Proceedings of the

BC Agricultural Data Protocols Workshop

February 23-24, 2023

BC Agricultural Climate Action Research Network

AGRICULTURAL CLIMATE SOLUTIONS
BC LIVING LAB



Acknowledgments

Contributors

Thank you to all of the Data Protocols Workshop presenters and participants whose contributions have provided a rich collection of approaches to improving agricultural data collection, analysis and management.

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Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

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Canada

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Introduction

The need for greater alignment between data collection methods has been a long-brewing conversation in BC's agricultural research community.

Several factors — including government investment in agricultural climate solutions; the increasing technical ability to collect, manage and share large data sets; and years of effort to bridge silos between disciplines and institutions — is making alignment on data collection approaches both more necessary and more achievable.

The BC Agricultural Climate Action Research Network (ACARN) hosted the two-day BC Agricultural Data Protocols Workshop to make progress towards defining collective approaches for measuring soil organic carbon, greenhouse gas emissions and co-benefits in BC agricultural production systems.

The workshop was designed to showcase the common research approaches that will provide a framework for the BC Living Lab and to build connections with provincial government initiatives as well as other aligned research and industry projects.

No single measurement or discipline holds the key for research on beneficial management practices (BMPs) aimed at providing benefits for climate change, for farmers' bottom lines and for ecosystems that can be resilient to current and future pressures. To reflect the multidisciplinary nature of this research, the workshop drew on expertise from across disciplines as well as new technologies that can improve data analysis capabilities.

In total, 15 presenters laid out foundational concepts and approaches while 70 participants joined the discussions. Forty participants met in person in Abbotsford, and 30 more joined virtually.

The workshop content focused on research protocol; however, participants included academic and government researchers, government staff, representatives from industry associations, and agricultural consultants.

The strong attendance, energy and commitment to collaboration indicate that workshop attendees will continue to work together to develop shared approaches to make research more effective, ultimately benefiting farmers and the climate.

Workshop objectives

- Increase understanding of research outcomes and data needs across disciplines.
- Support the development and adoption of standardized protocols for measuring and monitoring adaptation and mitigation outcomes.
- Identify opportunities, barriers and next steps for sharing research data.

Workshop outcomes

- **Workshop resource package**: Copies of all presentations, recordings and reference articles that support concepts and research presented
- **Workshop proceedings**: An overview of information presented, with key themes that emerged in breakout discussions, and a participant list
- **Action items summary**: An outline of next steps for moving toward standardized approaches for agricultural data collection and data sharing within and beyond the BC Living Lab

View all workshop video recordings

RESOURCES

» PDFs of supporting research listed in Resources boxes can be provided via email by contacting ACARN: info@bcacarn.com

1 Measuring Soil Organic Carbon

1.1 Soil organic carbon measurements for the BC Living Lab: Agriculture and Agri-Food Canada's approach

1.1. presentation slides (PDF)

KIRSTEN HANNAM, AAFC

Kirsten Hannam, PhD, Agroecologist at Agriculture and Agri-Food Canada Summerland Research & Development Centre, presented the approach that AAFC will be taking for soil organic carbon measurements for several Living Labs across the country.

The concept of carbon sequestration in soils requires reframing: soil organic carbon (SOC) does not just enter the soil — it also is released. The goal is to increase the net amount of soil organic carbon by ensuring that more SOC is entering the soil than is being lost through organic matter decay.

It's more accurate to think about managing the flow of SOC through the soil pool rather than "capturing" SOC in the soil.

AAFC will adapt methods described in Ellert et al. (2007), which are fairly consistent with international guidance on measuring and monitoring SOC stocks in agricultural systems. There are four main steps in this process:

1) Sample collection
2) Sample extraction from core
3) Sample processing and analysis
4) SOC stock calculations

RESOURCES

SOC sampling design

» Ellert et al., 2007. Measuring Change in Soil Organic Carbon Storage. Soil Sampling and Methods of Analysis. 25-38. Ch3.

Soil bulk density calculations

» Poeplau et al. 2017. Soil organic carbon stocks are systematically overestimated by misuse of the parameters bulk density & rock fragment content. SOIL 3: 61-66.

» Hobley et al. 2018. Comment on: "Soil organic carbon stocks are systematically overestimated by misuse of the parameters bulk density & rock fragment content". SOIL 4: 169-171.

Equivalent soil mass calculations

» Ellert & Bettany. 1995. Calculation of organic matter & nutrients stored in soils under contrasting management regimes. Can. J. Soil Sci. 75: 529-538.

» Fowler et al. 2023. A simple soil mass correction for a more accurate determination of soil carbon stock changes. Sci Rep 13, 2242.

Step 1: Sample collection

Ideal: Prior to visit, review site information (key to understanding factors that are in mind for farmers).

- Walk around site and identify relatively uniform areas.
- Use prior knowledge to obtain minimum detectable differences.
- Select appropriate sampling pattern.

- Record GPS coordinates of each sample location to facilitate resampling (key because other parameters may be measured at the same site).

Reality: Site may not be sufficiently homogeneous, so may need to stratify area; pre-existing data may not exist, so aim for ~10 samples per area, accommodating stratification as needed.

SOC is distinctly different under different management practices (i.e., in crops vs. drive rows), so collect representative samples from both areas.

Step 2: Sample extraction from cores

Ideal: Using a truck-mounted hydraulic corer equipped with a soil coring tube (internal diameter is 7 cm, allows bulk density and SOC measurement in the same sample), drill cores to 100 cm depth in the field and break core into sample depths.

Reality: Not all sites are accessible for a truck with a corer, and coarse fragments may prevent effective sampling or soil structure may not be appropriate for a corer. In these cases, may need to sample by hand using an auger and collect separate samples for bulk density.

Depending on soil structure, the soil may fall out of a 7 cm corer, so can try a smaller corer (i.e., a 5 cm sampling tube). Insufficient samples may be obtained when collecting soil in 15 cm increments, so collect more samples for shallow depth increments.

Step 3: Sample processing and analysis

Ideal: Dry, grind and sieve (2 mm). Use riffle box or centrifugal sampler when removing aliquots, and take simultaneous soil nitrogen and soil SOC measurements.

Reality: Coarse fragments and large roots are present. Remove these during sampling; record mass of both fractions. If a riffle box/ centrifugal sampler are not available, use cone and section method.

