Comparing Soil Health Assessment Frameworks to Strengthen Ontario's Soil Health Assessment and Plan

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Possibility grows here.

SOIL HEALTH INSTITUTE

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Introduction

Soil health assessment frameworks are essential for translating soil measurements into actionable insights that help farmers understand soil functioning and guide management decisions. Outcomes depend not only on indicator selection, but also on how they are scored, interpreted, and communicated. Understanding these design effects is critical as Ontario moves toward broader implementation of soil health testing.

This report presents the results of a comparative evaluation of two approaches for assessing soil health—the Soil Health Assessment and Plan's (SHAP) distribution-based approach and the Soil Health Institute's (SHI) reference-based benchmarking approach—with a focus on indicator performance, framework design, and the influence of statistical assumptions on the transmission of results.

The Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA) is updating SHAP, a cornerstone of Ontario's soil health programming. This presents an important opportunity to ensure SHAP's indicators, scoring, and interpretation accurately reflects soil function, responds to management, and supports practice change. The findings of this study are used to develop actionable recommendations to strengthen SHAP and improve its ability to support effective soil health management, advising, and program delivery.

The evaluation was guided by five key objectives:

1. Evaluate redundancy and management sensitivity among SHAP indicators.
2. Assess how indicator measurement methods influence interpretability.
3. Compare SHAP scoring outcomes with reference-based benchmarking.
4. Identify how texture stratification and experimental design affect indicator results.
5. Develop actionable recommendations to improve SHAP.

Top Recommendations

Based on the study's findings, a series of key recommendations were developed to strengthen SHAP and its implementation:

1. Review correlated indicators to remove redundancy, retaining those that capture distinct soil functions.
2. Reassess the method used for aggregate stability in SHAP.
3. Minimize distortions in scores caused by grouping scores by three texture categories; consider using continuous texture where possible.
4. Provide likely ranges of SHAP scores for similar cropping and management systems to help interpret results.
5. Improve communication of soil health potential in visualization of indicator results.
6. Further develop tools to support soil health management planning and advising farmers.
7. Offer cost-sharing for soil health testing to build interest and encourage adoption.

Evaluation Approach

Dataset and Study Design

The evaluation was based on a dataset of 262 soil samples collected across the Greater Golden Horseshoe region, targeting the dominant row-cropped soils at mid-slope positions. Sampled soils were collected from spring-planted fields with grains and oilseeds. Fields with higher-intensity tillage and no cover crops were categorized as **baseline** and fields with no-till or minimum tillage with winter wheat and/or cover crops were classified as **soil health practices**. To estimate maximum soil health potential, long-term undisturbed **reference** soils under perennial vegetation were also sampled. Each sample was accompanied by a detailed five-year management history.

BASELINE

Corn, soybean, with field cultivator in spring and vertical disk in spring or fall

79 fields

SOIL HEALTH PRACTICES

Corn, soybean, wheat, red clover or oats, with field cultivator before corn or no-till

81 fields

REFERENCE

Long-term pasture, hayfield, orchard, fencerow

102 fields

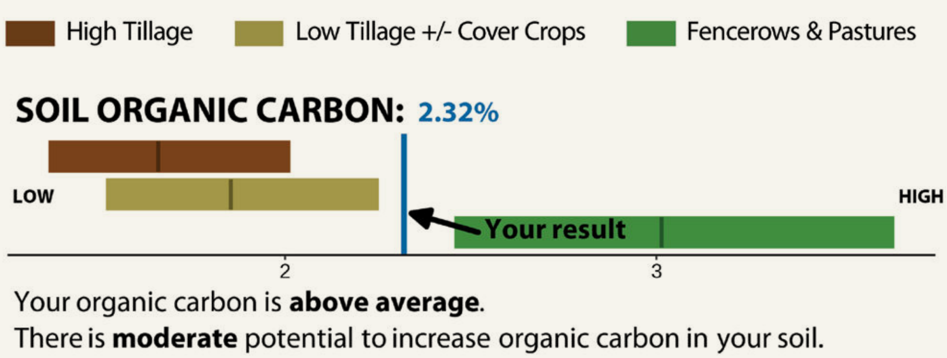
Overview of Distribution-Based and Reference-Based Methodologies

The framework used by **SHAP** includes five soil health indicators and employs cumulative normal distribution–based scoring functions derived from the Ontario Topsoil Sampling Project. Samples are grouped by categorical texture groups (coarse, medium, fine) with indicator scores expressed on a 0-100 scale and mapped to rating categories (very low, low, medium, high, very high; Figure 1).

