ORGANIC SOIL HEALTH BENCHMARKING

FINAL REPORT

ABOUT US

The Prairie Organic Development Fund (PODF) was incorporated as a federal non-profit association in x, as a platform to build the financial capacity of Prairie-based organic associations as well as to work across the Prairie on cross-cutting and innovative projects of benefit to the organic sectors in all three provinces. More recently, PODF has undertaken projects, including this one, that include organizations outside of the Prairie region. PODF is managed by a Board of Directors that includes representatives from the three Prairie Associations, organic farmers from three Prairie provinces, a scientist and funders who financially support PODF. current funder partners include:

ACKNOWLEDGEMENTS

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Updated June 2026

Funding for this project was generously provided by:

Project Partners:

Implementation Partners:

INTRODUCTION

Healthy, productive soils are the foundation of planetary life. Yet humans have not always treated soil with the respect it deserves.

In 1984, the Senate Standing Committee responsible for agriculture released a report called *Soil at Risk: Canada's Eroding Future*[1] that catalogued a litany of challenges that could accelerate deterioration of soil productive capacity, with soil erosion taking centre stage.

> Soil is and always has been, more than mere earth beneath our feet. It is the lifeblood of our nation's growth, sustenance, and prosperity. From the vast prairies of the West to the resiliency of the North to the fertile valleys of the East, Canada's soils have sustained generations of farmers, nurtured diverse ecosystems, and supported a thriving agricultural sector that is the envy of the world.[1]

Forty years later, the Committee released a second analysis of the state of Canadian soil health called *Critical Ground: Why Soil is Essential to Canada's Economic, Environmental, Human, and* Social Health[2]. The report noted that soil management had improved, but it also noted that yield gains fostered by external inputs, have masked continued soil degradation.

The 2025 report precipitated two significant developments. First, after releasing the report, the Senate introduced a bill (S-230, *An Act Respecting the Development of a National Strategy for Soil Health Protection, Conservation and Enhancement*) which, as of March 2026, had been approved in the Senate and was awaiting first reading in the House of Commons. The bill would require a national soil health strategy, improve data collection with respect to degradation, structure, composition, nutrient status, contamination, carbon and soil ecology, an increase in scientific research, knowledge transfer to soil managers and creation of a National Advocate for Soil Health.

Bill S-230 was followed by the announcement of a *National Agricultural Soil Health Strategy* in March 2026 to support improved data collection and sustainable soil management practices.

More important than what Government thinks, how do farmers view soil health? In a national poll commissioned by respected market research firm, Leger, for Farmers for Climate Solutions in 2024, farmers identified climate change as the number one threat to agriculture. Ninety-four percent of farms saw improving soil health as their top priority They listed practices such as improved nitrogen (N) management, reduced tillage, cover cropping, habitat conservation and rotational grazing as key practices to achieve this objective.

With its focus on holistic management, ecosystem and soil health, and limitation of soil-harming inputs, it seems like a no-brainer that organic farming will improve soil health outcomes. However, many would disagree with this assumption, arguing that its reliance on tillage for weed management has significant detrimental impacts on soil health. This view has led many farmers to adopt an emerging alternative – regenerative agriculture which like organic incorporates many soil-building methods but which typically maintains chemical tools, especially those for weed management.

Organic land managers use different, and potentially more, of the types of soil management practices below than their conventional counterparts. For example, typical organic farms are more likely to:

- Employ tillage more frequently;
- use cover crops that may include a diversity of legume and non-legume species;
- include more diversity both within crops and across crop rotations;
- incorporate perennial crops;
- integrate livestock into crops;
- incorporate animal manure or composted manure; and to
- maximize nutrient cycling.

While not intending to be a definitive scientific treatise, in this project, we set out to work with organic and low-input farmers in different parts of the country to get a snapshot of soil health. As part of the project, farmers told us about their management practices, and we helped them to set up a soil health benchmarking protocol and collect preliminary soil tests.

Canada's General Principles and Management Standards (CAN-CGSB-32.310-2020) - a legally binding 'rulebook' for organic production, requires organic farmers to establish management strategies designed to maximize soil health, nutrients and microbial populations. This starts from the principles and is codified through specific production requirements such as the clauses at right.

5.2.4 Management practices shall include measures to promote and protect ecosystem health on the operation and incorporate one or more of the following features: a) pollinator habitat; b) insectary areas; c) wildlife habitat; d) maintenance or restoration of riparian areas or wetlands; or e) other measures which promote biodiversity...

5.4.1 The main objective of the soil fertility and nutrient management program shall be to establish and maintain a fertile soil using practices that: a) maintain or increase levels of soil organic matter, b) promote an optimum balance and supply of nutrients, and c) stimulate biological activity within the soil.

5.4.2 Where appropriate, the soil fertility and biological activity shall be maintained or increased, through: a) crop rotations that are as varied as possible and include plough-down crops, legumes, catch crops and deep-rooting plants; b) incorporation of plant and animal matter in compliance with this standard…

5.4.3 Tillage and cultivation practices shall: a) maintain or improve the physical, chemical and biological condition of soil, and b) minimize damage to the structure and tilth of soil, and c) minimize soil erosion.

5.4.4 Plant and livestock materials shall be managed to maintain or improve soil organic matter content, crop nutrients and soil fertility, and in a manner that does not contribute to the contamination of crops, soil or water by plant nutrients, pathogenic organisms, heavy metals or residues of prohibited substances.

5.4.5 The organic matter produced on the operation shall be the basis of the nutrient cycling program. It may be supplemented with other nutrient sources described in the standard or listed in Table 4.2 (Column 1) of CAN/CGSB-32.311. …

General Principles and Management Standards (CAN-CGSB-32.310-2020)

PROTOCOL

Project Objectives

- To provide a benchmark for soil health indicators including soil carbon content, soil aggregate stability, and soil nutrient status on certified organic and transitioning farms in Atlantic Canada, Ontario and in the Prairie provinces
- To encourage farmers to try different soil health improvement interventions; and to support them by monitoring the effects of those interventions on soil health indicators

The Natural Systems Laboratory of the University of Manitoba developed a protocol, as well as a training document and videos with detailed instructions for collecting soil samples. The five participating organic associations hired regional soil health coordinators whose job was to sign up organic farmers in their region and to work with farmers, agronomists to ensure that the various soil tests were conducted at the right times and that the soil was sent to the right place for testing. An online training session hosted by the University of Manitoba ensured that Regional Coordinators were familiar with the protocol and soil sampling procedures.

The majority (81%), but not all, producers had organic certification. Several producers who utilized mainstream inputs such as synthetic fertilizers, and crop protection products were included in the benchmarking study, but their data was excluded from the analysis. Only operators that were certified organic or committed to using organic practices were included in the analysis. All production types, including vegetable, field crop, vineyard and mixed (livestock and crops), were welcomed.

PARTICIPANTS

Five partner organizations, including Atlantic Canadian Organic Regional Network (ACORN), Organic Council of Ontario (OCO), Manitoba Organics (MO), SaskOrganics (SO) and Organic Alberta (OA) recruited volunteers from within their membership bases. Participants were not required to be certified organic, but the majority were. Farms with all types of production and production methods were encouraged to participate.

THE 'EXPERIMENT'

While this project was not designed using a rigorous scientific protocol, we did ask producers to come up with a mini experiment that could be run over a single season on two fields or two parts of a single field. Farmers were asked to choose two neighbouring fields or a single field that could be divided into two parts. They were told that fields should be similar in terms of soils and topography The comparator field, called the Reference (R) field, was intended to be 'business as usual', i.e. what the farmer would have done with the land if they were not participating in this project. It could be a vegetable or field crop or pasture. The other field or field area where they were to try out a new management practice was called the Intervention (I) field.

Farmers were given text and video protocols that included examples of beneficial soil management practices, but farmers were asked to make their own choices about what they wanted to do on the I field. Examples provided included:

- seeding cover crops,
- adding manures or composts,
- reducing tillage frequency and or intensity by changing tillage implements, and
- incorporating livestock

Soil Health Indicators:

- Aggregate Stability
- Nutrient Status
- Bulk Density
- Total Soil Carbon
- Soil Organic Carbon

Regional Coordinators ensured that participating producers documented practices they planned to implement on the two fields, along with relevant background information such as precipitation history, cropping histories, typical crop rotations and cultivation practices in a detailed questionnaire.

Soil nutrient status was tested before and after the protocols were implemented. Producers were given the choice of doing the pre-test either in the Fall of 2024 or in the Spring of 2025 prior to seeding. All post-tests were done in the fall of 2025. A minority of producers also provided plant samples several weeks prior to harvest 2025.

SOIL TESTS

We looked assessed several key aspects of soil health, including chemical (nutrients), physical (soil aggregation and bulk density) and biological (soil organic matter, Fig. 1).

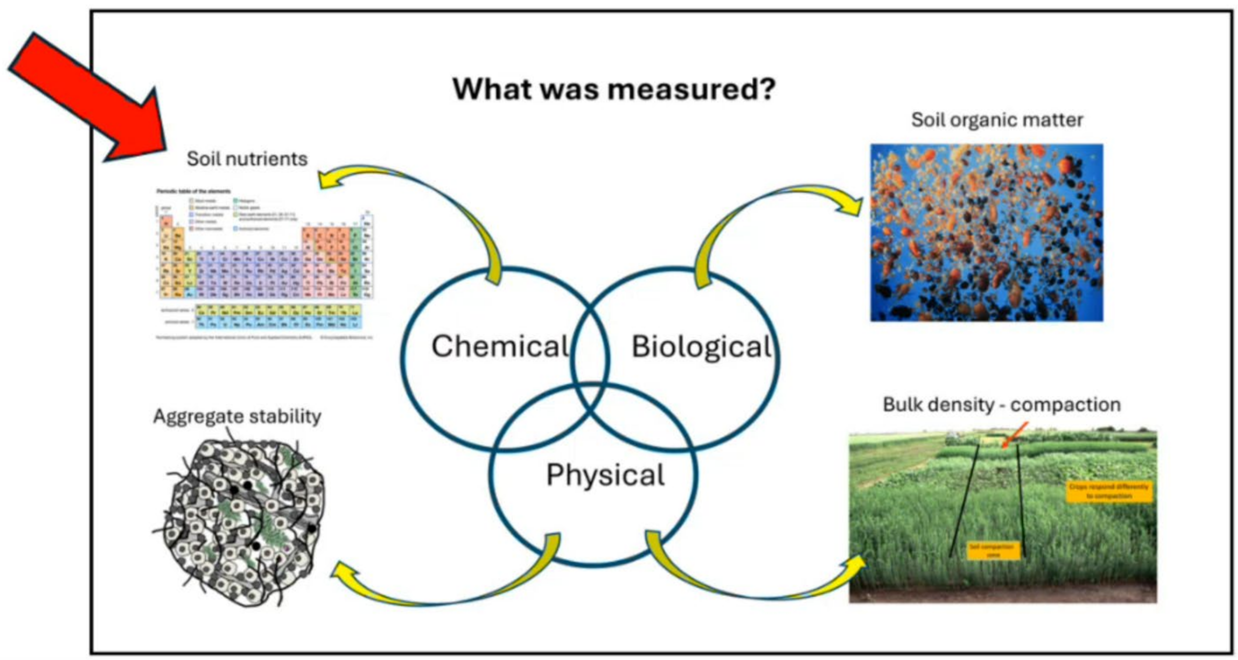
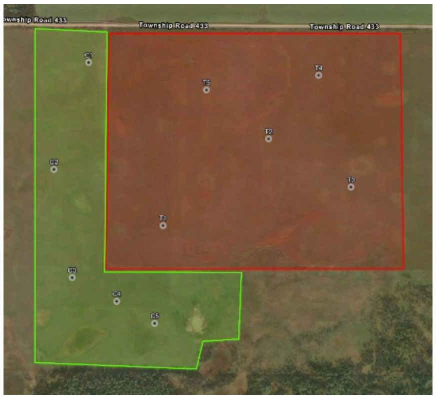


Figure 1 Soil attributes measured in this project

Soil tests were collected for nutrient analyses before and after the ‘experiment’ (pre and post-tests), with the post-test providing a more complete picture by including micro-nutrients not included in the pre-test. Bulk density, carbon and aggregate stability tests were performed using additional soil samples collected in the first set of tests.

Soil sampling professionals were subcontracted in each of the five participating regions to cover areas with the highest densities of participating farms. Farms were given a choice of collecting their own pre and post-test samples or outsourcing the sampling. Most chose to go with the professionals. Those outside of our collection ranges collected their own samples. Sampling, mailing and testing costs were covered by the project.



For both pre- and post-tests, five soil samples were taken in two fields/areas (R and I areas), with samples at least 30 m apart and 10 m from field edges (further if there were trees at the field edge) (Fig. 1). Samples for soil nutrients were collected at two depths: 0-15 cm (0-6”) and 15-60 cm (6-24”) using an auger or cylinder. In the pre-test, samplers were asked to either mark the locations of each sample or to take GPS coordinates so that subsequent tests could be done in the same locations (Fig. 2).

Figure 2 GPS map of sample locations created by soil sampling company

For the nutrient tests, five samples at each depth from each field/area were pooled, mixed and resampled.

During the pre-test, additional soil was collected using a volumetric tool such as a or a tulip bulb planter from five nearby locations in each field for bulk density and carbon analysis. Soil samplers and farmers were instructed to submit the volume of the soil core (height x diameter of tool) with their samples.

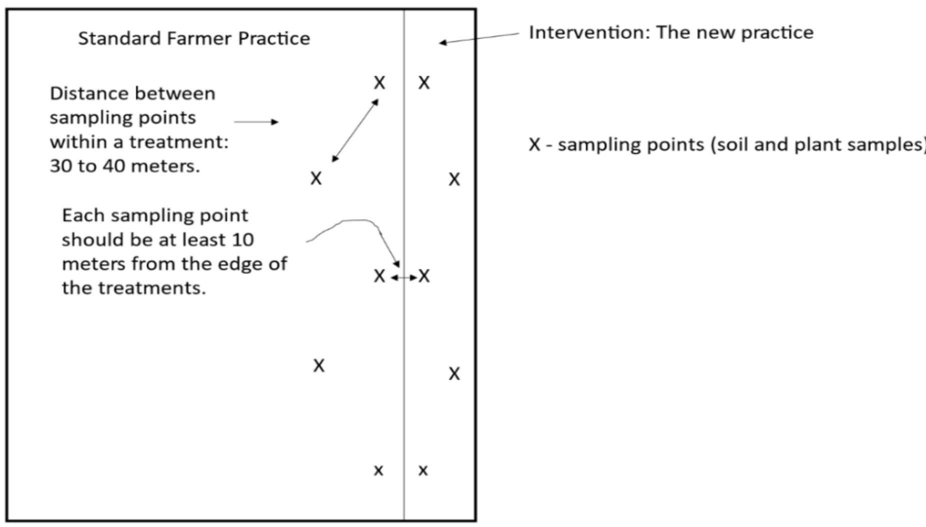


Figure 3 Soil sample design for nutrient and bulk density/carbon samples

Bulk density/carbon samples were collected at a single depth (0-15 cm; 0-6”) and samples were not aggregated, with each sample placed in its own collection bag.

Producers were also encouraged to collect their own plant samples for whole plant nutrient analysis. This was typically done using a quadrat – a 3-sided frame which could be placed randomly within a crop about three weeks prior to harvest. Farmers were instructed to use a sharp knife to cut the material within the frame down to the soil surface and to dry out the plant material before shipping. They included information about the sample area, date of harvest and the crop and submitted this, along with the samples, directly to AgVise. Once the material was dried down weighed and analyzed for nutrients, researchers at the University calculated nutrients on an area basis.

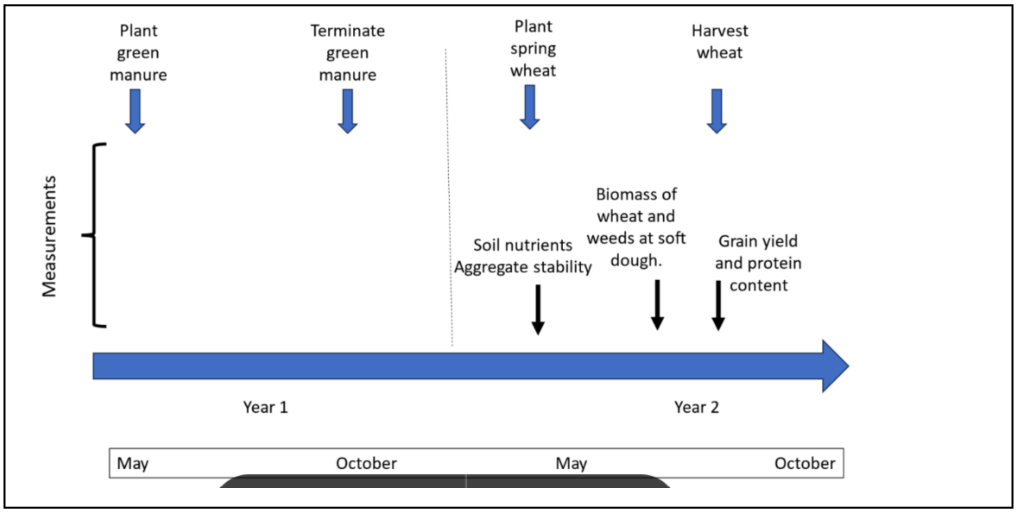


Figure 4 Timing of farming and sampling activities

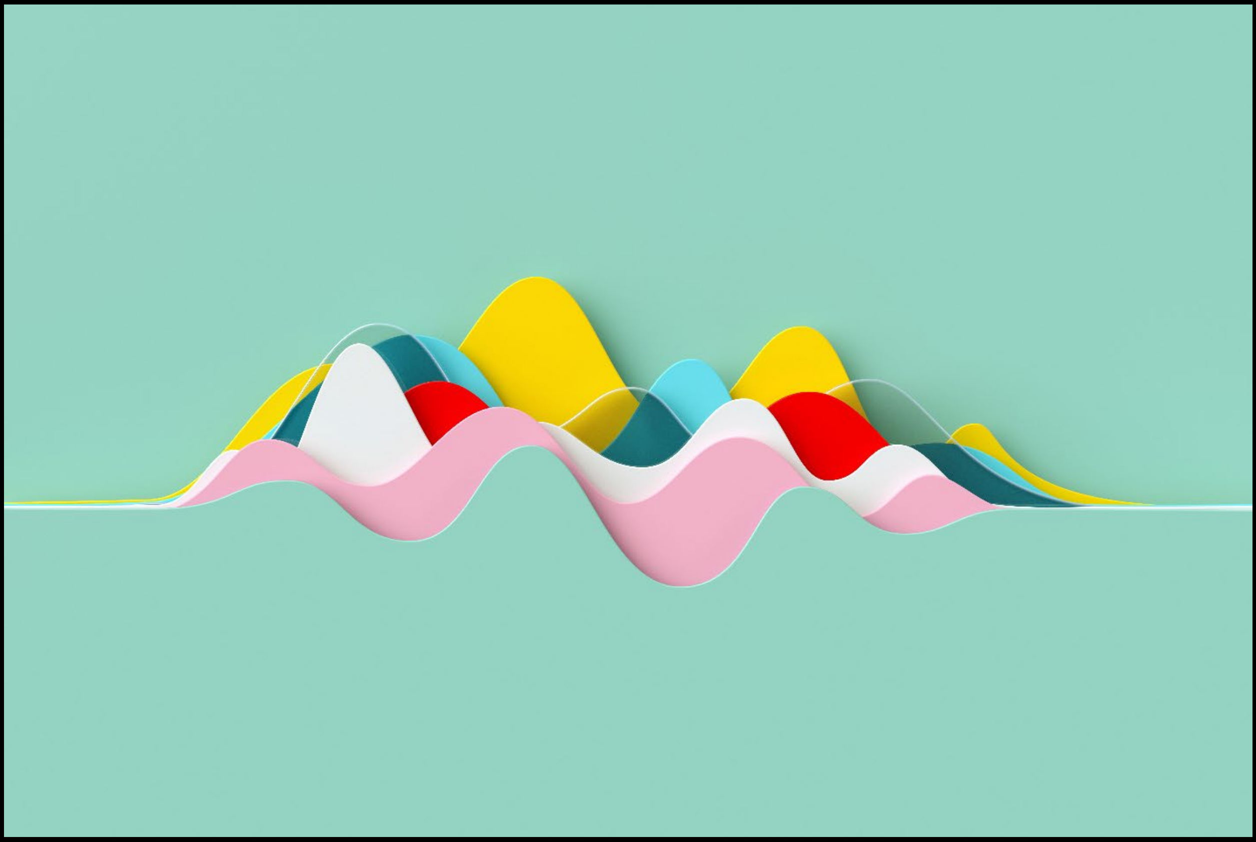
In Atlantic Canada, no soil samples were collected in potato blight control areas as soil movement is strictly controlled in these regions.