If not all carbon in the sample is organic, pre-test sample pH (~6.5 cutoff) to identify samples where soil inorganic carbon (SIC) is likely. Determine SOC + SIC separately (using acidification, two stage combustion or calcimeter, etc.).

Step 4: Soil organic carbon stock calculations

Ideal: Calculate SOC content (kg/ha) using bulk density (g/cm3).

Reality: Coarse fragments and large roots (> 2 mm) can lead to over-estimation of bulk density and, therefore, SOC stock. Account for their presence during bulk density calculations.

If differences in bulk density, introduce inconsistency in soil sample mass and use equivalent soil mass approach.

Important considerations

- Need to measure both control and treated areas in years 1 and 5 (for Living Labs projects) to separate effects of treatment and effects of time.
- Sample close to the original sample locations, but not too close. Surface material can fall in the hole and throw off the resample results.

1.2 Challenges of scaling soil organic carbon data over space and time

1.2 presentation slides (PDF)

SEAN SMUKLER, UBC

Dr. Sean Smukler, Associate Professor, Applied Biology and Soil Science, and Director of the Centre for Sustainable Food Systems at UBC Farm, presented examples from his research on approaches for scaling soil organic carbon measurements from the plot to the landscape level.

Questions about soil organic carbon that need to be considered for BC agricultural land:

- How do changes in SOC due to beneficial management practices compare with current practices?
- What is the baseline? What is the trajectory of the baseline?
- What is the maximum potential SOC capacity?
- Where do we prioritize interventions?
- How can we efficiently track impacts?

An example of sampling design used for research in the Fraser Valley

- Four quadrants and random point in middle of the plots
- Digital GPS with high accuracy: capture four points, and in repeat sampling, access one and use tape measure to find others
- Need to consider that there can be potential challenges with corer method due to inadvertent compaction. You do not want to composite drive row and row crop samples because there will be differences in these soils due to different management practices.

Sampling methodology

- Two augers, one for composite sampling
- Bulk density, down to 30 cm (limited by coarse horizons)

Sampling intensity and costs

- Mid-infrared spectroscopy offers a wider range of metrics and is lower cost than Aliko
- This approach offers an opportunity to develop spectro-libraries with data collected from multiple sites
- Using a hierarchical approach can provide higher precision data for analyzing, along with additional samples using cheaper mid-infrared.
- Use of drones makes it possible to scale from plot to field and field to landscape. The bigger picture approach is relevant for policy and land use planning.

Considerations

- Need to keep baseline sampling in mind
- Sampling other land uses in addition to land under agricultural production, for example riparian and forested areas of farm land
- Need to understand and consider field sampling trade-offs in terms of costs and accuracy
- Need to adopt strategies for integrating data when using a hierarchical approach
- At the outset, consider the longer term plans for analysis

RESOURCES

» Paul et al., 2019. Evaluating sampling efforts of standard laboratory analysis and mid-infrared spectroscopy for cost effective digital soil mapping at field scale. Geoderma, Volume 356.

» Paul et al., 2020. Tracking changes in soil organic carbon across the heterogeneous agricultural landscape of the Lower Fraser Valley of British Columbia. Science of The Total Environment, Volume 732.

2 Estimating Nitrous Oxide Emissions With Nutrient Budgets

2.1 Nutrient management with growers: Experiences from the field

2.1 presentation slides (PDF)

DRU YATES, ES CROPCONSULT

Dru Yates, IPM Consultant and Soils Specialist at ES Cropconsult — a private consulting firm that provides services to over 10,000 acres of berry and vegetable production in the Fraser Valley — shared experiences from her recent work developing nutrient management plans for Fraser Valley growers, including the type of information on nutrient use needed to estimate nitrous oxide emissions.

The information required to develop nutrient budgets:

- Field locations
- Soil tests and lab analysis
- Field management information including amendments, yield, etc.

Using this information, growers receive:

- A copy of lab results (which do not include interpretation)
- Nutrient report cards that interpret lab results and assess nutrient availability based on fall samples
- A package with input recommendations for the next growing season based on next year's crop plans and target yield; can use the BC Ministry of Agriculture and Food's nutrient management calendar

Grower involvement

Both the report card and input recommendation package require at least one sit-down meeting and one follow-up meeting with the grower to review the results. Revisions are often made based on these discussions with growers.

Grower benefits

Nutrient budgeting meets grower needs by:

- Providing records (soil tests, field management records)
- Answering the questions:
  - Is last year's application good or bad (in terms of agronomics, environmental impact, regulatory requirements)?
  - What should next year's plan be?
- One-on-one time for questions and problem-solving between an agrologist and the producer
- Providing timely results that can be applied immediately to plan for the next growing season

Challenges and realities to consider

- Getting field management info from growers can be challenging. Excel program and the detailed information required may be daunting for some.
- Field knowledge is needed by the agrologist (e.g., knowing the correct field locations is essential).
- Trust is needed between the grower and agrologist.
- Grower practices can be slow to change.

2.2 Nitrous oxide estimates and farm nitrogen budgets

2.2 presentation slides (PDF)

SHABTAI BITTMAN, AAFC

Shabtai Bittman, PhD, Research Scientist at Agriculture and Agri-Food Canada Agassiz Research & Development Centre, presented two approaches for estimating nitrous oxide emissions using nutrient budget information.

Background on agricultural nitrous oxide emissions:

- Nitrous oxide emissions in agricultural soils are a result of nitrogen fertilizer use where excess nitrogen (not taken up by plants) is converted from nitrate to nitrogen gas, a process termed *denitrification*. The gas is then released into the atmosphere.
- In Canada, agricultural soils account for 75% of national nitrous oxide emissions.

N2O estimation methods

Currently, in greenhouse gas emissions reporting, nitrous oxide emissions are estimated using IPCC protocols that use emission factors multiplied by specific activities (e.g., fertilizer use).

RESOURCES

» Hunt et al. 2013. Real-time Simulation Models—A Novel Tool for Farm Nitrogen Management (PDF)

» Environmental Defense Fund, 2022 How to use EDF's nitrogen balance model (PDF)

» Environmental Defense Fund, 2020. N-Visible: A Nitrogen Balance Framework (PDF)

There are also secondary emissions from leaching and volatilization.

