure 7). On its own, a value of 4% provides limited insight. However, when compared with results from fields using similar management practices, it can help farmers determine whether their soil is performing above, below, or near expectations and assess the potential benefits of implementing additional soil care practices.

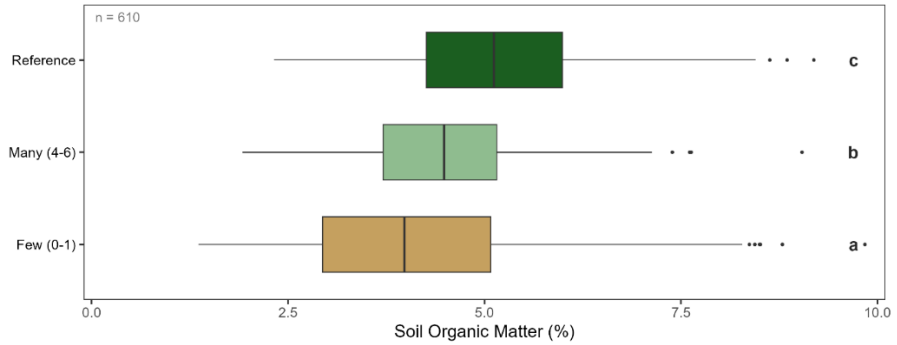



*Figure 7 - Box-and-whisker plots showing that as the number of soil management practices increases, **soil organic matter levels** also increase in the Ontario Ground Truthing SHAP Project database. Sites with 2-3 soil care practices were omitted because their values generally fell between those of the few (0-1 practices) and many (4-6 practices) categories.*

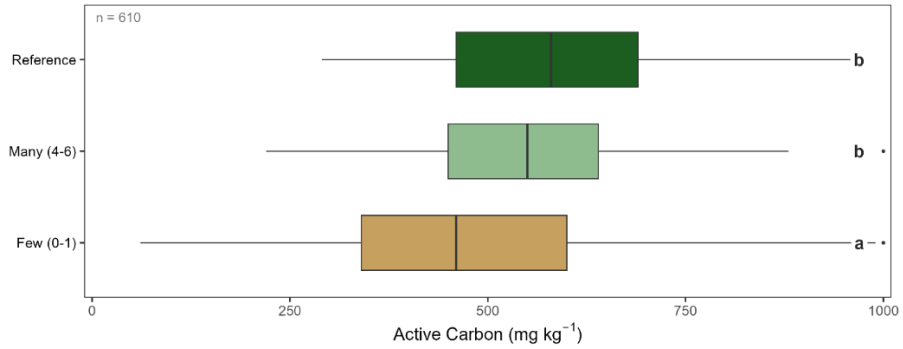



*Figure 8- Box-and-whisker plots illustrating that the reference sites (pastures + perennials) and sites with many soil care management practices have statistically higher **active carbon levels** compared to sites with fewer soil care practices in the Ontario Ground Truthing SHAP Project database. Sites with 2-3 soil care practices were omitted because their values generally fell between those of the few (0-1 practices) and many (4-6 practices) categories.*

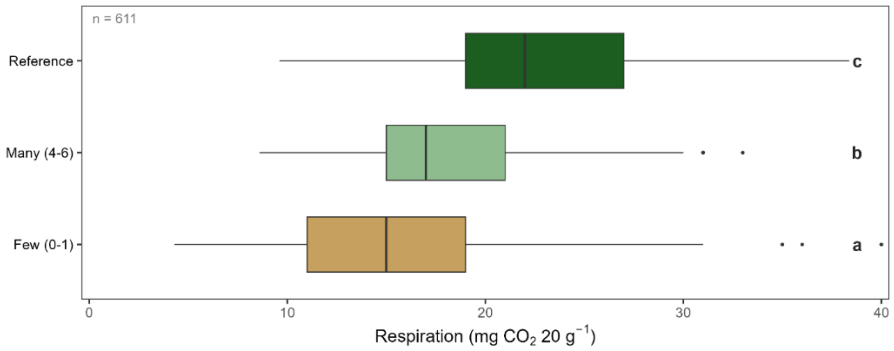



*Figure 9- Box-and-whisker plots showing that as the number of soil care practices increases, so do the **soil respiration levels** in the Ontario Ground Truthing SHAP Project database. This graph shows that the three categories are statistically different from each other. Sites with 2-3 soil care practices were omitted because their values generally fell between those of the few (0-1 practices) and many (4-6 practices) categories.*

Importantly, the data show that both soil texture and management practices influence soil health indicators. For example, in annual Grain Production Systems, soil organic matter levels generally increase from coarse- to medium- to fine-textured soils, as expected (Figure 10).