LABORATORY ANALYSIS

For the soil carbon analysis done in the fall of 2024 or spring (pre-seeding) of 2025, soil samples were shipped to the University of Manitoba where they were dried in an oven and weighed. Following pre-processing, samples for both nutrient and bulk density/carbon pre-tests were couriered to AgVise Laboratories in North Dakota for further analysis. The University subsampled a small amount of soil from the samples collected for nutrient analysis and these tests were packaged separately for aggregate stability analysis. Post-test nutrient samples were shipped directly to AgVise for macro and micronutrient analysis.

Once test results came back from AgVise, researchers calculated bulk density in grams per cubic cm of soil from the carbon samples and total organic carbon by combining the carbon percentage from the AgVise test with bulk density and sampling depth. This provided a measure of stored carbon in tons of organic carbon per hectare of land.

Once tests results and analyses were complete, the University of Manitoba and Manitoba Agriculture developed customized soil health reports for each producer with raw results, analysis and suggested management strategies to improve soil health.



RESULTS

Soil Health Profile

Anavi Davies | Chester Basin, Nova Scotia

Anavi Davies is transitioning to organic vegetable production, with plans to establish a 7-acre market garden integrated with willow and pecan trees. The property, located near Stanfield Airport in Halifax, has a unique history: it was historically used as a hay field but was reclaimed by nature over the past 30 years, developing into wild vegetation.

In spring 2024, the land encompassing both I (Intervention) and R (Reference) fields was cleared using a backhoe and seeded with a pasture mix of Devour orchard grass, perennial ryegrass, and Kentucky bluegrass. Pecans, hazelnuts, and willows were also planted to begin establishing a long-term agroforestry component. In 2025, sunflower, luffa and herbs were seeded in the R field. The I field was seeded with additional pasture species in April 2025, when hay grazer, alfalfa, and white clover are added to the existing pasture mix.

The main differences between fields was crop composition, with the R field in pasture and trees and the I field in crops. Both fields were managed using multiple regenerative practices including integrating clover, trench composting, compost tea, and permaculture principles such as intercropping with legumes, and sheet mulching. No cultivation beyond the initial clearing has been conducted, reflecting a commitment to minimal soil disturbance as the farm transitions from wild land to managed agricultural production.

Soil Nutrients: Table 1 shows generally lower nutrient levels than the Atlantic Canada average in the R field, with K in the low to very low range n both fields. P levels were at the upper end of the medium range in both fields, while N was considerably higher in the I field.

Field	Nitrate 0-6” (lb/ac)	Nitrate 6-24” (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 6-24" (lb/ac)	Organic matter (%)	pH 0-6"	pH 6-24"
R	4.0	18.0	11.0	12.0	18.0	48.0	5.2	5.2	5.0
I	12.0	81.0	10.0	10.0	22.0	54.0	7.9	5.0	4.8
AC Av	**11.3**	**24.2**	**31.4**	**108.1**	**12.8**	**30.4**	**6.4**	**5.9**	**5.6**

Table 1 Soil micronutrients from R and I plots compared to Atlantic Canada average

Organic Matter & pH: Both fields have acidic soils (5.0 – 5.2 vs. compared to the more neutral 5.9 average) that will limit nutrient availability (Table 1).

Micronutrients: Sampled fields had lower levels of most micronutrients than other participating farms in the region, except for copper, and boron (I field only) (Table 2).

Field	Cl 0-24”	Bo (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
R	24.0	0.1	0.4	103.8	6.2	0.6
I	24.0	0.3	0.3	169.3	6.5	0.6
AC Average	**56.0**	**0.3**	**2.5**	**116.4**	**9.8**	**2.2**

Table 2 Soil micronutrients from R and I plots compared to Atlantic Canada average

Aggregate Stability: The R field had a larger percentage of sand retained in the 53-micron sieve than the I field (Fig. 5, 68.4 vs 59.1). This was filtered out and therefore not included in the aggregate classes. Overall, aggregate stability was below average in the R field (27.6% vs. 37.2% AC average) with the intervention field closer to average at 35.1%. The I field had a higher percentage of aggregates in the two larger classes, but also more of the smaller aggregates and fine material because it had a lower percentage of sand (Fig. 5).

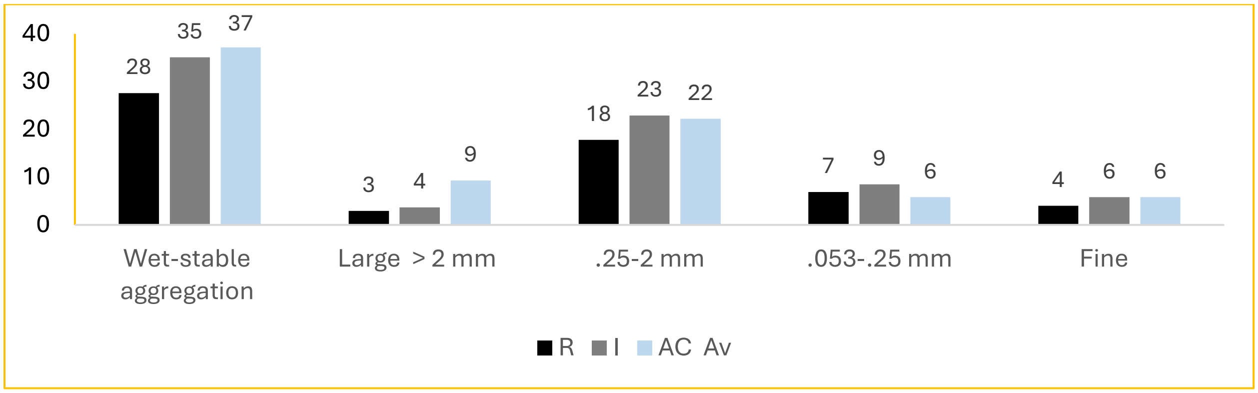


Figure 5 Aggregation stability from the R and I plots compared to Atlantic Canada average

Bulk Density & Soil Carbon: Bulk density and carbon were sampled at 10 cm (3.9"). The I field had very high levels of organic matter (7.9% vs. 6.4% average) and good bulk density (Fig. 6, 1.02 g/cm³ vs. 1.1 average), indicating minimal compaction despite the recent clearing work.

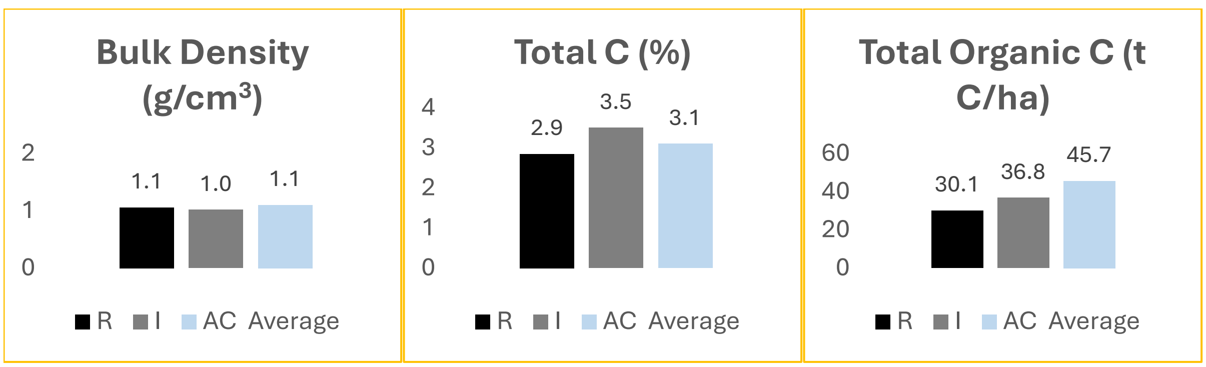


Figure 6 Bulk density, total carbon and organic carbon in R and I fields as compared to Atlantic Canada average

Recommendations:

1. **Tackling nutrient deficiencies.** The greatest need is for potassium (K) in the short term and phosphorous and nitrogen in the long-term. There are many different organically approved sources to choose from. Legumes will be important to maintain (I field) or improve (R field) N status. If manure is added as a source of potassium (K), this will also address phosphorous (P) levels, as well as important micronutrients such as copper and zinc. A combination of legumes in rotation and judicious use of manure or compost should satisfy the nutrient needs of this system. Another option to boost P levels is struvite, recently been approved for organic. Ongoing monitoring should be performed to assess nutrient status.
2. **Continue building organic matter and soil biology** through regenerative practices such as addition of manure or compost, growing cover crops, and reducing tillage.
3. **Soil physical properties** appear quite healthy. Bulk density levels are very good and should be maintained below 1.2. Aggregate stability is acceptable for land that had received heavy short-term intervention from a backhoe.
4. **Soil biological parameters** as measured by soil organic C appear very adequate for optimum vegetable and fruit production.

PROJECT PARTICIPANTS

In the spring and summer of 2024, Regional Coordinators signed up 156 participants in Atlantic Canada, Ontario, Manitoba, Saskatchewan and Alberta. By the spring of 2025, only 38% (59) remained in the project. This high drop-out rate was not unexpected as sample collection occurred during peak work periods for farmers prior to seeding and after harvest. A further four farms were excluded from the analysis because of their reliance on conventional inputs.

A breakdown of participants by region and production type is shown in Table 1. The vast majority (79.7%) of the farms were certified organic. Those that were not certified tended to be vegetable producers. All but two of the field crop producers were certified and one of these was in transition to organic. Fifty-eight percent of participants were field crop producers. Forty-seven percent of participants were based in Saskatchewan, and all grew field crops. Most of the producers in Atlantic Canada grew vegetables. One ON farm cultivated fruit trees, and another was a vineyard. Non-organic farms that were either in transition or were using organic methods with no use of conventional fertility or weed/disease inputs were included with the organic farms for analysis. Two farms were excluded due to use of conventional inputs.

Province	Participants	% of Total	Organic	Vegetable	Field Crops	Mixed	Perennial
AB	3	5.5	2	2	0	1	0
SK	26	47.2	25	0	20	4	2
MB	11	20.0	9	2	2	6	1
ON	8	14.5	8	1	2	2	4
NS	6	10.9	3	1	0	3	5
NB	1	1.8	0	1	0	0	0
Total	55	100	47	11	34	10	2

Table 3 Overview of production systems and organic status of participating farms

Note, in some cases, farm types do not sum to the number of participants. This is because different fields within a single farm could be categorized with a different production type.

FARM MANAGEMENT PRACTICES

While most participants had a long history of using experimenting with beneficial soil management practices, some of the practices chosen in this project are shown in Table 4. Typically the beneficial practice was employed in one field while a ‘business-as-usual’ practice was employed in a neighbouring field or field half.

	Vegetable	Field Crop	Mixed	Perennial
Reduced tillage intensity/frequency	• Tarps vs. tillage for weed management • Roto-tilling vs. flail mowing	• Mowing vs. discing • Direct seeding into litter vs. usual cultivation then seeding • Cereal grain u/s to clover. Clover allowed to grow following season with no cultivation vs. annual cereal crop • Reduction of # of tillage passes		• Tillage vs. rotary cutter
Livestock grazing	N/A	N/A	• Field crops terminated by grazing (rotational) vs. no till • Alfalfa (ungrazed) vs. grazed pasture • Bale grazing vs. no bale grazing • Pig tractor vs. no pig tractor • Grazing vs. mowing • Grazing vs. cover crop mixture • Chicken/rabbit tractors vs. not grazed • Grazing vs. no grazing in vegetable production • Strip tillage vs. rabbit grazing in vegetable production	• Intensive grazing with frequent moves using electric fences vs. less intensive grazing
Additional compost/ animal manure	• Manure from chicken grazing vs. approved commercial composted chicken manure	• One vs. two compost applications • Cash crop after perennials vs. continuous tillage • Composted oats applied to knolls vs. none • Raw cattle manure application vs. none		• One vs. 2 applications of composted manure
				•

	Vegetable	Field Crop	Mixed	Perennial
Increased plant species diversity		• Increasing # of species seeded together vs. single crops • Intercrops u/s with cash crops vs. as plow down • Oat yield inside vs. outside of 8' wide cover crop strips of 4010 forage peas		• Different grass-legume mixes in perennial alleyway between vines
Perennials		• Increased use of short-lived perennials vs. annuals to increase period with growing roots • Cash crop after perennial crop vs. following annual crop • Continuous cropping vs. field crops rotated with perennials	• Continuous cropping vs. breaking of 100 yr old pasture	
Inputs		• Radonic energy on cropping land vs. nothing on pasture • Foliar application of compost tea vs. none • Humaterra (composted microorganism prep) test strips vs none • 'Replenish' and iron supplements vs. none • 1 vs. 3 applications of amino-N on soft white wheat		
Other	•	• Comparing back-to-back wheat with and without summer fallow in between		

Table 4 Types of 'experiments' implemented on vegetable, field crop, mixed and perennial farms

Soil Health Profile

Green Beach Farm & Food | Strathclair, Manitoba

After completing a degree in Agroecology from the University of Manitoba, Zack Koscielny returned to his family's farm full-time in 2018. Prior to this, the farm focus was breeding pure-bred Charolais cattle. Zack helped to diversify the enterprise, introducing organic and regenerative principles to grain, livestock (grass-fed and finished beef and pork), custom grazing and forage production components. Pasture-raised meat and eggs are direct-marketed and organic grains are sold on the cash crop market. Most of the acres are diverse perennial pastures with about 210 acres in annual crops. Half of the annual acres are seeded to cover crops for animal feed with the other half are dedicated to cash crop grains. The farm has been moving towards integrating livestock at higher stocking rates into all field crop acres to enhance nutrient cycling, build soil organic matter and jump start soil biology. This approach has facilitated more diverse cover crops than would not have been possible using mechanical harvest (versus grazing). This is expected to reduce reliance on fuels and decrease soil disturbance.

Nutrients: N was slightly higher, while K and P were lower than the provincial average (Table 5). Both fields were low on phosphorus (4-7 ppm vs. 31.2 ppm average) and are thus the most pressing concern for crop productivity. Olsen P levels under 5 ppm are considered extremely deficient. Zinc levels were high in the R field (2.75 ppm) but low in the I field (1.3 vs. 2.1 ppm average).

Field	N 0-6" (lb/ac)	N 6-24" (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 0-6" (lb/ac)	Zn (ppm)	Organic Matter	pH 0–6"	pH 6-24"
R	18.0	30.0	7.0	251.0	16.0	354.0	2.8	7.3	7.4	8.0
I	17.0	21.0	4.0	236.0	44.0	90.0	1.3	5.6	7.6	8.1
MB Average	**13.0**	**28.5**	**31.2**	**331.5**	**35.6**	**157.6**	**2.1**	**5.6**	**7.7**	**8.1**

Table 5 Soil nutrients from R and I fields compared to MB average

Organic Matter & pH: Organic matter levels were average in the I field and high in the R field. pH levels were about average for Manitoba soils (Table 5).

Aggregate Stability: Figure 7 shows wet stable aggregation for Green Beach Farm to be similar to the provincial average. Both fields had a higher proportion of particles in the largest class (7.4-9.5 vs. 5.5%), but the R field also had more fine particles (24.1 vs. 21.8%). To maintain a healthy aggregate stability, ensure that cattle and heavy equipment do not travel the field when soils are very wet.

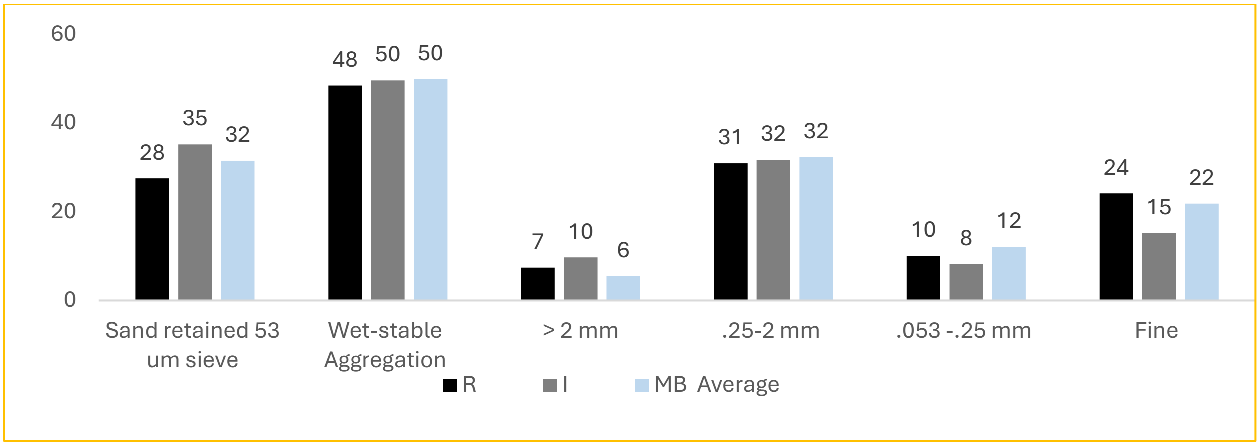


Figure 7. Aggregate stability from R and I fields compared to MB average

Bulk Density & Soil Carbon: Bulk density values were excellent (Fig 8., 0.86-0.96 vs. 1.05 g/cm³ average), which means the soil has excellent structure with minimal compaction. Total carbon is significantly higher than the Manitoba average (4.1-4.4 vs. 3.4%). Organic carbon stored per ha of land is slightly lower than the Manitoba average (37.4 – 37.8 vs. 40.2 t C/ha).