Tier 1 estimates use a default emissions factor (EF): 0.01 kg N2O-N/kg N applied. This measures for direct emissions from applied nitrogen as fertilizer, organic amendments, crop residues and soil mineralization.

Estimation and mitigation efforts

With the exception of reduced nitrogen inputs, the impact of mitigation measures on N2O emissions would not be captured by either Tier 1 or simple Tier 2 estimations used by the IPCC.

In the BC Living Lab, a challenge to understanding N2O emissions is the limited capacity for sampling capacity.

In-field measurements of N2O emissions require year-round measurements and are very expensive for each site.

Two approaches for estimating N2O emissions and reductions using nitrogen budgets

- Field budgets: estimate field inputs and subtract field outputs
  - Calculate losses (leaching, runoff, ammonia, N2O) then reduce by minimizing surplus
  - Calculate N2O (quantify fertilizer, manure/amendments/effluent)
- Farm budgets: consider the full farm, estimate farm imports and subtract farm exports
  - Calculate losses from field and buildings (ammonia)

We need additional farm practice info to make N2O estimates more meaningful.

Calculating N2O emissions

The Environmental Defense Fund's (EDF) guide on how to use their Nitrogen Balance Model provides calculations to convert nitrogen surpluses to their N2O emissions value.

3 Co-Benefits: Focus on Soil Health

3.1 Co-benefits measurements for the BC Living Lab

[3.1 presentation slides (PDF)]

KIRSTEN HANNAM, AAFC

Kirsten Hannam, PhD, Agroecologist at Agriculture and Agri-Food Canada Summerland Research & Development Centre, highlighted some of the environmental benefits that may be associated with the beneficial management practices being evaluated in the BC Living Lab.

The beneficial management practices selected by growers to trial in the BC Living Lab do not just have potential impacts for mitigating climate change — they have co-benefits, both economically and environmentally.

Co-benefits may include:

- Reduced costs/improved profits
- Crop yield and quality
- Plant health
- Biodiversity
- Improved soil health

Evaluating co-benefits is important because the co-benefits can increase adoption of climate mitigation BMPs and support broader goals of farm resiliency and environmental sustainability.

A co-benefit of interest across all parts of the BC Living is evaluation of the potential benefits to soil health.

There are many indicators of soil health. These can vary by commodity, soil type and management history, etc.

The Soil Health Institute recently published guidance on a "minimum suite of soil health indicators," which includes:

- SOC
- 24-hr soil respiration rate
- Soil aggregate stability

AAFC Summerland and Agassiz are adapting the protocols published by the Soil Health Institute for their own lab facilities to conduct these analyses on samples collected for the BC Living Lab.

Once complete, these protocols will be made available to anyone interested. At present, standard operating procedures for each of these measures are available on the Soil Health Institute website.

3.2 Choosing soil health measurements for large-scale adoption

[3.2 presentation slides (PDF)]

CHARLOTTE NORRIS, NATURAL RESOURCES CANADA

Charlotte Norris, PhD, Forest Soils Research Scientist at Natural Resources Canada, conducted research with the Soil Health Institute as part of their work to identify the best indicators for soil health for broad soil health evaluations.

RESOURCES

- » Norris et al., 2020. Introducing the North American project to evaluate soil health measurements. Agronomy Journal 112 (114).
- » Bagnall et al., 2023. A minimum suite of soil health indicators for North American agriculture. Soil Security. Volume 10.
- » Recommended measurements for scaling soil health assessments, Soil Health Institute web page.

A North American project to evaluate soil health measurements included a broad assessment of soil health indicators.

The core group has 30 measurements:

- Tier 1: common, indicative
- Tier 3: exploratory, show promise as indicative

One lab handled all pH or all genomics, etc.

Results

Physical

- Particle size analysis is important
- Water at field capacity is sensitive to site characteristics and management
- Aggregates (MWD, wet aggregate stability)

Chemical

- Carbon (POxC, SOC, potential carbon mineralization, beta glucosidase enzyme activity, water extractable carbon)
- Nitrogen (soil N, N mineralization rate, B glucosaminidase, water extractable N, water extractable NO3 and NH4)

Biological

- PLFA: differences with management practices
- Genomics: 16S rRNA differences with tillage

Three minimum measurements

- Total organic carbon (dry combustion)
- Aggregate stability
- 24-hr carbon mineralization

Having the same lab do the analysis for all soil samples is ideal to remove the risk of inter-lab variability.

3.3 Soil microbiology evaluation methods: What aspect of soil health do we care about?

3.3 presentation slides (PDF)

MIRANDA HART, UBC OKANAGAN

Dr. Miranda Hart, Professor, Biology, UBC Okanagan, investigated microbial ecology of soil microbes to better understand the role and applications of microbes in agriculture and ecological restoration and provided options for evaluating soil health by looking at soil microbiology.

Soil health equals soil biodiversity, but there is a question of what do we measure: which soil fauna group is most important?

One approach: “Who is there?”

Community sequencing

- Pros: Good resolution down to species level, gives indication of abundance, can see how species change with different treatments
- Cons: Many taxa remain undescribed, does not reflect functioning/activity, limited to group of interest, spatial heterogeneity and hyperdiversity means you have to sample intensively
- Cost of sampling/equipment is expensive

Sequence everything in the soil with eDNA profiling

- Pros: Targets entire soil community
- Cons: Groups not equally represented, may over-represent

Another approach: "What are they doing?"

Quantitative PCR: Specific gene assays

- Pros: Relatively cheap/fast, gives high resolution info about specific genes
- Cons: Only tells us about genes we're looking for

Metatranscriptomics

- Pros: Comprehensive info about bacterial/fungal functional capacity, can identify specific steps that are underfunctioning in a nutrient pathway
- Cons: Expensive

What is the most relevant for this study?

Preferred approach would be QPCR or metatranscriptomics, which may be affordable on a reduced set of plots.

3.4 Prevalence of soil-borne pests and diseases in relation to soil health

3.4 presentation slides (PDF)

TOM FORGE, AAFC

Tom Forge, PhD, Research Scientist, Applied Soil Ecology/Nematology at Agriculture and Agri-Food Canada Summerland Research & Development Centre, discussed how plant parasitic nematodes relate to soil health evaluation.