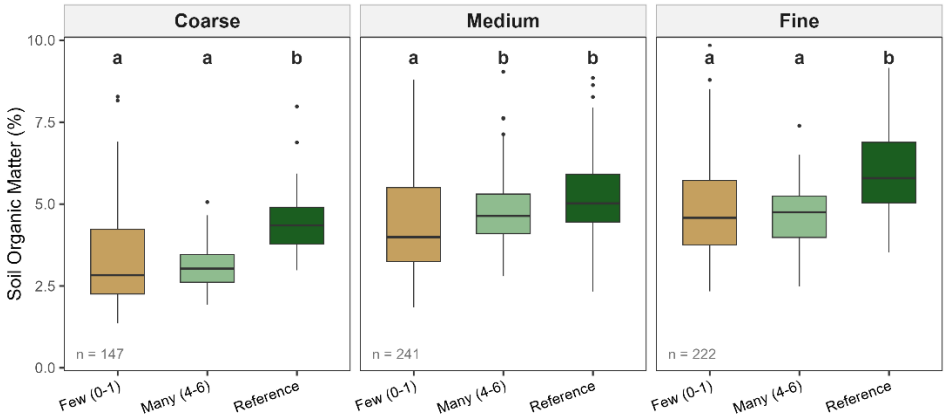



*Figure 10 – Box-and-whisker plots showing the **impact of soil texture** and **soil care management practices** on **soil organic matter** levels in annual Grain Production Systems in the Ontario Ground Truthing SHAP Project database; as soils move from coarse- to medium- to fine-textured soils, soil organic matter levels increase.*

## Potentially Mineralizable Nitrogen

The results show that the reference sites (pasture + perennial) had higher PMN values, but no difference between many or few soil care practices. Also notable is the high degree of variability in the reference sites (Figure 11), which requires further analysis of the data to find an explanation.

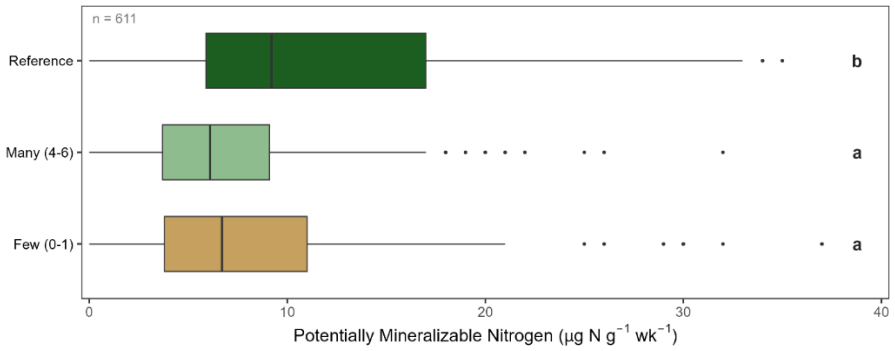



*Figure 11 - Box-and-whisker plots illustrating that reference sites (pasture + perennial) have high variability and statistically higher levels of **potentially mineralizable nitrogen (PMN)** levels compared to the other sites with varying degrees of soil care management practices in the Ontario Ground Truthing SHAP Project database. This graph also shows that the reference sites are statistically different from the other two categories. Sites with 2-3 soil care practices were omitted because their values generally fell between those of the few (0-1 practices) and many (4-6 practices) categories.*

## Aggregate Stability

While the results from the aggregate stability analysis showed a statistically significant difference between sites with few soil care practices (a) and those with many soil care practices or reference conditions (b), there was still a considerable variability within the dataset (Figure 12). In practical terms, this means that although aggregate stability generally improved with increased use of soil care practices, responses varied widely among individual fields. Further, it is unexpected to see that most values are high (>75% out of 100%). Understanding the factors driving this variability will require further study. Until these relationships are better understood, interpretation of aggregate stability results obtained using the modified Yoder method remains challenging. Fortunately, other methods for measuring aggregate stability are available and are recommended.