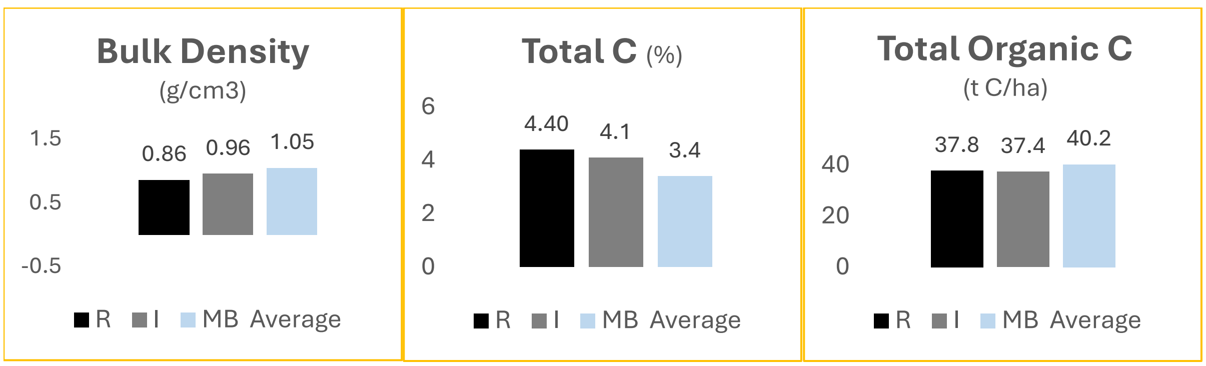


Figure 8 Bulk density, total carbon and total organic carbon in R and I fields compared to the MB average

Recommendations:

1. **Address the phosphorus deficiency** using manure, compost, struvite, or other allowed P inputs. Manure and/or compost will also increase micronutrient levels. P is a limiting factor for productivity, and the high pH makes what P there is less available to plants.
2. **Boost organic matter** in the I field by extending the period of perennial plant growth, adding well-aged manure or compost, and protecting the excellent soil structure by minimizing tillage intensity and frequency.
3. **Address micronutrient deficiencies** by applying manure or compost. Zinc sulfate or zinc oxide could also be considered in the I field, though manure or compost may be a more practical solution.
4. **Manure or compost testing.** It is important to know the nutrient content of manure or compost so that application rates can be adjusted to properly address soil nutrient deficiencies.

SOIL TEST RESULTS AND FARM PROFILES

This project and report were intended to inspire farmers to set up long term benchmarking systems to monitor the soil health over time. Since every region, production system and farm is unique, it is difficult to make meaningful comparisons between them.

Below, we have aggregated data across production systems and regions for readers who may be interested, but aggregate data are interspersed with individual farm profiles that may be more illustrative for producers interested in improving their soils or in setting up their own soil health benchmarking systems. In the pages that follow, we hope you will find something that will both inspire and assure you that you are part of a broader community of like-minded practitioners.

SOIL NUTRIENT TEST RESULTS

Harvesting grain and plant tissue removes nutrients from the soil. Many tools are available to help you determine whether you have sufficient nutrients to grow a particular crop based on your yield target. Table 6 gives you an idea of the nutrients removed by the grain component of the harvest. Online calculators are available to help you figure out total nutrients removed by grain and biomass at harvest.

RESOURCES:

Nutrient Budgeting App: This tool is tailored for organic farms. It will help you calculate the N, P, K and S generated by green manures and other inputs as well as the nutrients that will be removed from the field at harvest for each crop. This will allow you to create better crop rotations in which nutrients are balanced. This reduces environmental losses while optimizing production efficiency

https://pivotandgrow.com/resources/grain-resources/grain-production/nutrient-budgeting/

Prairie Nutrient Removal Calculator: This is an easy-to-use tool that tells you how much N, P, K, S, B, Cu and Zn will be removed at harvest for each field crop seed. You simply choose the crop and indicate a target yield for each. Note that this does not include the plant biomass that is removed.

https://prairienutrientcalculator.info/

Grain Component of Harvested Crop	Yield bu/ac	N lb/ac	P lb/ac	K lb/ac	S lb/ac
Barley	35	31	14	10	2
Corn	115	92	44	29	7
Flax	16	33	11	7	2
Oats	80	57	22	14	5
Field peas	20	39	10	13	2
Soybean	35	109	30	40	7
Wheat HRS	35	51	19	9	4

Table 6 Nutrients removed from the soil by different crops (units vary by crop)

SOIL MACRONUTRIENTS BY REGION

Test results (from pre-test) of key nutrients (N, P, K and S) are shown in Fig 9. for three project regions (data for the Prairie provinces are aggregated). Results from the R and I fields for each farm are also aggregated. For some farms, testing was performed on more than two fields. There were large differences in the number of fields in each region (Prairie: 87 fields, 40 farms; ON: 18 fields, 8 farms; AC: 16 fields, 7 farms).

N levels, particularly in the 0-24" soil profile were highest in ON where all farms were certified organic. Levels in Atlantic Canada (AC) and the Prairie were similar at all soil depths. S, particularly at the 0-24" profile, was highest in the Prairie region and lowest at the superficial soil depth in AC. P was highest in AC and similar in ON and the Prairie. In Nova Scotia and New Brunswick (AC), sulfur levels were very low on 71% of the fields tested at 0-15 cm and on 18% of fields at 15-60 cm. K was highest in the Prairie and similar in AC and ON.

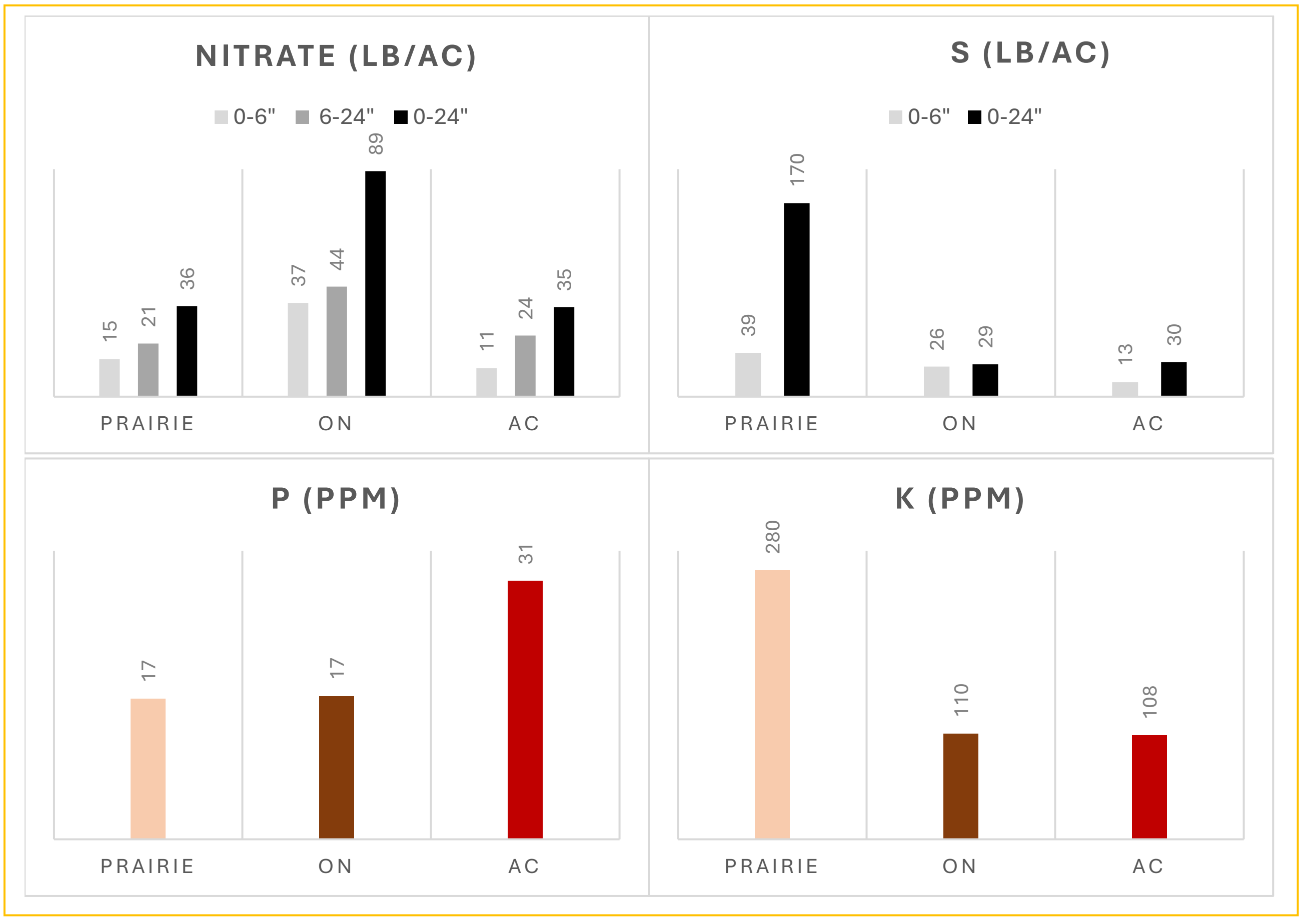
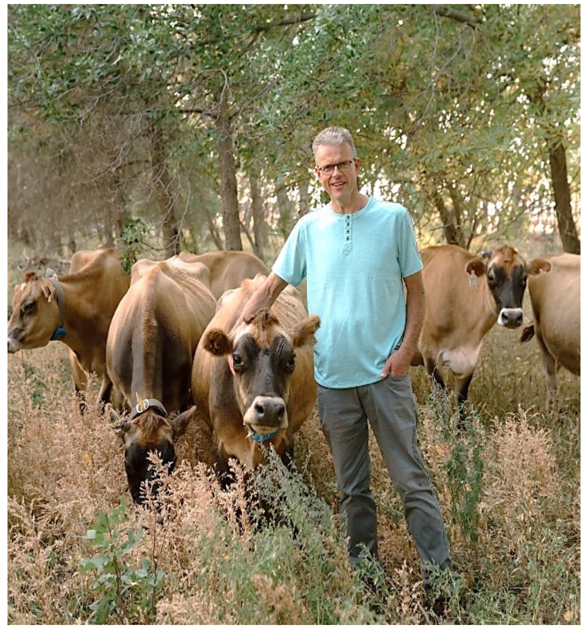


Figure 9 Average soil nutrient (N, P, K, S) levels by region

Soil Health Profile

Arnold Van Os | Wetaskiwin, Alberta



Arnold Van Os and his family operate an organic dairy operation in Alberta, where soils are generally loam to silty loam and annual precipitation averages 500-530 mm, with the majority falling during the growing season from late spring through summer.

The crop rotation includes cereals, forages, and occasional polyculture or cover crop mixtures. Weed management is entirely mechanical, relying on fall disking, spring cultivation, rod weeding, and competitive crops or forages. Fields maintained in hay provide continuous cover for multiple years, reducing weed pressure and the need for tillage interventions.

The R field has followed a rotation that emphasizes perennial forages with periodic grain crops. From 2018 to 2021, it remained in perennial hay and was never bare except briefly after cutting, receiving annual applications of liquid dairy manure at approximately 2,000-3,000 gallons (7,571 – 11,356 l) per acre, surface-applied without incorporation. In 2022, the field transitioned to an alfalfa-grass mix, receiving solid dairy manure in the fall incorporated with multiple tillage passes. The field grew wheat in 2023 without manure application, and barley in 2024, with liquid dairy manure applied after soil sampling at approximately 3,500 gallons (13,248 l) per acre in spring. When not in hay, the field typically receives multiple tillage passes including fall disking, spring cultivation, rod weeding, and seeding.

In contrast, the I field has been under more intensive cropping with more frequent and heavier manure applications. In 2019, the field grew flax with solid manure applied, followed by barley in 2020 with no manure. Wheat was grown in 2021 with solid manure applied, and barley in 2022, also with solid manure. In 2023, the field was seeded to a polyculture of multiple species that was silaged, followed by regrowth that maintained soil cover, with portions of the field grazed by cattle. Liquid manure was applied in fall 2023 at approximately 5,000 gallons per acre and incorporated by disking prior to winter. In 2024, the field grew barley under seeded with a hay crop, receiving no manure application.

The R and I fields demonstrate differences that tell an interesting story about management impacts.

Soil Nutrients: Table 7 shows very low levels of nitrate (3 lb/ac) in the R field and extremely high levels (73 lb/ac) in the I field. This means that there is insufficient N to grow most field crops in the R field, while the I field would have excess N for most crops except the highest N users such as corn or potatoes. N is also moving down in the soil profile, a common phenomenon on organic farms. The R field also had lower, but sufficient phosphorus (25 ppm vs. 49.2 ppm average) as well as lower sulfur levels than the I field and the provincial average.

These results make sense in the more intensively managed I field which received significantly more manure.

Field	N 0-6" (lb/ac)	N 6-24" (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 0-6" (lb/ac)	Zn (ppm)	Organic matter %	pH 0-6"	pH 6-24"
R	3.0	6.0	25.0	283.0	22.0	204.0	6.3	5.4	6.5	6.9
I	73.0	231.0	41.0	212.0	120.0	>360.0	6.3	8.4	7.5	7.4
AB Av	**40.0**	**84.5**	**49.2**	**235.8**	**44.7**	**144.0**	**5.2**	**7.6**	**6.7**	**6.9**

Table 7 Key soil nutrients, organic matter and pH compared to AB average

Organic Matter & pH: The R field was more acidic than the I field. The I field had outstanding organic matter (Table 7, 8.4 vs. 5.4% in R field and 7.6% average).

Aggregate stability: Figure 10 shows the R field to have poor aggregate stability (23.9% vs. 46.7% average) with high levels of sand retained in the 53 μ sieve (73.1% vs. 40.5% average), suggesting weak soil structure where particles aren't binding together well. The intervention field tells a very different story; it has significantly improved aggregate stability (36.1%), though still below the average).

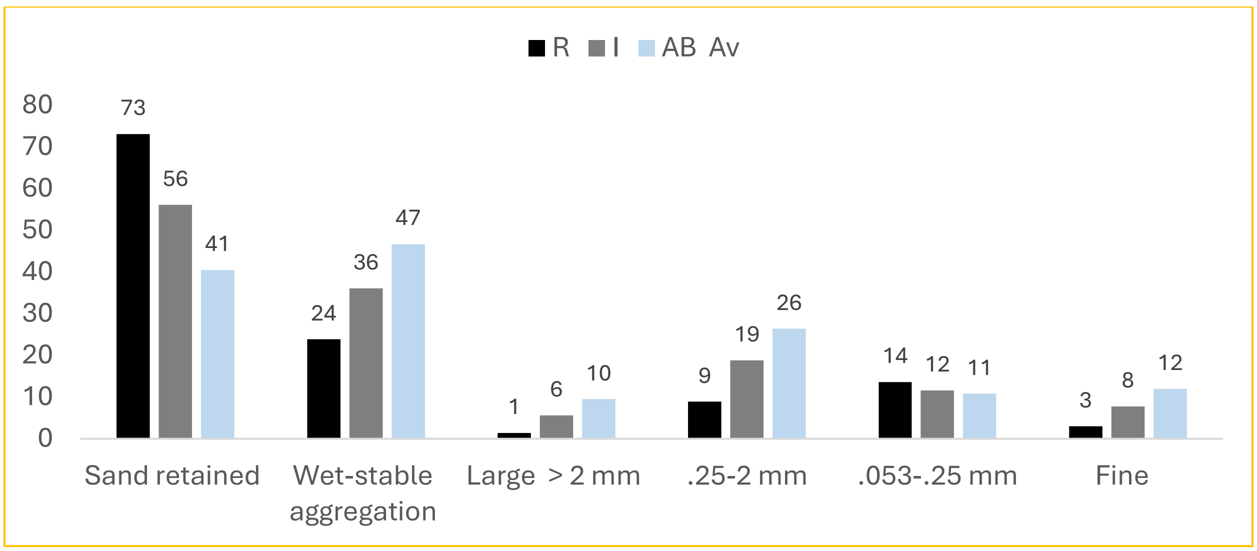


Figure 10 Aggregate stability in R and I 1

Soil Carbon: Soil samples were taken at a depth of 10 cm (3.9"). Bulk density is excellent in both fields (0.7-0.8 g/cm³), indicating minimal compaction issues (Fig. 11). Minimal inorganic carbon was present in either field (0.2 and 0.1%), indicating that virtually all the measured carbon was beneficial organic carbon. Both fields had good total carbon (4-5.2 vs. the average of 4.6%). The I field was particularly high in total organic C at 42 t C/ha.

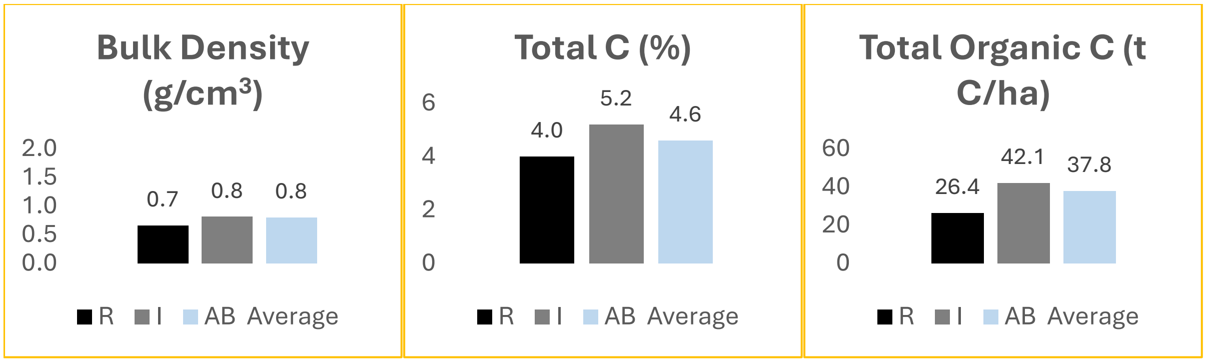


Figure 11 Bulk density and carbon data in R and I fields compared to AB average

Recommendations:

Soil health in these two fields is excellent overall. While there are differences between the two fields, both have high organic matter, adequate P, K and micronutrients, high levels of water stable aggregates, and very favourable bulk density levels. The low bulk density will allow optimum water infiltration resulting in efficient water use.

1. **Use a nutrient budgeting tool** such as the *Nutrient Budgeting App*, to better match supply and demand of nutrients for planned crops. This would help make optimum and efficient use of the high levels of N in the I field.
2. **Test soil and manure for nutrient content**. The liquid and solid dairy manure used on this farm likely explain the adequate P, K, S and micronutrient levels. Nutrient management would be improved by testing both the soil and the manure though. Soil and manure nutrient data would allow a more scientific approach to manure and rotation management.
3. **Maintain soil structure** by continuing to include perennial phases in rotation and by adding solid manure. This farm has the benefit of a strong manuring program; solid manure goes a long way to reduce the damage that tillage can do in an organic farming system. Good soil health can be maintained, even with tillage, provided manure and perennials are part of the farming system.