From an orchardist perspective, soil health indicators include:

- General: Total organic C, mineralizable carbon, aggregate stability
- Specific: Disease bioassay, root lesion nematode analysis, specific pathogen quantification

Increased organic matter inputs can increase natural enemies of nematodes, but BMPs do have the potential to backfire in terms of pest/disease suppression.

Proposed work for the BC Living Lab

- Can conduct research at a limited number of crops/site (specific number TBD)
  - Coordinate with soil micro analyses
- Will characterize plant parasitic nematode communities in Year 1
  - Baseline for post-BMP analyses
  - General site characterization
- Resample in Year 4
  - Compare nematode communities in BMP and non-BMP fields/plots
  - Use bioassays to compare net pathogenicity
  - Interpret in relation to other soil health indicators, microbial metagenomic data, crop health and vigour

RESOURCES

» Forge et al., 2021. Shifting prevalence of plant-parasitic nematodes in orchards and vineyards of the Okanagan Valley, BC. Plant Health Progress. Volume 22 (2).

» Munro et al., 2020. Soil biota from newly established orchards are more beneficial to early growth of cherry trees than biota from older orchards. Applied Soil Ecology. 155 (795).

4 Integrating Socioeconomics

4.1 Agricultural Climate Solutions — Living Labs strategy for socioeconomics

4.1 presentation slides (PDF)

SHAUNA MACKINNON, ACARN, AND EMMA STEPHENS, AAFC

Shauna MacKinnon, Coordinator, BC Agricultural Climate Action Research Network, presented an overview of how socioeconomics is being considered in the Living Labs program overall and socioeconomic research activities in the BC Living Lab.

Emma Stephens, PhD, Agricultural Economist at Agriculture and Agri-Food Canada Lethbridge Research & Development Centre, is supporting multiple Living Labs with the evaluation of social and economic factors that influence the adoption of beneficial management practices.

On-farm level enterprise analysis

- Cost of production of implementing BMPs

Whole farm analysis

- Synergies and trade-offs
- Whole farm benefits may show up here
- Short-run cost vs. long-term economic impact

Regional/industry level analysis of diffusion of innovation

- Year 1: Baseline survey to assess level of adoption of BMPs
- Year 5: Followup

Additional questions: What affects uptake of BMPs

- Marketing challenges
- Barriers such as cost, labour, equipment
- Stress/mental health supports

Economic analysis

The importance of economic analysis was identified by multiple industry groups. Based on feedback, ACARN is working with UBC Okanagan, Okanagan College, AAFC and industry leads to support socioeconomic and economic analysis.

- 2023: Baseline survey
- 2024-2026: Further analysis
- Follow-up survey: Adoption rates and recommendations

4.2 Socioeconomics: Designing the research

4.2 presentation slides (PDF)

JOHN JANMAAT, UBC OKANAGAN

Dr. John Janmaat, Professor, Economics, UBC Okanagan, provided a framework for teasing apart and evaluating the different factors that influence attitudes towards and uptake of beneficial management practices.

Socioeconomic research follows the same scientific method as other types of research: question, background, hypothesis, experiment, analysis and conclusion.

From previous research in this area, a predictive model has been developed that accounts for various factors that influence farmer decision-making about whether or not to adopt a specific BMP.

Factors that influence the intention to adopt a practice:

- Farm and farmer characteristics
- Attitudes: have to believe it will work, is it something they care about, etc.
- Norms: views of peers, social values, family and friends
- Control: Do I know how? What do I do if it and doesn't work? How much time and money will it take? (their perceptions of whether they have enough time and money)

Other factors either enable or constrain adoption. For example, financial aid or insurance can be enabling factors while lack of time, lack of access to equipment, or high costs can constrain adoption.

We need to measure not only uptake but also intentions, as intentions will turn into behaviour, depending on enablers and constraints.

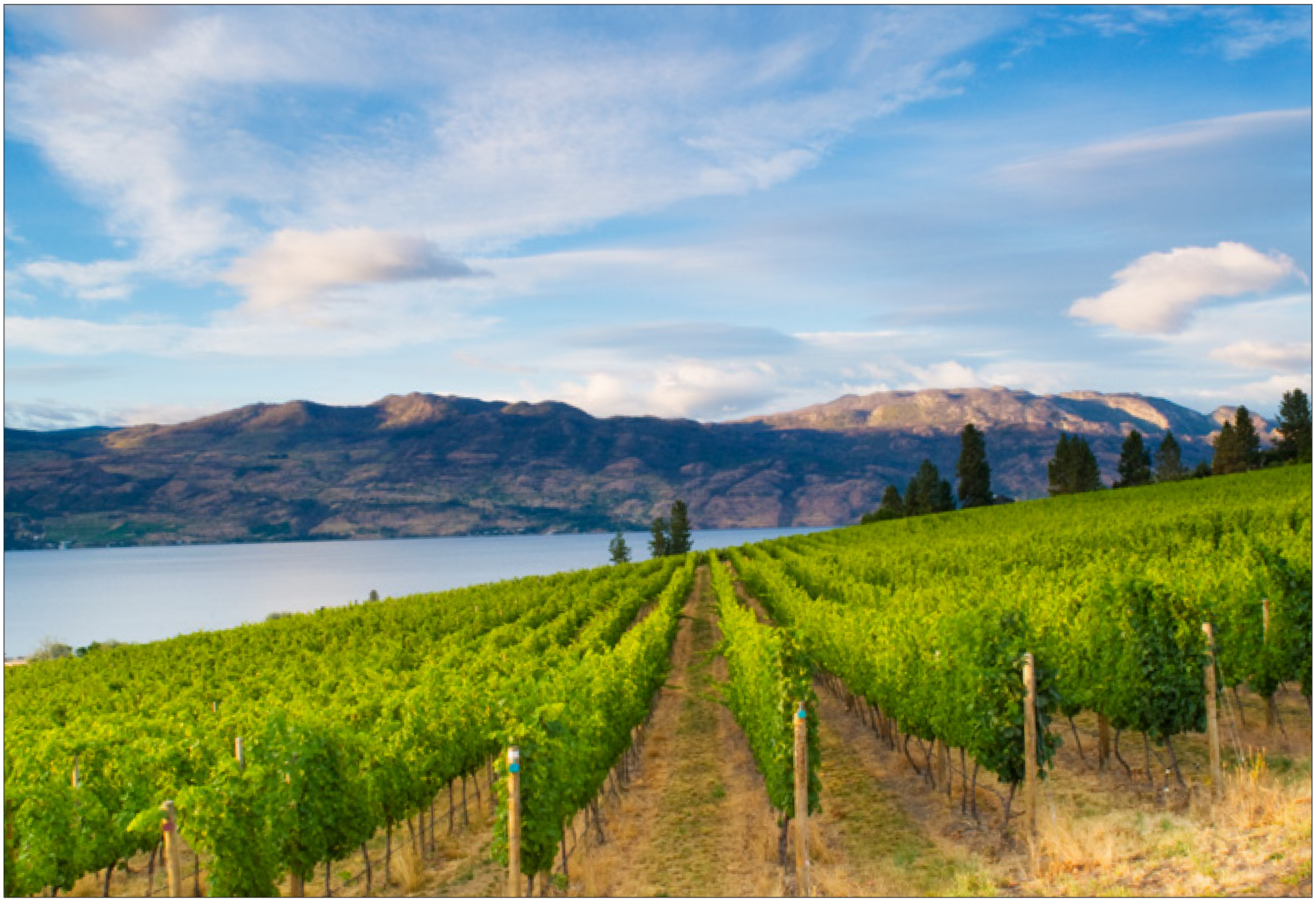
In the Living Lab, there is an interest in capturing the current state of intention and adoption of BMPs before the Living Lab activities start (the baseline) and then re-evaluating in Year 5 of the Living Lab.