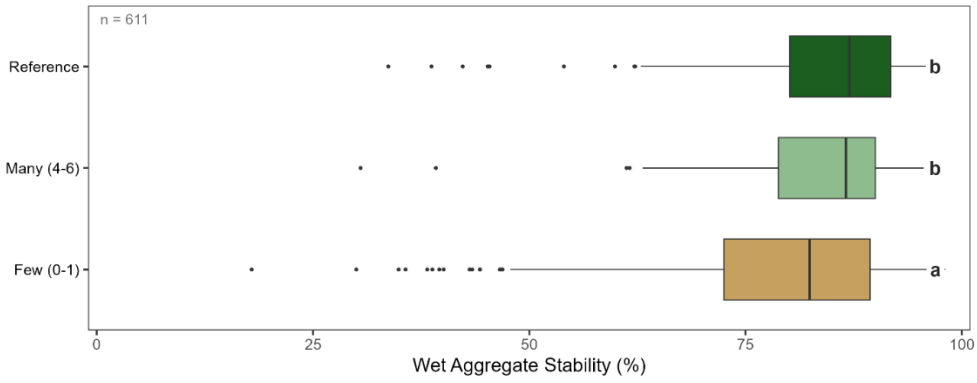



*Figure 12 - Box-and-whisker plots showing that the relationship between soil care management practices and **aggregate stability levels** in the Ontario Ground Truthing SHAP Project database was hard to interpret. The values have considerable variability within the dataset, and unexpectedly high values (>75%) for the majority of samples. Sites with 2-3 soil care practices were omitted because their values generally fell between those of the few (0-1 practices) and many (4-6 practices) categories.*

## Improving access and value for soil health tests: feedback from participants

Feedback from project participants provided valuable insight into how soil health tests were used and what characteristics made them most useful in practice. Participants emphasized the need for timely reporting of results, reduced data-entry and geo-referencing requirements, and interpretation support to help explain unexpected results. They valued benchmarking tools that allowed them to compare their soil health indicators with those of other fields but preferred box-and-whisker plots over red-to-green rating scales. Soil health tests provide different information than soil fertility tests, for example, and establishing realistic expectations for the use of soil health tests was identified as a need. In addition, there was value in farmers and advisors selecting sampling locations based on local knowledge and of sampling multiple locations within a field or farm to improve interpretability. The participant feedback and corresponding recommended actions are summarized in Table 1 and have been shared with regional and national soil health program and policy makers.

*Table 1 - Key feedback from Ground Truthing SHAP Project participants and the corresponding recommendations for the design and delivery of soil health testing programs.*

| Feedback | Recommended action |
|---|---|
| A timely turnaround time for sample results is important. | Selected indicators should be processed in a timely manner, or expectations for turnaround time clearly set. |
| Farmers and advisors have their own ways of documenting sample locations, soil management history, etc., and don't like duplicating effort. | Reduce technological and administrative burden by making the geo-referencing of sample locations and the need to report field management history optional. |
| Farmers and advisors appreciate knowing how their soil health indicator results rank, but using a color scale to indicate poor soil health seems to discourage rather than motivate. | Use box-and-whisker plots to report soil health indicator values situated within a range of possible values and avoid using green to red colour scale. |
| When receiving results that were higher or lower than expected, participants immediately wanted to know why. | Provide soil health result interpretation along with lab results. |
| A soil health test may inform a multi-year, multi-practice approach that takes time to change soil health test results. | Pair farmers with advisors so that farm specific conversations can inform practices and expectations. |
| Participants had a good idea how their soil and crops perform across fields, farms and seasons. | Have farmers and advisors chose soil health sampling locations based on their curiosity and knowledge.<br><br>Design soil health sampling programs to allow farmers and advisors to sample multiple locations across fields or farms.<br><br>Both enable comparison and interpretability. |

## Summary and Next Steps

**Summary of findings:**

- Soil health indicator values were influenced by soil texture; greater values in fine (clay) soils and least in coarse (sandy) soils.
- Despite these texture differences, stacking soil care management practices gave greater soil health values compared to sites where no or only a few practices were being used.
- Reference sites (Pastures + Perennials) had higher soil health scores than other crop production systems, confirming that sites with plant growth, year-round living roots, less disturbance and integration with livestock support healthier soils.
- Involving end users (farmers, advisors, laboratory, OMAFA staff) throughout the piloting process helped make the reports and recommendations more accessible, interpretable, and actionable for farmers and other decision-makers.

**Next steps include:**

- More analysis linking the effects of climate, topography, texture, and other soil properties (fertility, pH, CEC) on indicator values.
- Identify and prioritize soil management practices that build soil health most effectively.
- Anonymized data will be added to the provincial soil database.
- Continue to build capacity within the province and country around soil health testing.