SOIL MACRONUTRIENTS BY PRODUCTION TYPE

1. NITRATE (N)

Nitrogen tends to be the most yield-limiting nutrient on organic farms, especially during the initial years as new producers learn the intricacies of producing N from legumes.

Average residual nitrate levels are shown in Fig. 12 as function of production system. Fields were sorted into production system based on questionnaire responses. ‘Perennial’ fields were those that received no tillage and have not been cropped to vegetables or field crops in many years. Most of these systems included livestock, but the perennial farms in ON included a fruit orchard and a vineyard. Results from the first soil test were averaged across R and I fields. Dotted lines represent very low (red), medium (yellow) and very high (green) nitrate levels (AgVise classification). The fields classified as perennial and vegetable had the highest nitrate levels at 0-24” while field crop farms had the lowest N values with the average falling within the AgVise low (21-40 lb/ac) range. Between farm variability was very high, ranging from 5-470 lb/ac on perennial farms, 4-183 on vegetable farms, 2-95 on field crop farms, and from 4-304 lb/ac on mixed farms. Thirty-five of the 103 fields (34%) tested high for nitrates, while sixty-eight (66%) tested low.

In the figures below, dotted lines illustrate very low – red, moderate – yellow, and high (green) nutrient levels.

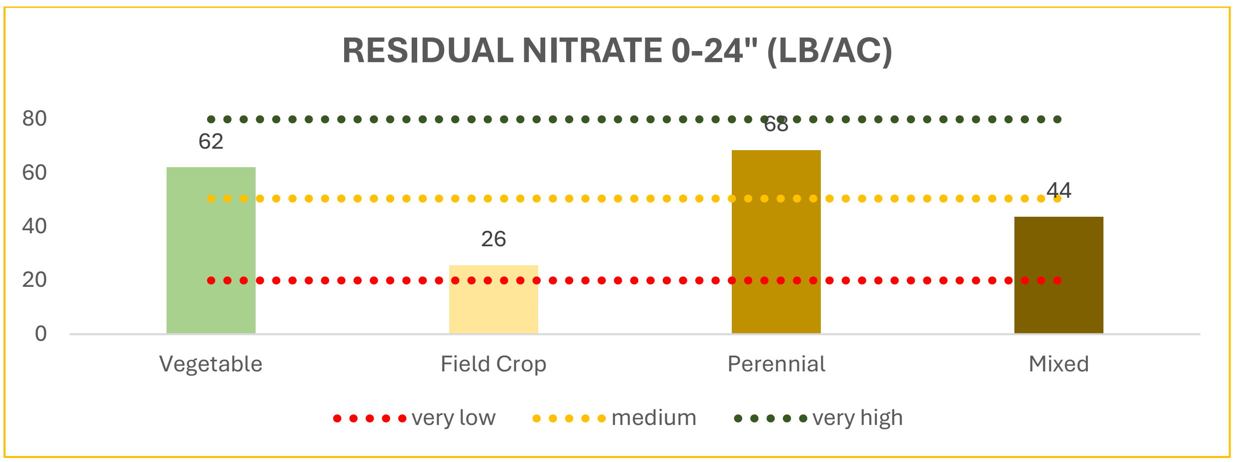


Figure 12 Average nitrate levels (residual N) by production type

Questionnaires and conversations with producers showed vegetable producers to be more likely to use animal manure or composted animal manure than field crop producers. This suggests high residual N on vegetable farms (Fig. 12) is at least partially a function of manure use. Differences in cultural practices are largely due to scale and availability of manure. Most of the field producers were in SK. Most did not have livestock and access to animal manure is low. Manure application over large acres would also be economically challenging.

2. Phosphorous (P)

Average P levels were very high on vegetable farms Fig. 13, with none of the 17 vegetable fields we tested falling below 10 ppm. Field crop systems had the lowest P levels at 8 ppm while the perennial and mixed systems were similar, at medium high P levels. The explanation for the high levels of P on vegetable farms is likely to be the same as that for N.

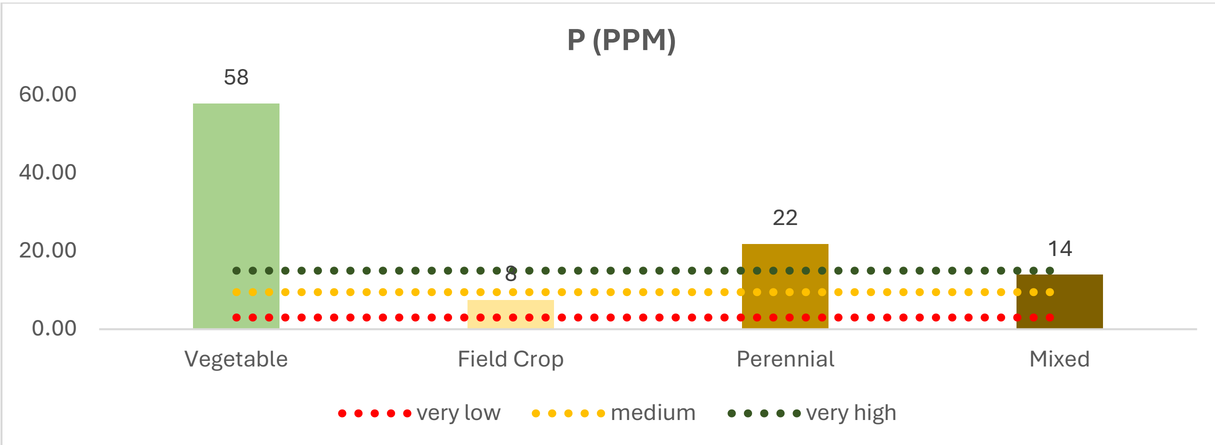


Figure 13 Average P levels by production type

3. Potassium (K)

Figure 14 shows average K levels to be similar across production types except for perennial farms which had lower levels. This is likely to be an artifact related to location, with the largest concentration of these farms in ON which is the region with the lowest K levels (Fig. 9). Prairie regions, in contrast, have naturally high levels of K – a factor that likely explains why field crop farms, the predominant production type in the Prairie, tested so high.

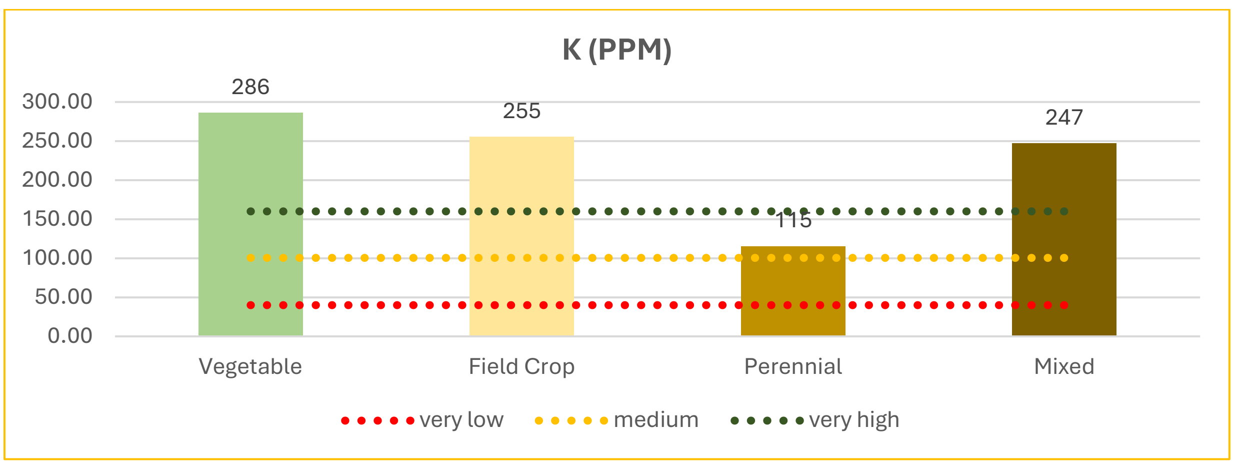


Figure 14 Average K levels by production type

Sulfur (S)

Sulfur levels were highest on field crop farms (Fig. 15), and averages for all production types was well above AgVise's very low level (red line). This is confounded by the fact that S levels are naturally highest in Prairie soils which are predominantly field-crop farms.

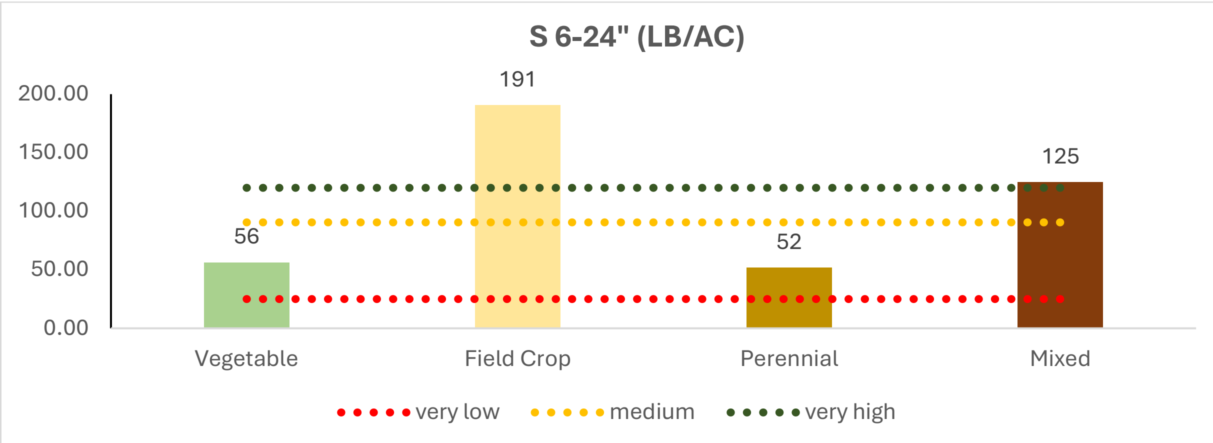


Figure 15 Average S at 15-60 cm (6-24") depths as a function of production type region

MICRONUTRIENTS

Micronutrients are needed only in small quantities for plant growth and development relative to macronutrients. Inorganic micronutrients occur naturally in soils. Both physical and chemical soil properties affect availability and plant uptake:

- Soils low in organic matter (< 2.0%) may have lower micronutrient availability
- sandy soils are more likely to have lower micronutrient levels than clay soils
- as soil pH increases, the availability of micronutrients decreases, except for molybdenum

Amounts of micronutrients removed by the grain portion of key field crops are shown Table 8.

Crops and portion used for analysis	Yield bu/ac	B lb/ac	Cu lb/ac	Zn lb/ac
Barley - grain	35	0.061	0.026	0.077
Corn - grain	115	0.017	0.014	0.102
Flax - grain	16	0.015	0.010	0.037
Oats - grain	80	0.004	0.018	0.077
Field peas	20	0.010	0.008	0.040
Soybean - seed	35	0.061	0.026	0.077
Wheat HRS - grain	35	0.003	0.012	0.067

Table 8 Micronutrients removed with grain seeds

SOIL MICRONUTRIENTS BY REGION

Micronutrient values shown in Fig. 16 come from the second soil test taken in the fall of 2025, except for zinc (Zn) which was from the first test. ON and AB data were not included except for Zn, due to low participant numbers.

There was significant difference between farms in terms of micronutrient levels, even within a single region. This is because some nutrients, such as copper, are heavily influenced by soil type, with low levels found in samples from sandy soils. In Canada, we tend to see widespread micronutrient surpluses and deficiencies that are due to geology and soil type as well as historical soil management practices.

However, on average, we found most of the micronutrients, including Cu, Fe, Mn to be highest on farms in New Brunswick and Nova Scotia (AC; Fig. 16). Boron, zinc and chloride were exceptions, with Bo at its highest level in Manitoba (1.6 ppm is considered as very high by

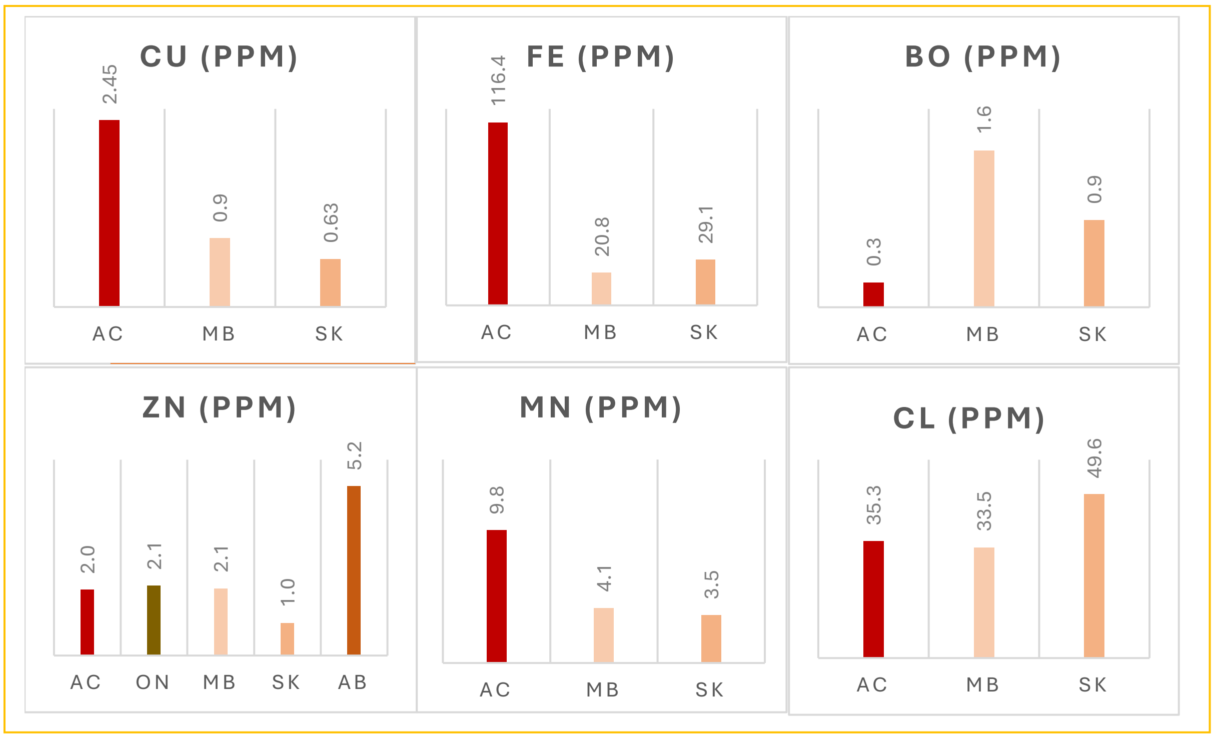


Figure 16 Soil micronutrient levels by region

AgVise). Boron levels in Atlantic Canada would be considered by AgVise to be very low. Zn was highest in Alberta and Cl was highest in Saskatchewan. Average manganese levels in all regions were in the AgVise high range. One of the most striking findings was the exceedingly high iron (Fe) levels on every organic farm tested for this nutrient, with the highest on farms in NB and NS. AgVise considers levels greater than 10 ppm to be very high. The lowest average Fe levels were observed in Manitoba (20.8 ppm).

Addressing Micronutrient Deficiencies:

If one of your fields tests reveals low levels of one more micronutrients, don't automatically reach for an approved input as levels can often be adjusted using good agricultural practices. Soil organic matter and plant and animal manure are excellent sources of micronutrients. Consider the following:

1. Check levels of macronutrients first
2. Check soil pH. Returning pH to a more neutral status can help to unlock micro and macro nutrients
3. Build soil organic matter
4. Grow green manures to help recycle micronutrients back into the soil surface
5. Rotate diverse roots such as large tap-rooted species like radish and alfalfa and fibrous rooted crops to pull trace minerals up from lower soil levels
6. Add composted manure
7. Approved biostimulants such as compost teas or liquid fish emulsions could help to stimulate the microbial breakdown of unavailable soil minerals,. struvite
8. Foliar feed liquid iron, manganese or zinc sulfates to treat acute deficiencies during critical plant growth stages
9. Ash, humates, humic acid, fulvic acid, microbial fertilizers?
10. **If you must resort to commercial micronutrient inputs, ensure that you have current documentation to show that the product is allowed for use in organic. Approved and prohibited products are shown in the table below**

Micronutrient	When Allowed	Approved Products CAN-CGSB-32.311-2026	Prohibited Products
Boron (Bo)	• When soil and/or plant tests show deficiency • Documented visual symptoms	• Hydrated borates of sodium (octaborate, pentaborate • tetraborate, • borax • boric acid • boron-lignosulphonate complexes Substances listed here may be chelated (see Table 4 in 32.311)	• Boron-lignosulphonate complexes containing ammonium lignosulphonate • Ammonium borates • Boron-amino acid mixes • Boron-potassium nitrate mixes
Cobalt (Co)	• When soil and/or plant tests show deficiency • Documented visual symptoms	• Sulphates • Carbonates • Chlorides • Oxides Substances listed here may be chelated with substances listed in Table 4 of 32.311	• Cobalt build up in soil will prohibit future use of approved products

Micronutrient	When Allowed	Approved Products CAN-CGSB-32.311-2026	Prohibited Products
Copper (Cu)	• When soil and/or plant tests show deficiency • Documented visual symptoms	• Sulphates • Carbonates • Oxides • Oxysulphates • Chelates in Table 4 of 32.311	• Nitrates • Amino acid chelates • Ammonia-copper complexes • Chlorides • Build up in soil will prohibit future use of approved products
Iron (Fe)	• When soil and/or plant tests show deficiency • Documented visual symptoms •	• Sulphates • Carbonates • Chlorides • Oxides • Oxysulphates • Citrates • Tartrates • Chelates in Table 4 of 32.311	• Ferric phosphate (iron ortho-phosphate, iron phosphate) • Nitrates • Amino acid chelates • Ammonia-iron complexes •
Manganese (Mn)	• When soil and/or plant tests show deficiency • Documented visual symptoms	• Sulphates • Oxides • Oxysulphates • Carbonates • Chlorides • Citrates • Allowable chelates (Table 4 32.311)	• Nitrates • Amino acid chelates • Ammonia-manganese complexes
Zinc (zn)	• When soil and/or plant tests show deficiency • Documented visual symptoms	• Sulphates • Oxides • Oxysulphates • Carbonates • Chlorides • Citrates • lignosulphonates • Allowable chelates (Table 4 of 32.311)	• Nitrates • Amino acid chelates • Ammonia-manganese complexes • polyphosphates

SOIL MICRONUTRIENTS BY PRODUCTION TYPE

Vegetable farms showed the highest levels of copper, iron, zinc and manganese, likely because most of them were based in Atlantic Canada where levels of these nutrients are naturally high (Fig. 17). These farms recorded the lowest levels of boron. Field crop farms had the highest chloride levels and the lowest levels of zinc and manganese.