The survey is intended to include farmers who are peripheral to the Living Lab (that is, beyond the farmers who are the producer collaborators in farm trials). We may see changes in both attitudes and adoption over the five years.

The split between attitudes and adoption can vary by BMP and sector, depending on investment needed to implement the BMP and operational timelines on the farms

RESOURCES

» Kleineberg, 2023. Socioeconomic Producer Surveys: Increasing BMP Adoption (PDF).



Vineyards in the Okanagan valley

5 Emissions Reporting Requirements

To meet Canada's international obligations under climate agreements, the federal government has a responsibility to estimate and report greenhouse gas emissions. Provincial and territorial governments also need to meet reporting requirements to support federal reporting and to track progress toward their own targets.

5.1 Data requirements for Canada's GHG inventory

5.1 presentation slides (PDF)

DAN MACDONALD, AAFC

Daniel MacDonald, Lead for Sustainability Metrics at Agriculture and Agri-Food Canada, manages operation and reporting of Agri-Environmental Indicators and presented data requirements for modelling carbon and GHG emissions and removals for Canada's GHG Inventory.

National GHG inventory reporting

- GHG reporting is submitted annually as part of Canada's commitments under the United Nations Framework Convention on Climate Change.
- The Intergovernmental Panel on Climate Change assesses the science related to climate change and provides guidance for generating national GHG inventories.
- Agricultural GHG modelling includes GHG emissions and removals from a number of agricultural sources, including soils, livestock, manure management, fertilizer use, farm energy use, etc.

Carbon modelling: Current practices

- The Ecostratification Framework allows for reporting at the regional, provincial and national levels.
- Soil Landscapes of Canada polygons serve as the primary analysis unit.
- Modelling the change in soil organic carbon associated with changes in agriculture land management and land use is based on the premise that changes in soil management influence the rate of soil carbon gains or losses for a period of time following the land management change.

Current carbon accounting methodology: Factor-based approach

- Carbon change coefficients are applied to net areas of change in land use and land management practices from one year to the next.
- The factor approach was implemented using the Canadian Agricultural Greenhouse Gas Monitoring Accounting and Reporting System (CanAG-MARS)
- The CanAg-MARS model was developed to estimate GHG sources and sinks for changes to agricultural land use and land management.
- The model uses carbon change factors developed using the CENTURY soil organic carbon model and empirical research.
- Carbon sequestration is accounted for in the Land Use, Land-Use Change and Forestry (LULUCF) category of Canada's National Inventory Report.

Factors not currently accounted for that could increase the amount of soil organic carbon (and lower total GHG emissions):

- Crop mix changes (annual crops)
- Cover crops
- Woody biomass change
- Grassland management

Considering these factors, reported soil carbon sequestration could increase significantly by 2030. AAFC is working with Environment & Climate Change Canada to better account for all factors affecting soil carbon.

Methodological improvements

We now have an updated methodology that considers changes in yield and corresponding changes in soil organic carbon resulting from increased nitrogen and manure application.

Updates to N2O emission factors in agriculture include:

- Meta-analysis recent data (Rochette et al. 2018); non-growing season emissions (Pelster)
- Cropland Carbon Model in LULUCF
- Multi-model analysis against long-term crop production experimental results and meta-analysis of long-term manure experiments (Liang and Thiagarajan)

Net downward revisions of GHG emissions:

- N2O emissions revised down by 4-5 Mt CO2 eq over the time series (included in national totals)
- Removals of CO2 revised upwards by, on average, 5 Mt CO2 eq over the time series and, on average, 10 mt CO2 eq post 2010

Carbon modelling: Data needs

Inclusion of land management activities for carbon modelling requires:

1) Activity data
   - Availability of the activity data from at least 2005 onwards. Inventory reporting begins in 1990, so any data will have to be backcast to 1990 or earlier.
   - Availability of the activity data nationally, or for the entire region in which the activity occurs, if the activity only occurs within a specific region of the country
2) Model coefficients / emission factors
   - Significance of impact on carbon stocks, e.g., having a large change in carbon per unit area of the activity, having a large aerial extent of the activity, or both
   - Coefficients applicable for Canadian conditions

There is an opportunity for improved emissions estimates through data collected by the Living Labs initiative.

Opportunities to improve existing carbon and GHG models

- Collecting field data on new BMPs or practices where estimates for modelling do not yet exist for Canada
- Types of cover crops not currently in the inventory
- Application of organic amendments such as municipal wastes, composts etc.
- Woody biomass (tree planting, shelter belts) with improved activity data (species type, planting density, monitoring of gains and losses etc.)

In general, work needs to be done to develop emissions factors and modelling coefficients that are applicable to Canadian conditions. Reliable and statistically robust time series activity data by region are needed.

RESOURCES

» Fan et al., 2019. Increasing crop yields and root input make Canadian farmland a large carbon sink. Geoderma. Volume 336.