Figure 1 A soil organic matter indicator result demonstrating SHAP's scoring approach

The framework used by **SHI** includes four soil health indicators and employs continuous models to predict expected indicator values under baseline, soil health practices, and reference management after accounting for inherent soil properties (e.g., clay content, pH). Outcomes are expressed as proportions of predicted reference values and interpreted visually, allowing comparison of soils under baseline and regenerative management as well as maximum soil health potential (represented by references; Figure 2).

Figure 2 A soil organic carbon indicator result demonstrating SHI's benchmarking approach



The soil health indicators used by SHI and SHAP are presented in Table 1. Abbreviations used in this report are given in parentheses.

Table 1 List of soil health indicators used by the Ontario Soil Health Assessment and Plan and the Soil Health Institute's essential soil health indicators

Soil Health Institute Benchmarking Approach	Ontario Soil Health Assessment and Plan
Essential Soil Health Indicators	**Analytical Indicators**
Soil organic carbon (SOC)	Organic matter (SOM)***
Aggregate stability (AS-Image)	Active carbon (POXC)
24-hr potentially mineralizable carbon (PMC)*	Wet aggregate stability (AS-Yoder)
Available water-holding capacity**	96-hr potentially mineralizable carbon (PMC)
	Potentially mineralizable nitrogen (PMN)

* substituted with 96-hr potentially mineralizable carbon in this study
** estimated from SOC and texture; not discussed here but reported to farmers
*** calculated by multiplying SOC by 1.9 in this study

Results

We evaluated both approaches using three criteria: (1) indicator performance (redundancy and sensitivity to management), (2) interpretive outcomes (distributions of scores and outcomes), and (3) assumptions related to texture groupings, management representation, and reference selection. The recommendations that follow focus primarily on indicator selection, scoring methodology, and interpretation and communication.

Key Findings

The evaluation of the two approaches revealed several important insights about indicator performance, scoring, and interpretation:

- Carbon and nitrogen indicators used in SHAP are correlated, while aggregate stability by wet sieving (AS-Yoder) shows little sensitivity to management.
- Aggregate stability measured by image analysis (AS-Image) is largely uncorrelated with carbon indicators and robust to manure effects and reference site selection, suggesting it measures distinct soil functions and represents a strong, independent soil health indicator.
- Since SHAP compares row-cropped soils against a database spanning all agricultural management types, including perennials, scores are influenced by database composition. For example, scores are likely to rise if more row-cropped fields are added to the database.
- Scoring within broad texture categories (coarse, medium, fine) introduces potentially confusing score distortions near texture boundaries that are likely to dwarf the increase in scores projected from beneficial management practices within row-cropped soils.
- The ranked order of soil health ratings is similar between the two approaches, but the approaches differ in visual results presentation (“low”, “medium”, “high”), with implications for how scoring is contextualized and understood.

Indicator Performance

Redundancy among carbon and nitrogen indicators

Carbon and nitrogen indicators (SOC/SOM, POXC, PMC, PMN) were strongly correlated, indicating they provide overlapping information. Multivariate analysis showed these indicators clustered along a single dominant axis of variation, suggesting that multiple indicators provide similar information for row-cropped soils. Additional work is needed to determine whether these indicators independently provide relevant insight into distinct soil functions given associated cost and implementation considerations.

Recommendation:

- Streamline carbon and nitrogen indicators to optimize cost efficiency while preserving functional coverage.

Management sensitivity and aggregate stability methods

Most indicators responded to management after accounting for inherent soil properties, with PMC and AS-Image showing the strongest sensitivity to management. AS-Image was not redundant with carbon indicators, more sensitive to management than AS-Yoder, and insensitive to reference site selection making it a strong indicator for soil health. In contrast, AS-Yoder showed no detectable management response once clay content was included in the analysis. Therefore, AS-Image better captures structural aspects of soil function relevant to management than AS-Yoder.

Recommendation:

- Reassess the role and laboratory method used for aggregate stability based on demonstrated management sensitivity.