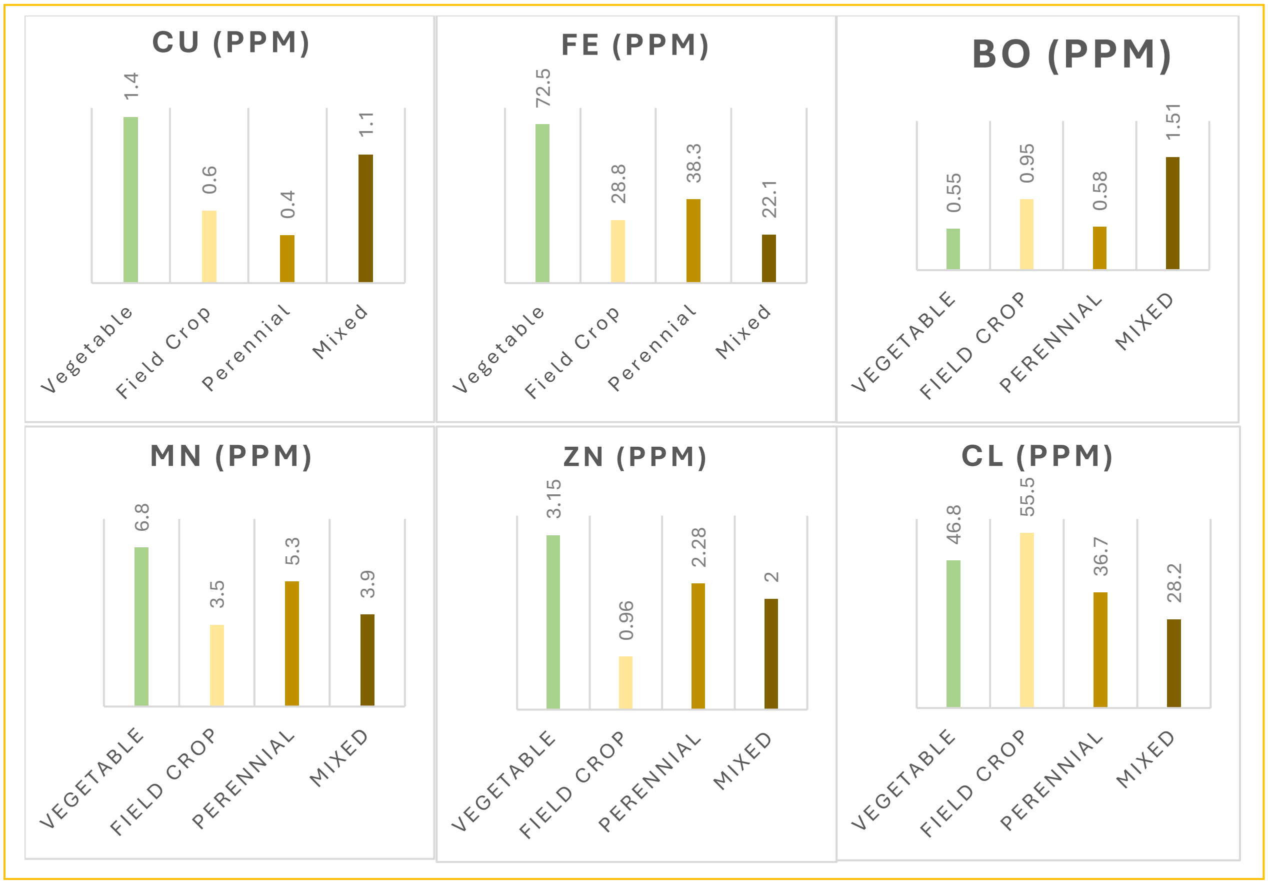


Figure 17 Micronutrients by production type

Soil Health Profile

Stu & Leanne Thiessen| Leask, Saskatchewan

The farm operates on light sandy soils under severe drought conditions. It receives only about 4 inches of annual rainfall, with less than 7 inches during the entire 2024 growing season and only 4 inches through mid-August 2025.

Until 2024, Stu and Leanne Thiessen's primary business was a 200-head cow-calf operation managed using holistic management principles that allowed them to see firsthand the soil benefits that accrue from regenerative practices such as perennials and cover crops. When they had an opportunity to buy a farm that included 22 quarters of deeded and leased land that had been operated as a certified organic grain farm, they saw it as a chance to expand their business to include the next generation – a son & daughter-in-law and daughter who all wanted to return to the farm full-time. Since the land was already certified organic, no transition period was required when ownership changed hands, allowing the partners to seed their first organic grain crop in 2024. Recently the farm has also gained Regenerative Organic Certification.

The Thiessens believe that soil nutrients had been depleted over twelve years of continuous cropping that included minimal legumes in the rotation though they did not conduct intensive soil testing before or after the land purchase. The fields have established populations of perennial weeds including quack grass and Canada thistle. The Thiessens participated in this project to benchmark the health of their newly acquired organic fields so they could begin tracking the impact of their management practices over time. They are committed to regenerating the soils through cover cropping, green manure plow downs, and crop-livestock integration, drawing on their experience from the cow-calf operation. As new organic field crop farmers without a well-established rotation yet, they did not have the lead time needed to implement a soil health experiment in 2025. Instead, the two fields involved in the benchmark study received identical management: they were seeded to Endure oats in spring 2024 and again in spring 2025. For the near future, the Thiessens plan to rotate oats with grazed legumes such as clover and peas, integrating their livestock and cropping systems to build soil health on these light sandy soils that have been continuously cropped for over a decade.

Soil Nutrients

Nutrient levels in the R field are all in the medium to high range, except for phosphorus, although it is a typical value for organic farms (Table 9). Except for K and S, soil nutrients were higher than the average of the other participating farms in SK. Interestingly, your nitrate levels are very high (62-64 lb/ac vs. 12.7 lb/ac average), which likely reflects mineralization from the organic matter breaking down during the drought conditions.

Field	Nitrate 0-6" (lb/ac)	Nitrate 6-24" (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 6-24" (lb/ac)	Organic matter (%)	pH 0-6"	pH 6-24"
R	62.0	21.0	6.0	223.0	24.0	78.0	3.5	6.4	7.1
I	64.0	27.0	9.0	226.0	24.0	66.0	2.8	6.7	7.0
SK Average	**12.7**	**10.6**	**6.7**	**259.8**	**39.1**	**179.2**	**4.2**	**7.5**	**8.0**

Table 9 Soil nutrients from R and I plots compared to the SK averages

Plant Nutrients: Tissue tests were run on the gluten-free Endure oats grown on both fields in July 2025. Results are shown in Table 10. Note that SK averages are based on results from only three farms.

Despite the low soil phosphorus, plants are taking up reasonable amounts of P (13.5-21.5 kg/ac), with the I field showing better uptake, likely because of its slightly higher soil P level and better nitrogen availability (101.5 kg/ac N vs. 91.5 kg/ac in the reference field).

Field	Nitrate (kg/ac)	P (kg/ac)	K (kg/ac)	Ca (%)	S (%)	Bo (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
R	91.5	13.5	85.1	0.15	0.12	2.0	3.0	37.0	46.0	24.0
I	101.5	21.5	78.1	0.18	0.01	3.0	3.0	44.0	48.0	32.0
SK Average	**67.5**	**10.6**	**49.8**	**0.25**	**0.17**	**10.0**	**6.0**	**85.7**	**48.8**	**32.8**

Table 10 Plant nutrients from R and I plots compared to the SK averages

Micronutrients: Soil test levels of boron, copper and chloride were low on both fields compared to SK average values (Table 11), while zinc and manganese were higher than average. Iron levels were higher than average in the R field, and lower than average on the I field.

Field	Cl 0-24”	Bo (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
R	8.0	0.3	0.2	36.9	4.8	1.6
I	16.0	0.5	0.2	24.2	3.8	1.3
SK Average	**49.6**	**0.9**	**0.6**	**29.1**	**3.5**	**0.8**

Table 11 Soil micronutrients from R and I plots compared to the SK average

Organic Matter & pH: Organic matter is in the medium range for the R field and at the top of the low range for the I field, slightly below average for other participating farms in Saskatchewan (Table 9). This is consistent with your understanding that these fields were continuously cropped without legumes for twelve years, depleting soil carbon and nutrients. Soil pH is neutral, just on the edge of slightly acidic for the top depth.

Aggregate stability: Samples from both fields contained about 10% material that was smaller than the smallest sieve of 0.053 mm and got washed away, leaving about 90% of the material. On average, in the other SK farms we looked at, 26% of soil particles were washed away. The R field had a slightly higher proportion of particles in the largest size class (Fig. 18).

Overall, both fields are showing exceptional aggregate stability (89.9-90.2 vs. 40.3% average), which is truly outstanding and indicates excellent soil structure. Despite the light sandy texture, these soils are binding together remarkably well.

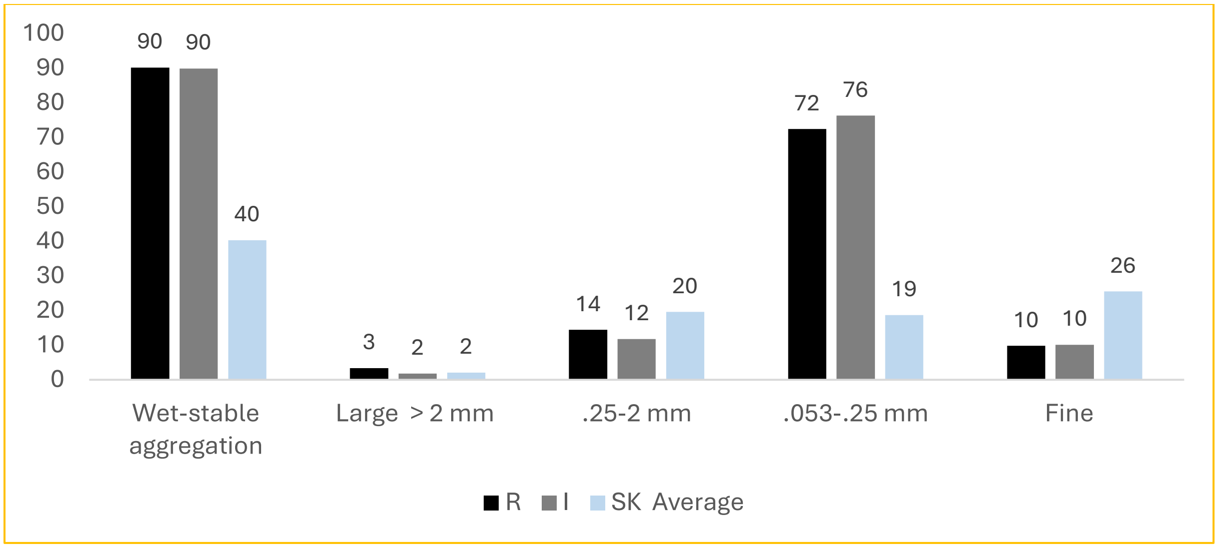


Figure 18 Aggregate stability data from R and I plots compared to the SK averages

Soil Carbon: Carbon samples were taken at 15 cm (5.9"). Bulk density is good (1.07-1.23 g/cm³ vs. 1.29 average), particularly in the intervention field at 1.07, showing minimal compaction (Fig. 19). Total carbon levels are also below average (1.94-2.24% vs. 2.98% average).

The R field samples averaged 34.6 tons of carbon per hectare while the I field averaged 30.7 t C/ha. These values are quite a bit lower than the average of other participating SK farms (49.8 t C/ha).

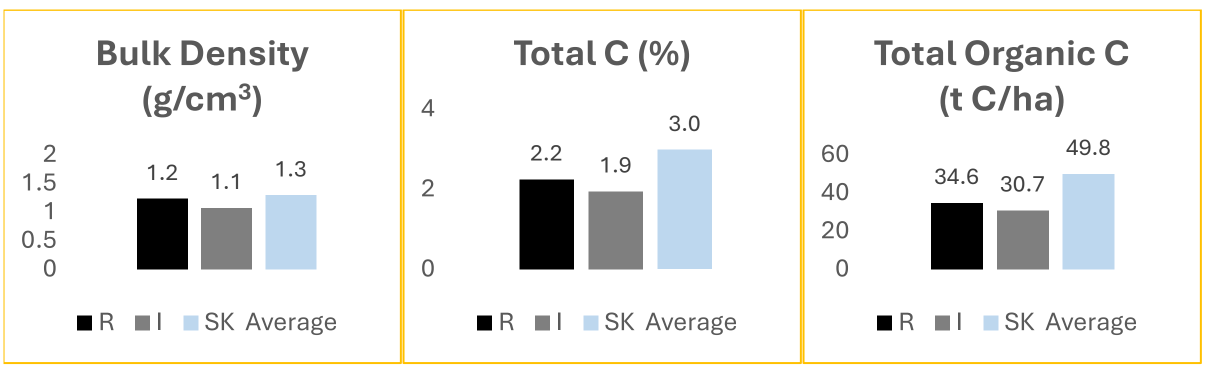


Figure 19 Bulk density and soil carbon data from R and I fields compared to SK average

Recommendations:

1. **Build organic matter** as the top long-term priority by implementing your planned cover crop program and grazed legume rotations as soon as possible, incorporating diverse species including deep-rooted plants and adding compost or well-aged manure from your cow-calf operation when available to accelerate organic matter building in these depleted, light sandy soils
2. **Maintain current management plan** to rotate field crops with grazed legumes, integrate livestock and cropping systems to build soil health on light sandy soils that have been continuously cropped for over a decade. Having the grazed cover crop in the system every other year will provide the opportunity to add N through legumes. With annual cropping (oats and green manure), fall tillage can be done each year and this will be important for Canada thistle control. If this perennial weed is not controlled by these measures, consider seeding a perennial crop such as alfalfa/grass for several years as perennials provide better thistle control than annuals. Grazing management can also help control thistles, so a mob grazing approach would be best
3. **Continue to invest in soil nutrient testing**. This will provide an important ongoing record of macro nutrient status (ie., N, P, K and S). The one micronutrient that should be monitored is copper, which can be low in sandy soils. One of the best sources of copper is manure. Make sure to test the manure before adding, so that you know exactly how much copper you are adding
4. **Avoid growing peas every other year** either in a cash or green manure crop, as it will lead to build up of root rot (Aphanomyces). This is a real threat on the Prairies; peas should ideally be grown only once every six years, so, rotate legume species used in the grazing mix

Soil Health Profile

Jim Robbins| Delisle, Saskatchewan

Jim Robbins and his family operate an organic grain farm in Saskatchewan.

On average, the farm normally has about 400 mm of precipitation annually, but weather patterns have recently shifted recently with only 213 mm of precipitation in 2023. In 2024, the farm received 1,143 mm of snow plus 366 mm of rain.

Both study field areas were seeded to oats plus sweet clover in 2023, establishing a common baseline. However, the winter of 2023-2024 resulted in significant sweet clover winterkill, with nearly half of the 95 acres (fields of 35 and 60 acres) having poor survival. This challenge prompted different management paths. The I field was seeded to Berseem clover on June 19, 2024, while the R portion maintained the sweet clover for plow down in 2024. The surviving 25 acres of sweet clover were mowed in late July 2024, and Berseem clover was seeded on the remaining 35 acres in June 2024 with plans to mow in September 2024. The R field was seeded to flax on May 23, 2025, while the I field was seeded to alfalfa on July 24.

The cultivation approach reflects careful management of perennial weeds. In fall 2023, quack grass patches were disced, and Canada thistle patches were cultivated. In spring 2024, the I portion received deep tillage before Berseem clover was seeded using a demonstration Pottinger Terrasem disc drill to gauge its usefulness for establishing field cover where winterkill had left bare ground. The R portion was mowed at the end of July, and the I area was mowed in September 2024.

Soil Nutrients: Most of the key nutrients were low compared to provincial averages, except for K (Table 12). Low N levels in the I field are of particular concern and may limit crop yields. One possible reason for low N levels is that the legume biomass has not yet fully released (mineralized) it's N. Potassium levels are exceptionally high, particularly in the I field, but this is not unusual on Prairie mineral soils that are inherently high in K. P levels less than 5 ppm are considered very deficient, with levels between 5 and 8 considered marginally adequate. So, P management is required, especially on field R.

Field	Nitrate 0-6" (lb/ac)	Nitrate 6-24" (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 6-24" (lb/ac)	Organic matter (%)	pH 0-6"	pH 6-24"
R	5.0	9.0	4.0	387.0	14.0	>360.0	4.6	6.7	8.0
I	2.0	3.0	8.0	516.0	10.0	30.0	3.6	7.1	8.3
SK Average	**12.7**	**10.6**	**6.7**	**259.8**	**39.1**	**179.2**	**4.2**	**7.5**	**8.0**

Table 12 Soil nutrients from R and I plots compared to SK average

Organic Matter & pH: The I field had significantly lower organic matter (3.6 vs. 4.6% in the R field). The I field had a slightly more neutral pH in the top soil profile than the other field and as compared to other farms from SK in this study (Table 12).

Micronutrients: These were, on average, higher than the Saskatchewan average, excepting boron. Copper levels were similar. Micronutrients in the I field were higher than those in the R field, excepting manganese and zinc (Table 13).

Field	Cl 0-24"	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
I	108.0	0.5	0.6	39.0	5.2	1.0
R	52.0	0.3	0.5	31.0	7.6	1.0
SK Average	**49.6**	**0.9**	**0.6**	**29.1**	**3.5**	**0.8**

Table 13 Soil micro-nutrients from I, R and HF plots compared to the SK average

Aggregate Stability: Considerably less sand was removed by the 53-micron sieve than on the other SK farms in this study, while wet-stable aggregation was similar. The proportion of particles in each size class was similar to other participating SK farms except for very high levels of fine material (41-41.2% vs. 25.5% average), suggesting the soil structure isn't holding together as well as it should despite the good organic matter in the reference field (Fig. 20).