» Rochette et al., 2018. Soil nitrous oxide emissions from agricultural soils in Canada: Exploring relationships with soil, crop and climatic variables. Agriculture, Ecosystems & Environment. Volume 254.

5.2 Priorities, programming and reporting

5.2 presentation slides (PDF)

GREG REKKEN, BC MINISTRY OF AGRICULTURE AND FOOD

Greg Rekken, Team Lead, Mitigation and Soil Health, Resource Management Unit, BC Ministry of Agriculture and Food, provided an overview of the new Sustainable CAP priorities and how climate-focused BMPs fit within the Ministry's climate and environment programming and priorities.

Government agriculture sector program support through the Canadian Agricultural Partnership ended March 31, 2023.

The Sustainable Canadian Agricultural Partnership (Sustainable CAP) is a new $3.5-billion, five-year agreement from April 1, 2023, to March 31, 2028, between the federal, provincial and territorial governments to strengthen the competitiveness, innovation, and resiliency of the agriculture, agri-food and agri-based products sector.

This new agreement places a higher priority on climate change adaptation and mitigation in the agriculture sector and offers new opportunities to investigate and implement beneficial management practices that can reduce GHG emissions and provide additional environmental and economic benefits.

Priorities under Sustainable CAP

- Tackling climate change and environmental protection to support GHG emissions reductions and long-term vitality of the sector
- Positioning producers and processors to seize economic opportunities from evolving consumer demands

Sustainable CAP: BMP lists

National list

- Associated with environmental benefits from the Guelph Statement
- Primary list of beneficial management practices derived through federal, provincial and territorial consultations
- Broadly worded for flexible implementation: multiple specific practices may fit under a single BMP
- Basic reporting requirements
- Research opportunities: Identify and develop new BMPs for inclusion on the list

Priority BMPs: Best emission factors

- Subset of the national BMP list with the best emissions factors
- Will be used by AAFC to estimate GHG reductions (national target: 3-5 MT CO2e)
- Additional reporting on adoption rates, likely through EFP/BMP and other cost-share programs
- With more information/research more BMPs can be added to the priority list

Resilient Agricultural Landscapes Program: Ecological goods and services

- BMPs providing ecological goods and services, limited direct farmer benefit
- Ecological goods and services incentive payment approach (e.g., per acre payments and land use agreements)
- Existing program reference: Farmland Advantage, Delta Farmland & Wildlife Trust
- Regional flexibility to determine details

How current programming supports BMP priorities

- Regenerative agriculture is an overarching priority for the Ministry and has many linkages to current climate change and environment programming and services.

- Current programming supports research and tool development as well as evaluating new practices and technologies -- effective from an environmental/climate sustainability standpoint and financially feasible in BC.
- Extension and knowledge transfer: working with producers to put research and tool development to use on their farms
- On-farm adoption supports historically included cost-share funding of equipment and infrastructure (EFP/BMP program) and new Extreme Weather Preparedness for Agriculture pilot program.

Opportunities for research collaboration

- Developing emissions factors for BC
- Identifying which BMPs in BC are priorities for farmers (evaluating co-benefits) and for mitigation (GHG reduction)
- Identifying and addressing barriers to adoption
- Evaluating BMPs in additional regions and production systems, building out more on-farm demonstration of BMP trials
- Evaluating effectiveness of program delivery and identifying how programs can be enhanced to improve adoption of BMPs
- Gathering data from BMP programs to estimate GHG reductions

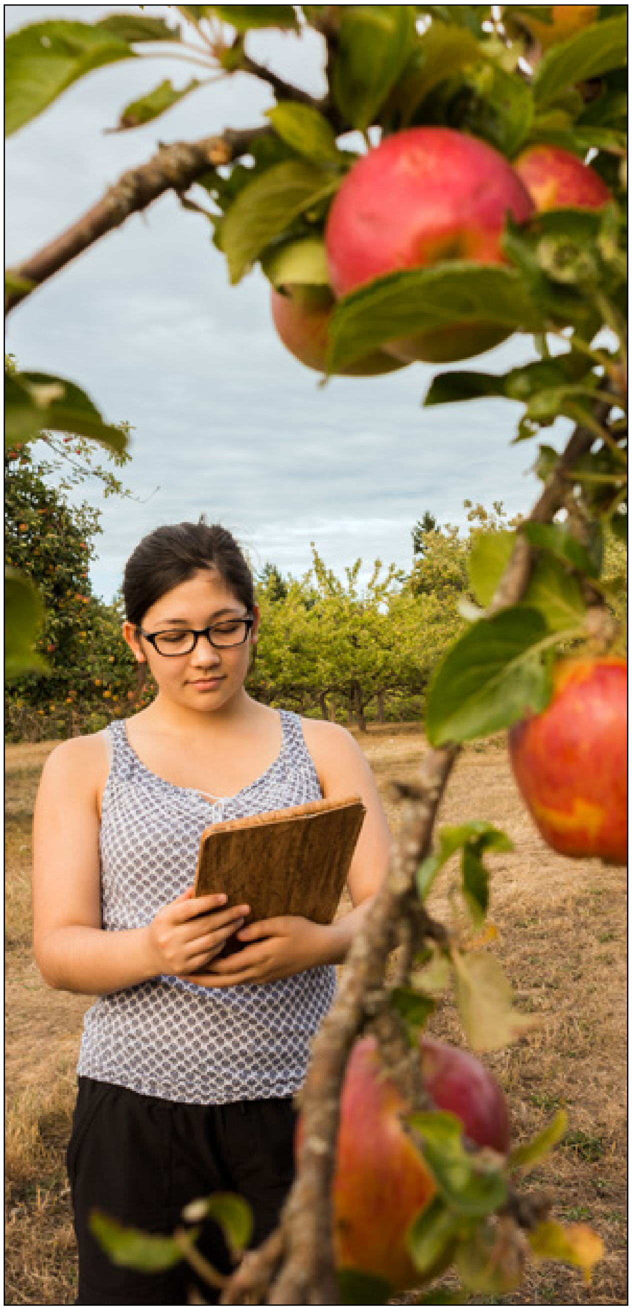
Plenary discussion themes

1. A better understanding of the BMP list and how mitigation vs. co-benefits are being prioritized will help aid implementation.