Framework Performance

Scoring vs. benchmarking

The distribution-based and reference-based approaches often produced similar rankings of soils but differed in categorical interpretations. The distribution-based approach tended to score row-cropped soils lower regardless of management, while the reference-based approach partially accounted for the influence of non-manageable factors on soil health, such as access to organic amendments. This difference reflects the fact that SHAP compares row-cropped soils to the full range of agricultural management (including perennial) on the Ontario landscape, whereas SHI stratifies by row-cropped management (e.g., baseline, soil health, reference).

Recommendations:

- Explicitly frame attainable score ranges for specific cropping systems.
- Contextualize effects of non-manageable factors such as access to organic amendments when reporting scores.

Texture stratification

The use of broad texture categories in SHAP produced score fluctuations of up to ~30 points at texture boundaries. While the broad texture categories simplify analysis, it introduces discontinuities that may overwhelm management effects near boundaries.

Recommendations:

- Explore continuous treatment of soil properties and management (e.g., clay content) to minimize boundary artifacts.
- Evaluate strategies to reduce score discontinuities due to texture categories without sacrificing statistical power.

Experimental design

Simulations showed that SHAP scoring curves shift depending on the proportion of row-cropped versus reference soils in the parent database. Similarly, SHI outcomes varied with reference site selection, particularly for carbon and nitrogen indicators, with unmanaged references (woodlots, fencerows) giving higher maximum soil health than managed references (hayfields, orchards).

Recommendations:

- Separate communication of progress from maximum potential.
- Consider more explicit treatment of management effects in scoring development (e.g., grain and oilseeds, pasture, orchard, etc.).

These findings demonstrate that assessment outcomes depend on framework choices.

Implications for Use and Implementation of Results

While the analyses above focus on indicator and framework performance, their ultimate value depends on how results are translated into meaningful, actionable guidance. The following section considers implications for reporting results and management recommendations to farmers, as well as program implementation.