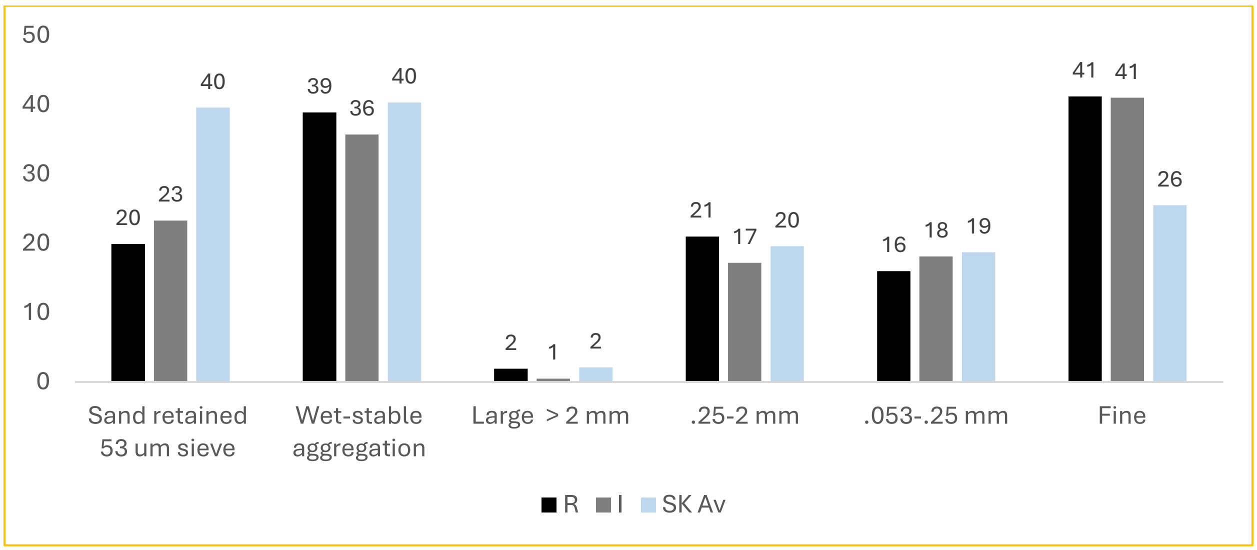


Figure 20 Aggregate stability data from R and I plots compared to the SK average 1

Bulk Density & Soil Carbon: Fields were sampled at a depth of 15.25 cm (6"). Bulk density was good (1.25-1.26 g/cm³ vs. 1.29 average), indicating minor compaction at present (Fig. 21). However, getting bulk densities closer to 1.0 would be a valuable goal as the present levels are indicative of intensive tillage. Both fields show very low calcium carbonate equivalent values (0.4 and 0.3%) which means that virtually all the measured carbon is beneficial organic carbon. The I field shows concerning trends with significantly lower organic matter, lower total carbon (1.9 vs. 2.6% in R field, and well below the 2.9% average), and lower aggregate stability (35.7%), possibly reflecting the impact of the deep tillage cultivation in spring 2024. Averaged over the two fields, total carbon was 43.1 t C/ha which is below the mid-range for productive Saskatchewan soils.

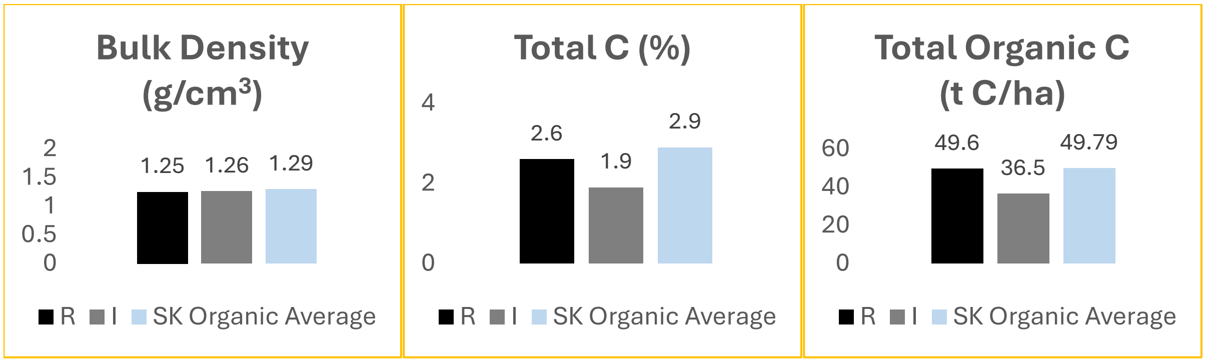


Figure 21 Bulk density and carbon from R and I plots as compared to the SK average

Recommendations:

1. **Switch to a perennial grass/legume mixture for 3 to 5 years** Doing so would address your most significant challenges which include low levels of soil aggregation, low P and some N challenges. The ideal solution would be to seed the land to a pasture mix and add manure. Grazing the perennial would be better than haying since it would allow the land to retain more nutrients.
2. **Tackle the P challenge separately if option 1 is not an option**. If the land remains in annual cropping, add a reliable P source; manure, struvite, or a combination would be best.
3. **Continue to include legume green manures**. Low N levels appear to be the result of slow legume mineralization, so may not be as serious as the data suggests. Increasing soil P levels (step 2) will improve the N fixation of any legumes in the system. P deficiencies are particularly problematic for optimum legume plant growth.
4. **Minimize tillage.** Tillage cannot be avoided since it is required for weed control. However, steps should be taken to make tillage as soil-friendly as possible - such as reducing tillage speed, avoiding machine traction or tillage when soil is wet, using narrow shovels that leave larger aggregates intact, avoiding deep tillage, and delaying tillage for thistle control to late fall when soil is much cooler. Minimizing tillage will help increase aggregate stability and build organic matter.
5. **Maximize crop residue return to the fields**. Always leave straw and chaff in place.
6. **Enhance biological activity** by keeping living roots in the soil through as much of the year as possible and diversifying species mixes and crop rotations.

ORGANIC MATTER (SOM) BY REGION

Building a high percentage of soil organic matter (SOM) should be a key goal of every farmer. SOM is made up of carbon (C) from plant and animal residues at varying stages of decomposition. C is the basic building block of life and is critical to soil health and fertility. SOM provides numerous benefits; acting as a reservoir for soil nutrients, especially of N, improving water infiltration, supporting microbial communities, maintaining soil structure by holding soil particles together and recycling nutrients. SOM helps to mitigate climate change by capturing and storing atmospheric carbon in the soil and it plays a role in filtering toxins by binding harmful substances such as heavy metals and pesticides. Under increasing climate volatility, maintaining high levels of SOM is your best defence for both high and low water scenarios.

Like all other soil attributes, SOM is affected by many factors including ground cover, climate and agricultural practices. SOM makes up between 1 and 5% of most soils. In Canada, undisturbed black soils of the Prairie Parkland region have the highest native SOM levels (6-10%) with the lowest levels found in Atlantic Canada. Cultivated land has lower SOM. For example, average SOM in cultivated land in the Prairie Parkland is in the range of 4-6%. The Ontario Government provides recommendations for SOM minimums by soil texture with sandy soils in the range of 2.5% SOM, sandy loam 3.5%, loam 4% and clay loam and clay soils at 4.5%.

Canada has a Soil Organic Matter Indicator which tracks changes in SOM over time. From Ontario eastward, SOC decreased between 1981 and 2021 due to the conversion of perennial pastures to cropland associated with declining cattle populations. The Prairies and BC have seen large gains in SOC due to reduction in tillage intensity, reduction in summerfallow and application of livestock manure.

Since organic relies on tillage to disrupt weed communities, the system appears to be at odds with building SOM. How can we reconcile this? SOM represents the net of two competing processes: C deposition from crop residues and C losses from soil respiration and decay. This means, if you want to increase SOM, you need to return more C to the soil. This can be done by:

- Adding more organic matter by leaving crop residue on the soil surface at harvest or by adding mulch
- return on-farm nutrients to the field in compost or animal manure. This will increase the amount of C available for decomposition
- planting crops which have higher residues, seeding cover crops, including those that will have a living root and nourish microbial communities over a longer time (i.e. fall covers)
- reducing tillage. Tillage increases contact between residue and soil, increases soil oxygenation, and exposes organic matter that was previous protected in the soil. All of these things accelerate organic matter breakdown and losses. Reducing tillage on an organic farm is challenging, but not impossible. By focusing on what you can do, such as decreasing tillage depth, intensity, or frequency, you can reduce tillage over time

In this project, average SOM was highest in the Alberta fields (7.6%), but this region had only a small number of participants (3 farms, 6 fields) and was lowest on Ontario (4.1%) and Saskatchewan (4.2%) farms (Fig. 22). AgVise considers SOM above 6% to be very high and that below 1.5% to be very low. Soils in the range of 3.1-4.5 are considered as average. By this metric, averages for all regions fell within at least the medium range, with MB, AC and AB in the high to very high range.

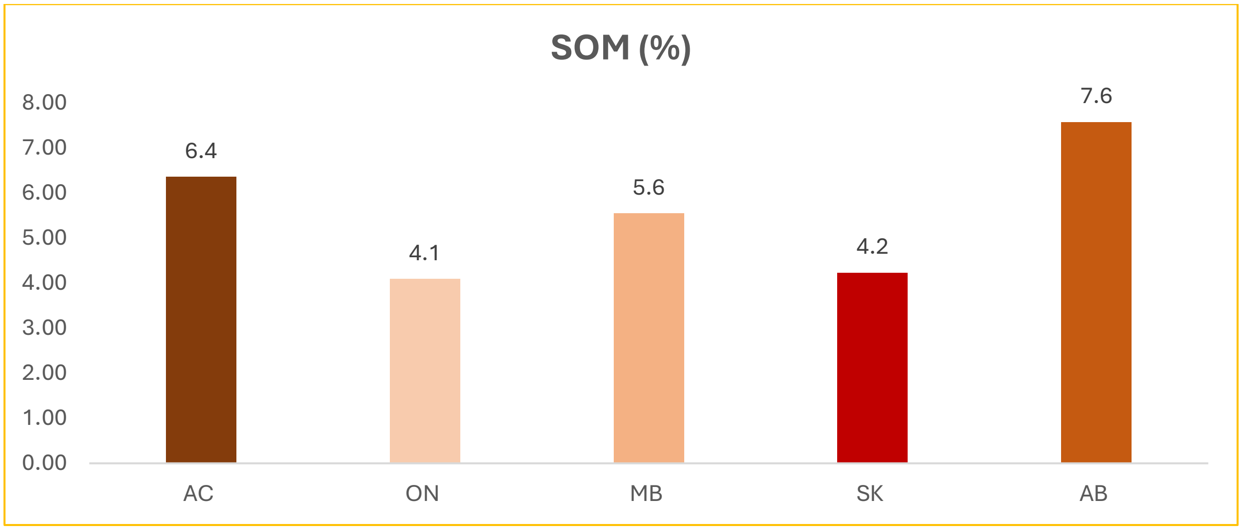


Figure 22 Soil organic matter (%) by region

ORGANIC MATTER (SOM) BY PRODUCTION TYPE

Fig. 23 shows that field crops had the lowest SOM (4.1%), but the average still fell within AgVise's medium range, while vegetable farms had the highest SOM (7.4%). As with other soil health properties, the regional and production type analyses were confounded by the fact that most of the vegetable farms were in AC, while most of the field crop farms were in SK. However, as noted above, native SOM tends to be highest in the Prairie and lowest in Atlantic Canada suggesting that tillage and use or non-use of animal manure is playing a role, with the vegetable farmers of AC actively building SOM through management. Prairie field crop farmers could do more to bring more C into their production systems (e.g. cover cropping, manuring, etc.) and to prevent its loss by finding ways to minimize tillage intensity.

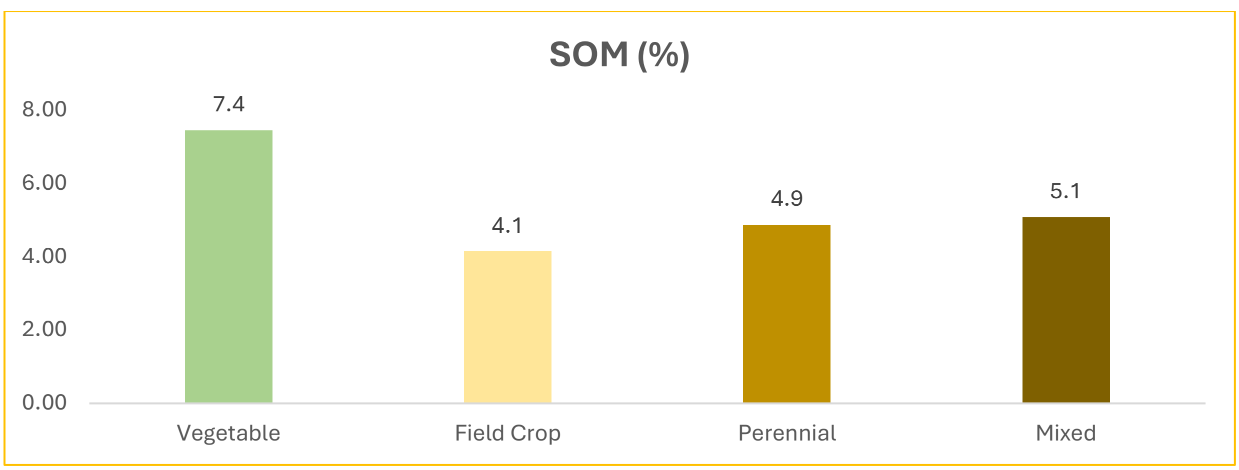


Figure 23 Soil organic matter as a function of production type

Soil Health Profile

South Brook Vineyard | Niagara-on-the-Lake, Ontario

South Brook's production system integrates perennial vineyard management with diverse alleyway plantings. Grape vines are planted in rows with perennial vegetation maintained in the alleys between rows, creating a dual-zone management system. The alleys remain as a permanent perennial system with no cultivation, preserving soil structure and providing continuous ground cover throughout the year.

The impact of different alleyway plant communities on soil health was examined. The R field was maintained in a sod-grass-legume mix in 2025, following grass/alfalfa in 2024, representing a traditional approach to vineyard alley management. In contrast, the I field was seeded to pollinator plants in 2025, testing whether supporting beneficial insects and pollinators through targeted plant selections can be integrated with vineyard soil health goals. Both alleyway systems remain undisturbed, allowing this comparison to focus purely on the effects of plant species composition, rather than tillage or other management variables in the perennial vineyard environment.

Soil Nutrients: Phosphorus levels were excellent (41-46 vs. 17 ppm average, Table 10). The pollinator area (I) has notably elevated potassium (335 vs. 110 ppm average) and zinc (13.25 vs. 2.2 ppm average), suggesting these diverse flowering species may be mining nutrients from deeper soil layers (Table 14).

Field	Nitrate 0-6" (lb/ac)	Nitrate 6-24" (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 6-24" (lb/ac)	Zn	Organic matter (%)	pH 0-6"	pH 6-24"
R	37.0	60.0	41.0	210.0	10.0	18.0	3.8	6.6	7.1	7.5
I	23.0	69.0	46.0	335.0	10.0	30.0	13.3	7.1	7.3	7.4
ON Average	**37.1**	**43.5**	**17.3**	**109.9**	**26.4**	**28.6**	**2.1**	**4.1**	**7.0**	**7.4**

Table 14 Soil nutrient content of R and I fields compared to ON average

Organic Matter & pH: Table 14 shows organic matter to be higher than on typical Ontario organic farms (6.6-7.1% vs. 4.1% average). pH is ideal for grapevines (7.1-7.5), so no amendments are needed in those areas.

Aggregate Stability: Fig. 24 shows that both field areas have outstanding aggregate stability (63.6-70.3% vs. 52% average), with the R field's grass-legume mix showing particularly impressive results and an extraordinary 43.7% large macroaggregates (vs. 16.2% average).

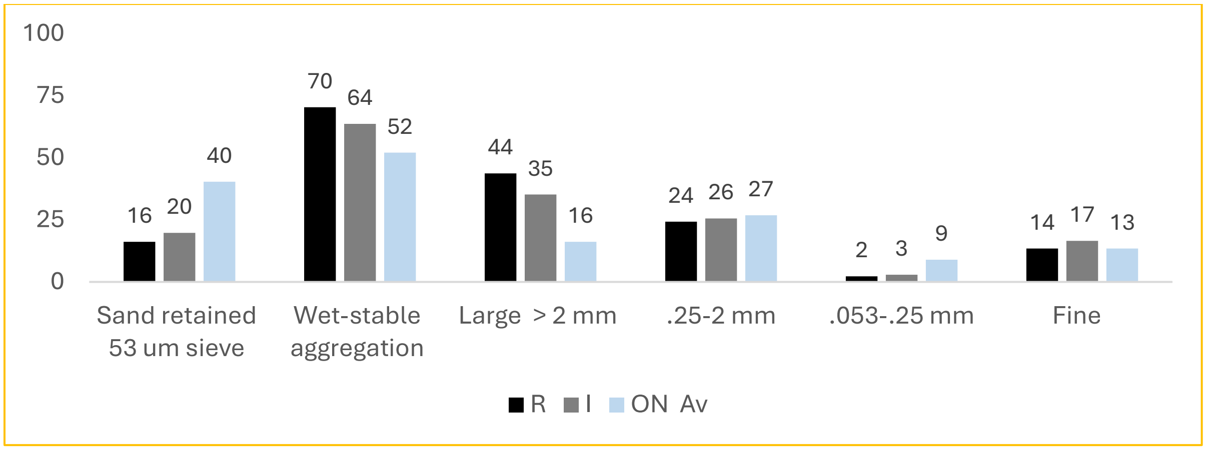


Figure 24 Aggregate stability from R and I plots compared to Ontario average

Bulk Density & Carbon: Soil carbon was assessed at 10 cm (3.9”). Bulk densities were excellent, indicating well-structured soil with good porosity and minimal compaction (Fig 25). Tested soils had minimal inorganic carbon, with very low calcium carbonate equivalent values between 0 and 0.3%, indicating that virtually all measured Cwas organic carbon – the biologically active form that supports soil fertility and ecosystem health. Overall, the fields are storing less organic carbon than other participating farmers in Atlantic Canada (30 -37 vs. 46 t C/ha).

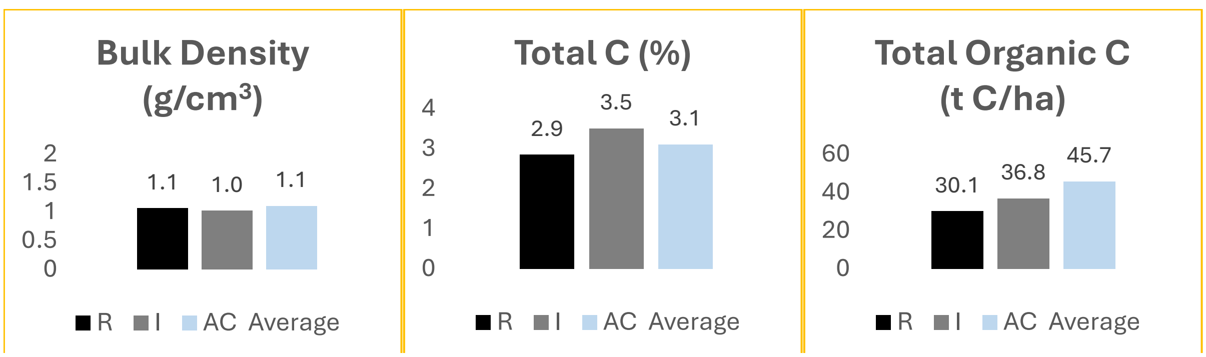


Figure 25 Bulk density and soil carbon from R and I plots compared to Atlantic Canada average

Recommendations

1. **Continue the successful perennial alleyway approach** – both the grass-legume mix and pollinator plantings are delivering excellent results, so consider maintaining both strategies in different vineyard blocks to balance soil health benefits with pollinator support.
2. **Monitor nutrient levels carefully**, particularly in the pollinator area where the very high zinc (13.25 ppm) and potassium (335 ppm) may indicate excessive accumulation or specific plant uptake patterns. While these levels are not immediately problematic, they are worth watching to ensure balance.
3. **Maintaining the diverse perennial plantings** that are building such impressive organic matter and aggregate stability will ensure long-term vineyard health and productivity.