2. There are challenges with only tracking and rewarding farmers who are newly adopting these practices. Some farmers may already have been doing this a long time. Other farmers may need more than a one-time incentive to continue to do the practice and accrue the climate benefit.

3. How do BC BMPs fit into federal emissions reporting and government GHG reduction targets? There is interest in better understanding how changes on the farm can be fed into climate mitigation reporting and meeting reduction targets.

4. Exploring opportunities to better track BMP adoption beyond cost-share programs and working with partners — like local stewardship groups that are helping implement similar practices — would provide a fuller picture of adoption and benefits.



Field monitoring in an apple orchard

6 Provincial Soil Initiatives

6.1 Soil health and carbon sequestration protocol for BC

6.1 presentation slides (PDF)

GREG REKKEN — PRESENTING ON BEHALF OF DIETER GEESING, BC MINISTRY OF AGRICULTURE AND FOOD

Dieter Geesing, Provincial Soil Specialist, BC Ministry of Agriculture and Food, has been working in soil science and composting for the private industry, NGOs and academia in Canada and worldwide for almost three decades. He has been testing soil health evaluation methods on BC farms to identify the best options for increasing the understanding of soil health conditions and supporting farmer access to soil health data.

Assessing soil health and carbon sequestration in response to practices, such as regenerative agriculture, includes evaluating the following:

- Impact on soil health
- Impact on soil carbon
- Impact of soil health on climate change

Soil health protocol

A soil health evaluation protocol is needed to:

- Select most effective practices
- Target intervention
- Promote adoption by demonstrating effectiveness to industry and policy makers
- Provide baseline information for planning and reporting

Propose the following four components for a soil health protocol:

1) Best indicators
    - Select the best soil health indicators and the best methods for measuring these indicators
    - Identify who is doing the measurements and collecting the data
2) Modalities of data sharing
    - What do we do with the data once we obtain them in the field? Who is analyzing them? Reporting them? Confidentiality?
    - Overlap and connection with data collection in the field
3) Identification of needed infrastructure (and how to fill any gaps)
4) Coordination of the use of research and technology to collect soil health information

Survey on soil health indicators

The BC Ministry of Agriculture and Food conducted a survey on soil health indicators:

- Sent to 40 persons knowledgeable in soil health (19 academia, 7 government, 7 industry, 7 research); 18 completed survey
- Proposed indicators: 12 physical, 14 chemical, 16 biological
- Selection based on literature study and communication with soil health experts, but there are many more

Top results (% of votes)

- Tier 1: Indicator should be included and can be conducted by a non-scientist
    - Soil structure (78%)
    - Soil Ph (72%)
    - Soil EC (67%)
    - Bulk density (67%)
    - Penetration resistance (56%)

- Tier 2: Indicator should be included; requires specialized skill set or equipment
  - Potential mineralizable nitrogen (78%)
  - Soil fertility: micronutrients (72%)
  - Cation exchange capacity (72%)
  - Base saturation (67%)
  - Particle organic matter (67%)
  - Soil fertility: macronutrients (61%)
  - Reactive carbon (61%)
  - Hot water extractable carbon (61%)
  - Hot water extractable nitrogen (61%)
  - Additional info needed: soil data needs to be paired with management and climate data to be meaningful

Data collection, analysis and storage

To develop a provincial soil health / soil organic carbon database, consideration has to be given to who is collecting the data and who analyzes it, as well as data management, data ownership and data storage.

Based on personal experience doing field tests with students, farmers and alone, it is not practical to have growers conducting the tests themselves. It is also easier to manage data coming from a limited number of stakeholders than from hundreds.

Infrastructure for soil testing needs to be set up, including labs able to do the analysis and trained advisors/consultants able to do the testing.

Looking ahead, the development of research and technology — as well as data sharing infrastructure — can help move towards the goal of comprehensive soil health assessments.

Recommended next steps

The Ministry contracts managers for four task forces:

- Task Force 1: Indicator and protocol
- Task Force 2: Infrastructure
- Task Force 3: Data collection and stewardship
- Task Force 4: Partnership research and technology

Each task force would be composed of 3-5 people (researchers, industry and government), and the task forces would be a part of a permanent provincial soil working group.

The task forces would be assembled immediately and would draft protocols and recommendations to move from ideas to action immediately.

RESOURCES

» Summary of a survey and literature reviews: Soil health and carbon sequestration indicators for BC soils (PDF)

6.2 Soils technical working group, draft recommendations

6.2 presentation slides (PDF)

GREG REKKEN, BC MINISTRY OF AGRICULTURE AND FOOD

In 2022, the BC Ministry of Agriculture and Food formed a Minister's Advisory Group on Regenerative Agriculture and Agri-tech to provide strategic advice to the government on opportunities to promote innovation, technology, adoption and regenerative practices. The advisory group included five technical working groups: Defining Agri-Tech, Extension Services, Incentives, Regenerative Agriculture Standards, and Soil Health.

Greg Rekken presented the recommendations of the Soil Health Technical Working Group.

In January 2023, the advisory group released a strategic framework for promoting regenerative agriculture and agri-tech. The Soil Health Technical Working Group also released a set of recommendations.

Background context

A lack of consensus on how we assess soil health leads to the absence of soil health data that can be compared across sites, regions and commodities.

The working group was tasked with developing recommendations for a provincial soil health monitoring and evaluation strategy.