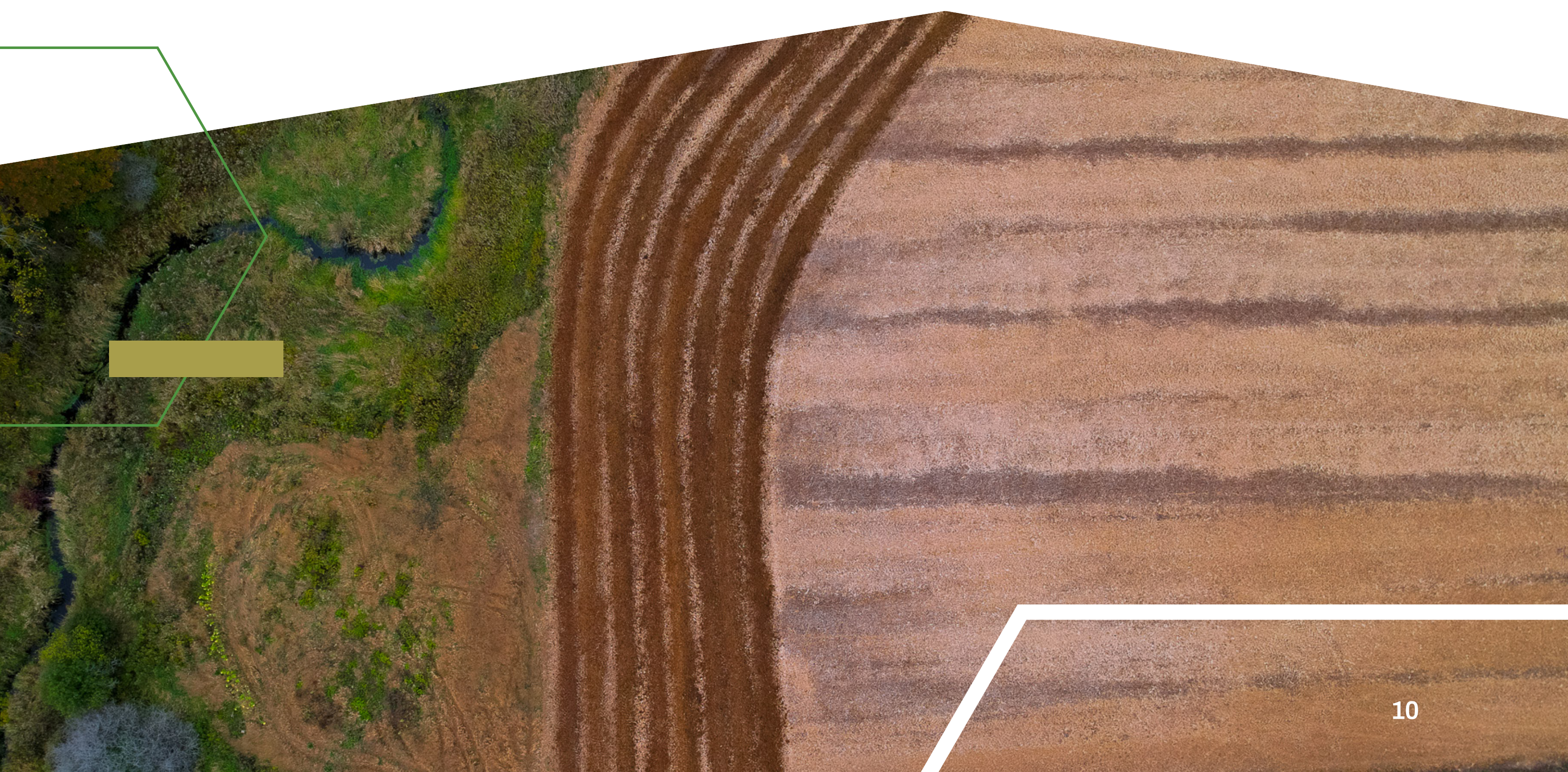
Soil Health Management Plans

Soil health assessment is still an emerging practice in Ontario and must provide clear, practical value to farmers to achieve acceptance and widespread adoption. SHAP recognizes the need to translate the indicator values into actionable recommendations rather than reporting scores alone.

Building on this foundation, this project expanded the existing soil health management plan template to make it easier to generate tailored recommendations for farmers seeking to improve their soil health. Tools were developed to guide the creation of customized management plans from an inventory of inherent soil properties, measured indicator values, and five-year management histories. These tools draw on existing resources, including Environmental Farm Plan worksheets, to help rank management recommendations based on priority. Recommendations also consider farmers' goals and operational constraints, ensuring that plans are practical and achievable.

Recommendation:

- Further develop and refine soil health management plan tools to strengthen their usability and impact.



Cost

Paying for a soil health assessment represents a new cost for farmers and is higher than the cost of conventional soil fertility testing. Fertility tests have a well-established value proposition through optimizing fertilizer input costs. An equivalent, widely recognized economic value proposition for soil health testing has not yet been established.

In this study, farmers who participated received soil health tests at no cost. Laboratory costs for soil health tests for each approach were in the range of $100 to $150 CAD per sample, and future retail costs could be higher. While these costs are not prohibitive, new practices that generate both private and public benefits are often cost-shared to encourage adoption beyond innovators and early adopters.

Cost-sharing for soil health testing is widely available across the United States through major Farm Bill programs (e.g., EQIP). In Canada, some Conservation Authorities in Ontario have supported soil health testing and Prince Edward Island offers free soil health tests. Soil health testing is unlikely to gain broad traction without a complementary cost-sharing program to encourage uptake that will, in turn, create a market for laboratories to offer the tests.

Recommendations:

- Establish cost-sharing programs for soil health testing to support adoption and market development.
- Encourage the commercialization and accessibility of soil health testing at Ontario laboratories.

Conclusion

This assessment demonstrates that soil health outcomes depend as much on framework design and statistical assumptions as on measured soil properties. SHAP provides an accessible and operationally efficient assessment, but targeted refinements could improve interpretability and buy-in from farmers.

By maximizing independence of indicators, minimizing score fluctuations from texture groups, and adding agronomic context to results, SHAP can better support realistic and actionable soil health improvements across Ontario's agricultural system. Pairing soil health testing with robust soil health management plan tools and cost-sharing mechanisms will be critical to translating soil health measurement into meaningful practice change.

Looking ahead, successful scaling of SHAP will require attention to commercialization considerations, including laboratory capacity, standardized methods, and consistent approaches to interpretation. Addressing these factors alongside technical refinements will position SHAP as a credible, scalable foundation for Ontario's soil health programming.

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