SOIL AGGREGATE STABILITY (A/S)

Soil aggregates are the building blocks of soil structure. While soil texture refers to the percentage of sand, silt and clay in the soil, soil structure describes how each of these particles is arranged. Soil aggregates are 'glued' together with soil organic matter, exudates from roots and microorganisms such as fungi.
Aggregate stability (A/S) is the ability of soil aggregates to resist breaking apart when wet. You can see aggregates that are larger than 2 mm with your eyes but measuring the proportion of each of the different water-stable aggregate sizes must be done in a lab.

Understanding A/S Results

Sand retained: Sand can skew results because it is the same size as small aggregates. In this project, sand was filtered out using a 53-micron sieve. It is not included in the aggregate classes

Wet-stable aggregation % total: proportion of the sample that was greater than 0.053 as measured by different sieve sizes

Large Macroaggregate %: proportion of the sample that is > than 2 mm, i.e. the part of the sample that stays in a 2 mm sieve

Macroaggregate %: proportion of the sample that is between 0.25 and 2 mm

Microaggregate %: proportion of the sample that is between 0.053 and 0.25 mm

Fine %: proportion of the sample that is washed away in a sieve of 0.53 mm

There are no set values of aggregate stability to illustrate health soil, but in general, the higher percentage of larger aggregates, the better. Keep in mind though, that the formation of soil aggregates is heavily affected by soil type. Coarse-textured (sandier) soils take longer to form aggregates, while find-textured (more clay based) soils develop aggregates more quickly. Results from A/S tests on sandy soils can be distorted because sand particles are the same size as small aggregates. For this reason, our lab uses a sand correction using a 53-micron sieve to remove sand particles before assessing the proportion of aggregate sizes in the sample.

In the individual farm profiles, we provide data on wet-stable aggregation as a percentage of the total sample, along with the proportion of soil aggregates in each of four size classes (> 2 mm, 0.25-2 mm, 0.053-0.25 mm, and < 0.053 mm).

Figure 26 shows the proportion of four key soil particle sizes in each region. The black and grey bars represent larger sizes (> 2 mm and 0.25-2 mm), while the gold bars represent the small particles. If the two large particle classes are summed, ON and MB had the highest percentages with 43 and 38%, respectively. Ontario had the highest percentage of particles in the > 2 mm class with 16% of the total. Saskatchewan had the lowest percentage of large particles.

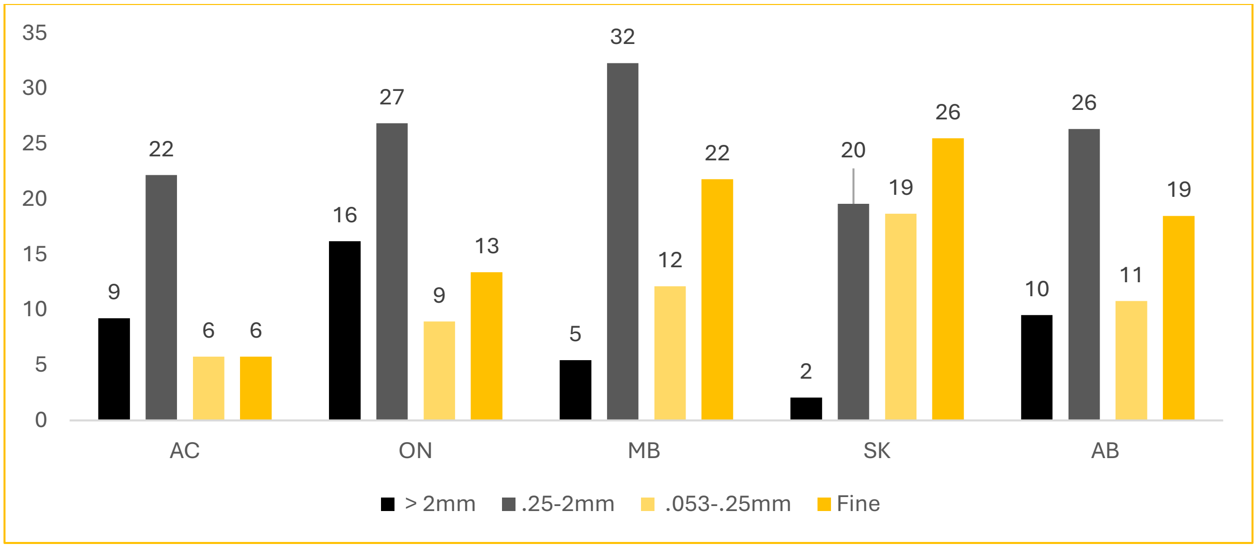


Figure 26 Proportion of soil particles in four soil aggregate size classes in five regions

When the two largest particle sizes are summed, vegetable farms came out on top with the largest proportion of large particles. Field crop farms had the lowest proportion of large aggregates and the highest proportion of fine particles (Fig. 27). Farms with large amounts of perennial crops had the lowest percentage of small particles (just over 8% in each small particle class).

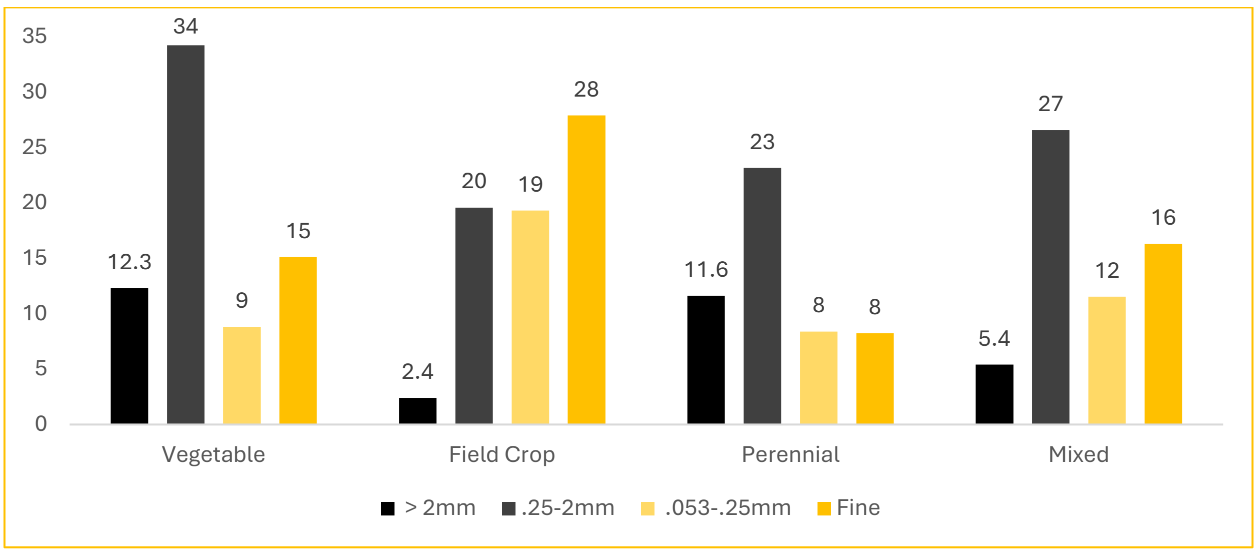


Figure 27 Proportion of soil particles in four size classes as a function of cropping system

SOIL HEALTH PROFILE

Danny Bruce| Bridgetown, Nova Scotia

Danny Bruce manages a diversified organic operation near Bridgetown, Nova Scotia, producing beef, forage, fruits, vegetables, poultry, and grains. An aggregate stability test was conducted during the pre-seeding period on May 21st, 2025, when garlic had emerged in the Intervention field and all other areas remained in forage. Following harvest in 2025, soil carbon and nutrient testing was also completed for both the R and I plots. The farm's three study areas share a common origin as part of an old orchard, pasture, and hay field complex. The R area has remained in continuous hay and pasture for over a century, receiving regular applications of manure, but no cultivation. This undisturbed management preserves the soil's long-established structure.

Both the R and I areas were brought into crop production around 2021. Following initial tillage, these fields were seeded to oats for two years, returned to forage for another two years, and then transitioned to cereals or vegetables.

Across all managed areas, Danny regularly incorporates solid animal manures and compost, adjusting applications based on specific crop requirements. This three-way comparison offers insight into how cultivation history and cropping intensity affect soil aggregate stability under organic management.

In this experiment, the permanent cover hayfield (HF) is the true control in hay/pasture for over 100 years. The primary difference between the I and R fields relates to the crops chosen, with the I field being more intensively managed with continuous cropping while the R field has been in a few years of forage for grazing since 2021.

Soil Nutrients: The nutrient picture is mixed: the I and R fields show good phosphorus levels (26-38 ppm), but the HF field is much lower at 10 ppm (Table 15). 10 ppm P is considered adequate for crop production, though further monitoring is required to ensure the level does not go lower.

Field	Nitrate 0-6” (lb/ac)	Nitrate 6-24” (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 6-24" (lb/ac)	Organic matter (%)	pH 0-6"	pH 6-24"
I	32.0	96.0	26.0	192.0	18.0	36.0	5.0	5.5	5.6
R	15.0	63.0	38.0	176.0	16.0	36.0	5.4	5.4	5.4
HF	2.0	3.0	10.0	68.0	8.0	12.0	7.2	5.2	5.3
AC Average	13.6	46.6	30.2	117.9	15.8	32.5	6.4	5.7	5.6

Table 15 Nutrients in I and R fields as compared to Atlantic Canada average

Soil Organic Matter & pH: The hayfield (HF) and both actively cropped fields have acidic pH levels (Table 15, 5.2-5.5 vs. 5.7 average for 0-6"). Organic matter (OM) levels are good in all three fields, but are slightly lower than the AC average except in the perennial pasture which had very high OM at 7.2%. This seems to indicate an advantage of leaving the land in permanent forage. But this may also reflect spatial variation in OM across the landscape.

Micronutrients: These were higher than the regional average, except for boron (Table 16). Values in the two actively cropped areas were higher than in the undisturbed hayfield (HF), except in the case of iron and manganese which were considerably higher than regional averages.

Field	Cl 0-24”	Bo (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
I	152.0	0.2	3.5	138.3	13.3	3.7
R	68.0	0.2	3.5	143.7	16.1	3.8
HF	16.0	0.1	3.2	254.	19.2	1.90
AC Average	**35.3**	**0.3**	**2.5**	**116.4**	**9.8**	**2.2**

Table 16 Soil micro-nutrients from I, R and HF plots compared to the Atlantic Canada average

Aggregate Stability: The century-old hayfield (HF) shows excellent aggregate stability (44.1 vs. 37.2% average), demonstrating what undisturbed management can achieve (Fig. 28). However, the actively cropped fields (I and R) are showing below-average aggregate stability (28.2-30.1 vs. 37.2% average), with high sand retention (63.4-67.2% vs. 57% average), indicating that soil particles are not clumping together as well as they could be. This outcome is not unexpected as we know that soil disturbance that comes from reestablishing annual crops each year compromises aggregate stability. The two cropped fields also have a smaller proportion of large particles than the permanent pasture (HF). The good news is that for all fields, the proportion of fine and small particles is small compared to the two larger particle size classes.

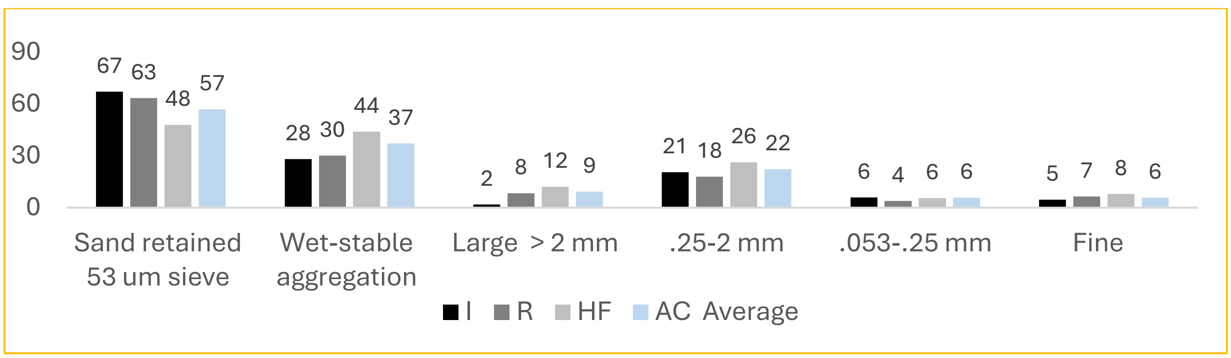


Figure 28 Aggregation stability from three fields (I, R and HF) as compared to AC average

Soil Carbon: Sampled fields are building good carbon levels, averaging 3.0% total organic carbon (Fig. 29), which is in the good to high range for Nova Scotia agricultural soils in which the typical range is 1-2% TOC in sandy soils, 2-4% loam soils, and 3-6% clay soils. The fields also demonstrate good carbon storage, averaging 50.3 t C/ha, with perennial HF field especially strong at 58.1 t C/ha. The HF field also shows excellent structure at 0.96 g/cm³. The I field is sitting at 1.29 g/cm³ (vs. 1.1 average), which indicates some compaction that's making it harder for roots to grow and water to move through the soil,

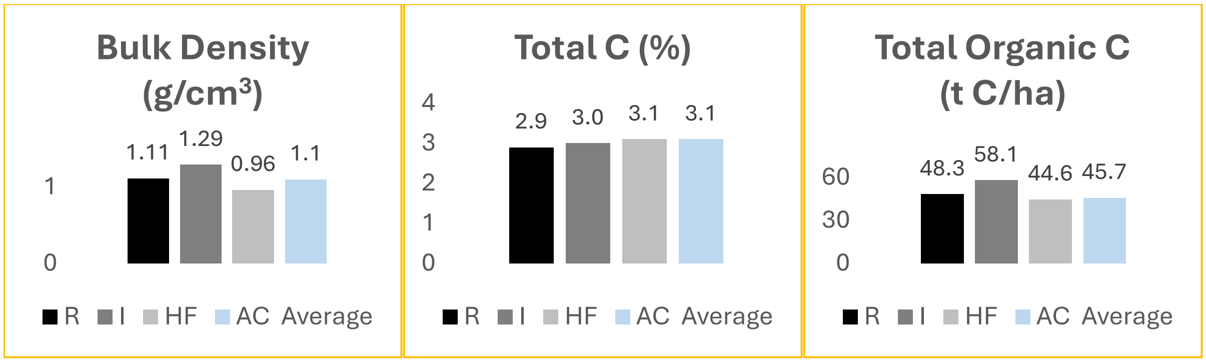


Figure 29 Bulk density and carbon from 3 fields (R, I and HF) compared to Atlantic Canada average

Recommendations:

1. **Keep doing what you're doing**. Soil health on this farm is very good. While the long-term perennial HF shows higher levels of OM -mall fields scored very well. Therefore, there are no red flags regarding soil health on this farm, and managers should continue to apply best management practices with regards to nutrient management, tillage and other practices.
2. **Monitoring nutrient levels in both soils and manure** is advised to optimize nutrient management.
3. **Building soil structure** by reducing tillage where possible, adding more diverse cover crops between cash crops, and incorporating high-carbon materials like straw or wood chips along with your manure to create better aggregates. The hayfield control shows you can achieve 44% aggregate stability on this farm, so there's clear potential for improvement.
4. **Address compaction** in the I field by avoiding working the soil when it's wet, using controlled traffic patterns, and considering deep-rooted cover crops like tillage radish or chicory to break up that dense layer naturally.

ORGANIC MATTER, BULK DENSITY & SOIL CARBON

You can learn a great deal about the success of soil management practices from soil tests that measure bulk density and carbon. Lower bulk density numbers indicate less compaction, larger pore spaces and more room for air and water movement. This means improved moisture retention during dry periods, reduced runoff and risk of erosion and improved microbial activity – all good signs of healthy soil.

Measuring bulk density accurately doesn’t require fancy equipment, but tests have to be done right. If it’s not, as we saw on many farms in this study, carbon values will also not correct as they must be correct for bulk density. Values should be between 0.9 and 1.5. Values above 1.5 are cause for suspicion.

Soil carbon calculations are dependent on getting the bulk density right. If your soil is at a lower density, the amount of carbon will be overestimated.

In this study, we did not include carbon data from farms where bulk densities were higher than 1.5. Most samples with high values were collected using tulip bulb planters which proved to be difficult to use in hard soils. In SK, most of the samples were collected using sophisticated truck-mounted metal tubes that were mechanically pounded into soils.

Bulk densities and total Carbon are shown in Figure 30 for each region. Saskatchewan farms stored the most carbon in the soil (49, t C/ha) with those in Ontario, the least (30 t C/ha).

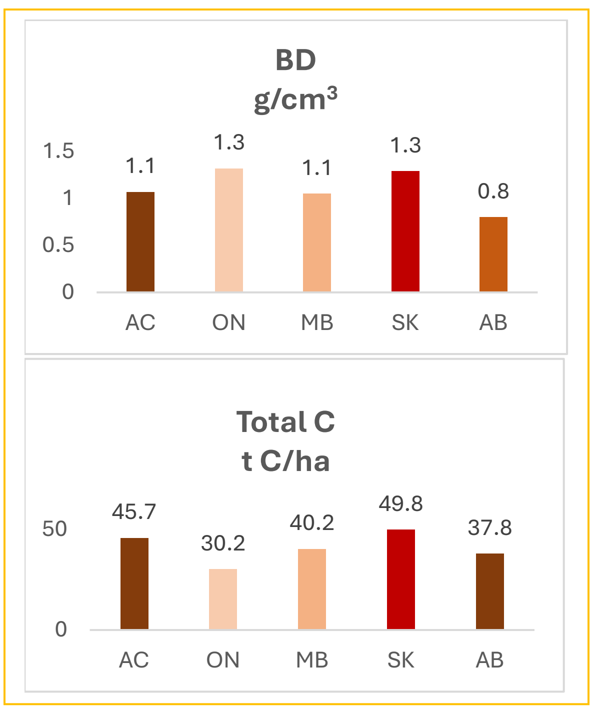


Figure 30 Bulk density and total carbon as a function of geographical region

Understanding Soil Carbon Tests:

Bulk density measures how tightly packed the soil is. It is defined as the mass of dry soil per unit of volume. When soil is compressed as it would be when tractors repeatedly drive over the soil, pore spaces within the soil, which can make up as much as 50% of total volume, are compressed. Pore spaces allow water, air, microorganisms and roots to move through the soil. Bulk density is thus a proxy measure for soil compaction.

Total carbon measures all the carbon in the sample, including organic matter (from plants and animals) and inorganic carbonates such as limestone.

Total organic carbon measures only carbon from organic matter – the living and decomposed plant and animal material. It is calculated by combining the carbon percentage from your soil test with bulk density and sampling depth. This tells us to how many tons of organic carbon are stored in each hectare of land.

Calcium Carbonate Equivalent (CCE) measures the limestone-like materials (calcium carbonate) naturally present in soil - the inorganic carbon content. High CCE values mean significant inorganic carbon is present, which can make total carbon measurements appear higher than the actual organic carbon content—the portion that comes from decomposed plant and animal matter.

Soil Health Profile

Peggy Baillie and Eric Blondin | Gore Bay, Ontario

Peggy Baillie and Eric Blondin operate an organic vegetable production system near Gore Bay, Ontario, where annual precipitation averages 804 mm.

Both sampled fields share a common history as pastureland. The R field, located on the western portion of the property, maintained its pasture function and supported pastured poultry operations throughout 2024 and 2025. This field has not been cultivated, preserving its soil structure. In contrast, the South field (Field I) underwent a transition to vegetable production. In spring 2024, this field was plowed and harrowed to prepare for cropping. Prior to the 2025 growing season, Actisol compost was applied to build soil fertility before the field was seeded to vegetables.

This side-by-side comparison offers valuable insight into how different management practices—pasture with minimal disturbance versus tillage-based vegetable production—influence soil health characteristics under organic management.

Soil Nutrients: The transition from pasture to vegetable production in the I field has created some significant nutrient imbalances. While the undisturbed R pasture field was very high in nitrate (310 lb/ac vs. 38 average), phosphorus (39 ppm vs. 17 average), and potassium (243 ppm vs. 110 average), the I field had lower levels of phosphorus (10 ppm) and potassium (49 ppm) despite the Actisol compost application (Table 17). These differences may be the result of management, but more likely reflect natural variation across the landscape with the I field having inherently different properties. For example, a short-term intervention such as breaking up a perennial stand would not result in a drop in P from 39 to 10 ppm.

Field	Nitrate 0-6” (lb/ac)	Nitrate 6-24” (lb/ac)	P (Olsen, ppm)	K (ppm)	S 0-6" (lb/ac)	S 6-24" (lb/ac)	Zn (ppm)	Organic matter (%)	pH 0-6"	pH 6-24"
R	310.0	160.0	39.0	243.0	118.0	118.0	3.7	6.4	6.2	6.5
I	48.0	54.0	10.0	49.0	49.0	36.0	1.9	6.6	6.9	7.0
ON Average	**37.7**	**43.5**	**17.4**	**109.9**	**26.4**	**28.6**	**2.1**	**4.1**	**7.0**	**7.4**

Table 17 Soil nutrients from R and I plots compared to ON average

Organic Matter & pH: pH at both depths was neutral in the I field and slightly acidic in the R field. Organic matter was high in both fields - at 6.4 (R) and 6.6 (I). Organic matter levels are also well above average at 6.4-6.6% (Table 17).

Aggregate Stability: Both fields have outstanding aggregate stability (Fig. 32, 88-91% vs. 52% average). In the R field,12.3% of the sample was finer than the smallest sieve so it washed out with 87.7% of the sample remaining. Fig. 26 shows that the I field had a higher percentage of large macroaggregates (> 2 mm) and macroaggregates (0.25 – 2 mm) and less of the smaller microaggregates (<0.53 mm), so the I field has better aggregation.

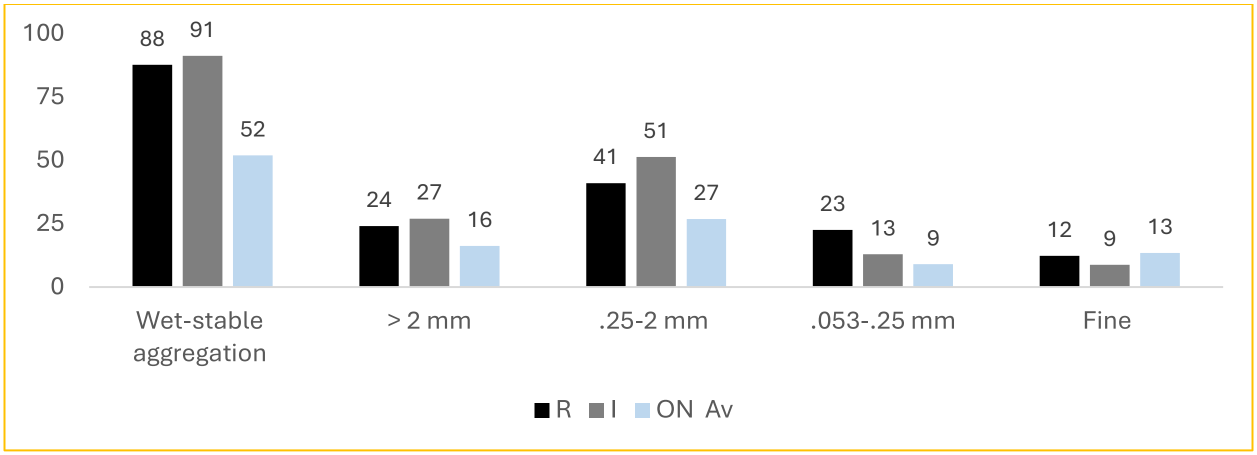


Figure 32 Aggregate stability in R and I fields compared to ON average

Bulk Density & Soil Carbon: Soil bulk density levels are unrealistically low (Fig.33). Rocks were found in some of the samples, and it is very difficult to get an accurate measure of bulk density in rocky soil. Since bulk density usually falls between 1 and 1.6 g/cm^3, bulk density is likely much higher. The difficulty in establishing an accurate bulk density value means that both the bulk density and total organic C data are not accurate. The C % data is the best indication for soil organic matter in this dataset and shows high levels relative to the Ontario average. The

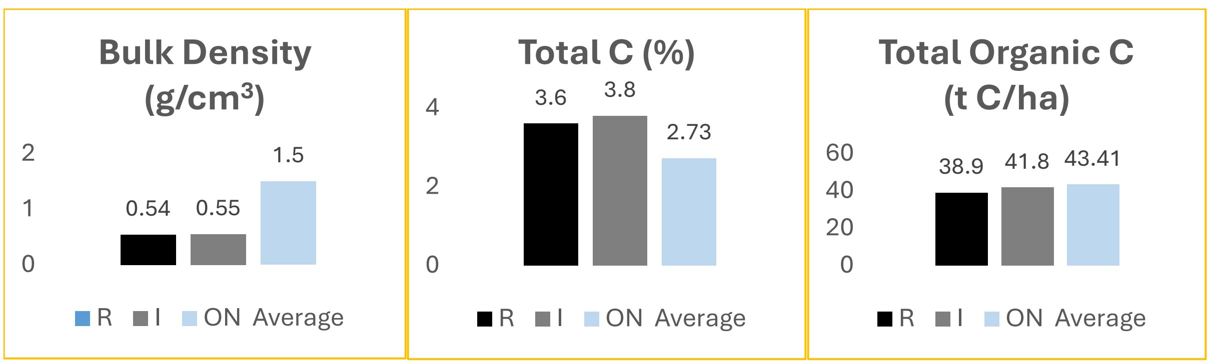


Figure 33 Bulk density and carbon in R and I fields as compared to ON average

soil samples that were taken at 20 cm (7.9 in) showed that the I field had slightly higher C% than the R field, and both were above the provincial average from this project (Fig. 33).

Recommendations:

1. **Keep doing what you're doing**. The soil health on this farm is very good. Because there are no red flags regarding soil health on this farm, managers should continue to apply best management practices with regards to nutrient management, tillage and other practices.
2. **Monitoring nutrient levels in soils** is advised to optimize nutrient management.

WHAT DID WE LEARN?

Results across a wide range of Canadian farms revealed that organic farmers are using a wide range of innovative management approaches which they are constantly adapting to improve soil health

We observed that perennial crops, such as forage legumes and grasses, produced the highest levels of soil health with high levels of organic matter and a high proportion of large aggregates. Many of these farms have manuring programs that contributed to the improved soil physical and biological parameters, but which also produced an adequate nutrient supply for crop production.

The dairy, beef, vineyards and other fruit farms in this small sample of diverse Canadian organic farms hosted the highest proportion of perennial plants, which in turn, produced the highest level of soil health. The organic and natural system vegetable farms that were included often included long perennial phases between vegetable cropping and added manures. Therefore, these farms also experienced high levels of soil physical, biological and chemical properties.

Differences in pH between farms is based on where farms are located, with eastern farms tending to have lower pH and Prairie farms tending to have higher pH levels. Lower pH on eastern farms is a function of the natural history of the area with forest soils naturally having lower pH than the grassland Prairie soils.

Prairie organic grain fields were often characterized by low levels of soil P, a challenge that these farmers are well aware of. We recommend they seek information on traditional P sources allowed in an organic system such as manure and newly allowed P sources such as struvite. The best information comes from provincial or university agronomists or other scientists. If you choose a commercial product, exercise caution as there is little science and the efficiency of many of the products is unknown. Organic farms will need approval from their certification bodies for each product.

Prairie organic fields also showed evidence of low N levels. In one case, very low N levels after growing sweet clover or berseem clover were attributed to lack of mineralization. That means the N in the legume plant had not yet been released from the organic form to nitrate (which is what the soil test measures). Tissue testing crops the year after legume green manures through tissue testing provides a more accurate measure of how legumes in rotation supply N to following crops. However, there are still many instances where the intensity of legume crop in rotation is still suboptimal for adequate N nutrition for cereal and oilseed crops. The recently developed Nutrient Budgeting App (https://www.thenutrientbudget.com/) will assist farmers and agronomists in planning rotations and cropping systems that enable adequate N to be produced.

Prairie grain fields showed some evidence of compaction, with bulk density levels sometimes above 1.3. This is evidence of tillage disturbance and fallow periods. Best management practices to improve soil structure include perennial crops, fall-seeded crops, cover crops after or before cash crop production, avoiding tillage or any machine traffic on wet soils, reducing tire pressure on heavy machinery when on the land, slowing down tillage, using narrow sweeps when possible and creating a farm landscape that reduces windspeeds across fields.

This study has provided a valuable benchmark for all participating farmers. One recommendation is to continue soil (and manure, where applicable) nutrient monitoring, as nutrient supply is so critical for stable production on organic farms.

DESIGNING A SOIL HEALTH MONITORING PROTOCOL

Soil Attributes

- Nutrient levels
- organic matter
- pH
- biological and microbial activity
- bulk density
- water infiltration
- electrical conductivity
- structure and aggregation

Just as you perform regular checks on your tractor and other valuable farm equipment, soil needs regular checkups to assess condition, to catch any problems early and to maintain long-term productivity. If you are introducing changes to your management, a monitoring program is essential for determining whether these interventions are effective.

Healthy soils provide many ecological and agricultural functions, including sustaining crops and other biological diversity, regulating water, filtering, buffering and breaking down organic and inorganic materials, cycling nutrients and providing physical support for plants. There is no single test that can monitor the full complexity of soil health. Nor can soil health be measured directly. Instead, we look at indicators that can provide indirect information about how soils are functioning across a range of functions. Different indicators measure changes in chemical, physical and biological properties of soil (Fig. 1), so it is best to include a broad range of indicators that touch on all these properties.

Designing and implementing a long-term monitoring system does not need to take an excessive amount of time or money, nor do tests necessarily have to be repeated every year. Some tests can be done on farm, with no need to send soil out for analysis, while others can be done routinely by submitting a few bags of soil to your local lab. Developing a routine and a standard place to keep results will turn this chore into a habit which will yield benefits in terms of agricultural productivity not only during your management, but long after.

To develop your protocol, first identify the soil attributes that you want to measure across the range of physical, chemical and biological properties of soil. Then figure out the best indicators to measure the outcomes you are trying to achieve and that fit within your budget. Identify the fields or parts of fields that you want to sample, using the schema we provide in Figure 3 on page 9. Your plan should indicate not only where sample, but when to sample. When you take your first samples, identify the locations using physical or GPS markers so that future tests can be done in the same locations. You can print out a map such as the one in Figure 2 for your records. By sampling in the same place and same time of year, you can decrease variability by removing the impact of location and season.

Another thing to keep in mind when choosing the tests for your protocol is the demands of other programs or standards that you may already be participating in. For example, if you decide to do the ROC (Regenerative Organic Certified) add-on to your organic certification, this program requires certain soil tests to be done at regular intervals. Other regenerative standards also typically require soil testing.

Below is a list of some commonly used tests of soil health that measure a wide range of physical, chemical and biological soil health attributes. You do not have to include them all in your monitoring program. They are included here to give you an idea of the options that exist.

SOIL TESTS

There are many soil tests out there – some off the shelf products that you can order online, some standard lab tests and some tests that you can do with materials you put together in your workshop. Below we provide some common soil health tests, along with the preferred time and frequency of testing. As noted above, when you perform a particular test is not as important as maintaining consistency. If you prefer to sample N in the fall, do that, but stick to that schedule. And don't forget to record the GPS coordinates!

SOIL NUTRIENTS

1. **Macronutrients – Soil Tests**
   Macronutrients are typically sampled using a soil probe or auger, but you can use a trowel or a spade. Most labs will provide sample bags upon request, but you can also use zip log bags. Just be sure to label them with your name, type of sample and GPS coordinates. Collect multiple samples in a W-pattern as described on page 9, aggregate and take a subsample. For some nutrients, two soil depths are preferred, for others, testing is needed only at the superficial depth.

   N

   Frequency: annually, pay attention to legume phases
   Time of year: spring, prior to seeding
   Depth: usually paired samples at two soil depths - typically 0-6" and 6-24"

   P

   Most soil labs offer two P tests. If your pH is less than 7, request the Bray test. For soils with pH greater than 7, opt for the Olsen test

   Frequency: once per rotation cycle
   Time of year: flexible
   Depth: single depth 0-6"

   K

   Frequency: less frequency on clay or loam soils in Prairie region
   Time of year: flexible
   Depth: single depth 0-6"

   S
   Frequency: Same as for N
   Time of year: Same as for N
   Depth: paired at two soil depths' typically 0-6" and 6-24"

2. **Micronutrients (Zn, Cu, Fe, Mn) Soil Tests**
   Frequency: every 2-4 years
   Time of year: any time
   Depth: single depth 0-6"

3. **Macro and micronutrients – plant samples**
   Frequency: every 2-4 years
   Time of year: summer, several weeks before plants enter reproductive phase
   Type of test: Note that the methods below allow you to calculate nutrients on a per acre basis. This is different than the usual nutrient sufficiency tests used in mainstream agriculture
   a. Quadrat method
      Instructions:
      You can make your own quadrat out of wood or heavy wire. It is a three sided square frame with each side measuring 50 cm. Place this over an area of plants and use a sharp knife to cut everything to the ground within the frame. Total area of the sample will be 0.25 m^2. Dry the plant material, weigh it, record (both on the bag and in your records) and place in a paper bag or box to ship to your lab.

      See: https://www.youtube.com/watch?v=3aiXI7HR5Y8
   b. Linear method
      Instructions:
      Best for row crops. Lay a meter stick beside a row and cut the crop level with the ground using a sharp knife along the length of the stick (above ground biomass only). Dry the plant material, weigh it, record (both on the bag and in your records) and place in a paper bag or box to ship to your lab.

      See: https://www.youtube.com/watch?v=3aiXI7HR5Y8

4. **SOIL ORGANIC MATTER soil test**
   Frequency: every 6-10 years, do at same time as bulk density tests
   Time of year: spring, prior to seeding

5. **AGGREGATE STABILITY**
   Frequency: Every 2-4 years
   Time of year: spring, before any field work
   Type of test:
   a. DIY Slake Test (Soil Stability Test)
      Instructions:
      https://fyi.extension.wisc.edu/danecountyag/files/2020/02/Slake-test-handout.pdf
   b. Lab Test
      Instructions:
      You'll need to take a sample separate from those for nutrient sampling, and preferably from an undisturbed part of the field. The sample should not be dried or overly disturbed. Use a spade or a tulip bulb planter which helps to prevent destruction of soil aggregates. Place the sample in a plastic bag and label it 'SOIL AGGREGATE STABILITY. DO NOT GRIND".

6. **BULK DENSITY**
   Frequency: every 6-10 years, together with soil organic matter test
   Time of year: spring, prior to seeding
   Type of test:

   Soil Ring**:**

   Instructions:

   Purchase or make a soil ring out of PVC tubing or metal. Aim for a ring that is approximately 4" long and 2" in diameter. Place a board over the top and hammer the ring into the soil until it is level with the surface. Use a spade to dig the ring out of the soil and a knife to level off soil at the top and bottom of the ring. Place the soil in a plastic bag and label with the type of test and GPS coordinates. If you are taking multiple samples, repeat the process, keeping each sample in its own labelled bag. Mail or courier the samples to your lab, along with your soil organic matter samples

7. **BIOLOGICAL ACTIVITY**
   Frequency: every 1-3 years
   Time of year: Microbial activity is heavily dependent on ambient temperature. Check specific temperature requirements for each test. Solvita test kits for example, work best at 20 C. For each test, ensure you conduct repeat tests at the same time of year, whether it is before seeding or after harvest
   Type of test: Check with your local lab to determine whether they do these tests

   a. Microbial respiration (Solvita CO_2 burst): Amount of Co_2 emitted by microbial activity in 24 hours
   b. Microbial biomass: Estimate of the total weight of living bacteria and fungi in the soil.
   c. Active carbon (POXC): Measure of readily available carbon used by microbes:

8. **WATER INFILTRATION**

   Standing water and surface runoff can be a sign of poor aggregate stability, crusting, lack of cover, compaction or poor soil structure.

   Frequency: every 1-3 years or at least once per crop rotation cycle
   Time of year: Flexible, but as with all tests, repeat tests should be done at the same time of year

   Type of test:
   a. Visual Observation

   Instructions:

   Assess within 24 hours of a typical rainfall or irrigation. Note whether the ponding is patchy or occurring across an entire field.

b. <u>infiltration test</u>

Instructions:

This test will help you calculate how long it takes for water to be completely absorbed into the soil in millimetres per hour. You can compare rates with averages for your soil type. Clay soils will absorb water more slowly while sandy soils will have much faster infiltration rates.

The test is easy to do and there are plenty of youtube videos with detailed instructions. It requires only a stopwatch (you can use the app on your phone), a shovel, water and container, tubing, knife, tape measure and a notebook and pen. Choose an area that is not compacted – i.e. not in turning areas or traffic lanes.

See: https://www.youtube.com/watch?v=OIFI-Tv3RIg

9 PENETRATION RESISTANCE

This is a measure of soil compaction. Compaction slows movement of water and gas through soil as well as interfering with root growth, microbial habitat, nutrient cycling, and plant growth. Compaction usually occurs at depths between 2 and 8 inches, but it can be deeper.

Type of test:

<u>Wire flag method</u>

Instructions:

Choose 8-10 locations randomly in a field. Hold the wire at the flag end and push it into the soil. Take note of the depth at which resistance becomes high. Compare to an area that you know is not compacted, such as a fence row or field edge.

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