Five draft recommendations

- Soil health baseline
    - Very little data is available provincially that defines the status or trajectory of soil health; producers do not have benchmarks to compare to
    - Absence of provincial soil health assessment protocol
- Monitoring and evaluation
    - Little data linking Soil Health Institute (SHI) with measurable changes in agriculture
    - Society does not recognize benefits that producers are providing in terms of ecological services from farm and range land
- Data management and sharing
    - No common protocols
    - Data that does exist is not widely shared with government/academia
- Visualization and dissemination
- Long-term support

Recommended action items

Soil health baseline

- Identify and agree to a set of soil health indicators
- Launch a series of projects at various scales to develop a provincial baseline of soil health indicators

Monitoring and evaluation

- The working group engages with producers to identify and prioritize soil health outcomes they are interested in quantifying
- Prioritize regions, commodity groups and BMPs to evaluate (2023-24)
- Develop and launch a series of research and demonstration projects for that priority list (2024-29)

Data management and sharing

- Develop data-sharing protocols, in coordination with ACARN, Living Labs and national efforts, to establish soil data-sharing infrastructure (2023-24)
- Enhance current data collection capabilities and capacity of the Ministry and ACARN to gather and share data until the national infrastructure is fully operational (2023-24)

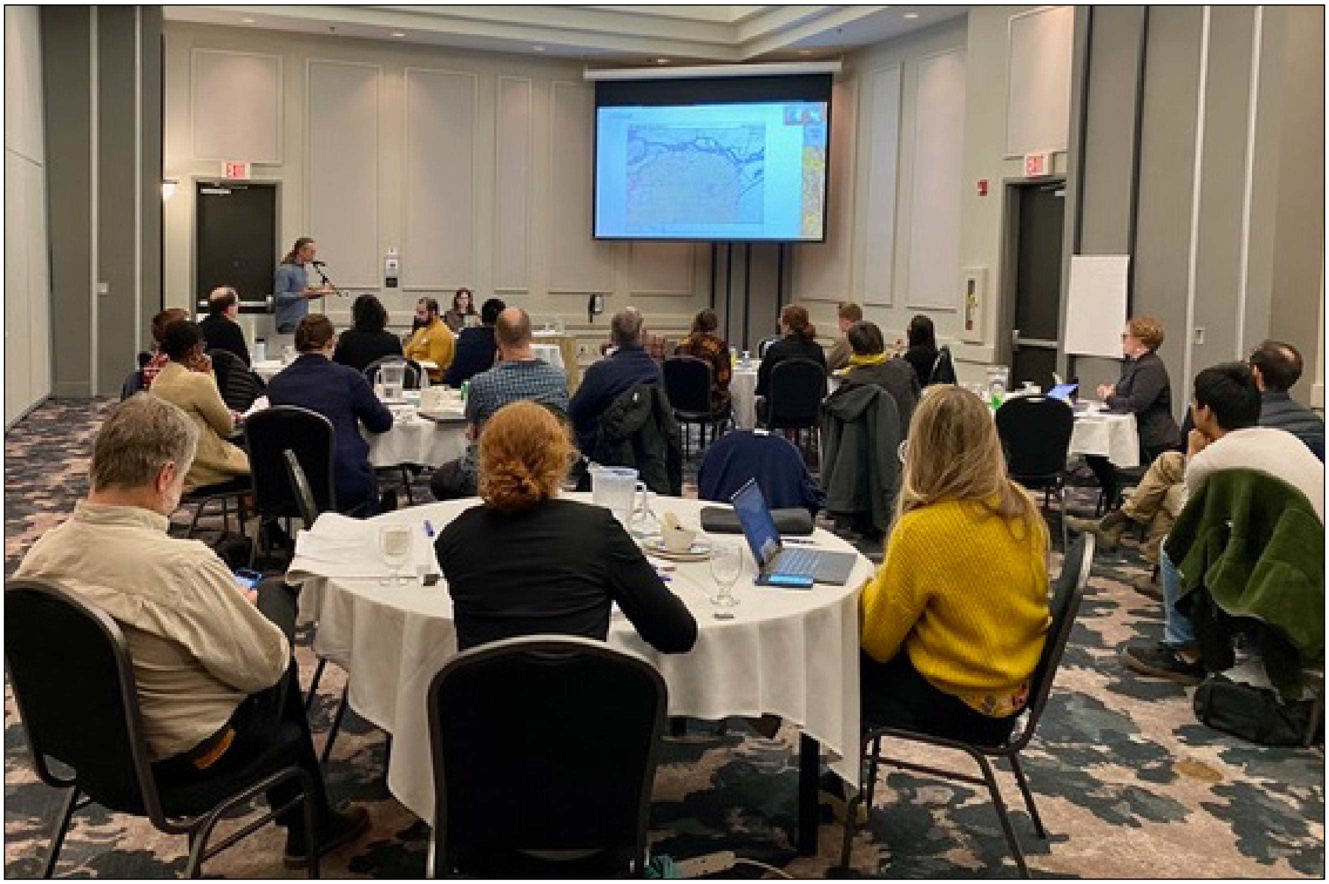
Visualization and dissemination

- Producer and agrologist targeted soil health extension, tools and outreach (e.g., interpretive dashboard)
- Multi-year extension to promote and support adoption of soil health indicators and tools
- Common soil health benefit interpretation framework: (i) biological diversity and function; (ii) environmental quality; and (iii) plant, animal and human health

Long term support

- Support a long-term soil health technical working group for the collaborative development and implementation of a provincial soil health strategy, facilitated by the Ministry

Breakout discussions: Provincial government role in soil health



Data Protocols Workshop in Abbotsford, BC, February 2023 (*Photo by Shauna MacKinnon*)

1. To build a provincial database and monitoring system, keep soil health indicators to a small set of measurements, preferably analyzed at the same lab.

- Instead of offering a range of options, simplify and choose the three key indicators identified by SHI: soil organic carbon, aggregate stability and inorganic carbon.
- Programs/projects/regions could add additional measurements, but the three indicators recommended by SHI can provide a common basis across all BC agricultural soil research.
- The Living Lab sites alone are too few to build a representative baseline data set for BC agriculture as the sample size within each commodity is too small and not all regions are represented. Additional sites need to be tested.
- Lab capacity and consistency need to be considered. Ideally, all tests for the provincial data set could be sent to the same lab.

2. Regional needs must be identified and accommodated in a provincial soil health assessment strategy.

- Specific regional and commodity needs must be identified, and additional regional/commodity-specific measurements could be added to the three base indicators.
- Requests for soil health measurements need to be targeted to avoid overburdening producers or requesting irrelevant information.
- The development of a provincial soil health database provides an opportunity to invest in research capacity of additional universities, in particular in areas where there are data gaps.
- The University of Northern BC has a strong soils faculty department and the University of Victoria is developing a soils lab.
- There will be increased pressures in these regions as more intensive agriculture sectors move in.

3. A soil health monitoring and evaluation strategy needs to be designed with the goal of increasing adoption of BMPs. The strategy should include how to provide information to producers that can inform on-farm decision-making.

- Better information and additional research is needed to establish the relationships between soil health indicators and co-benefits.
- Soil health data and accompanying research is needed to fill in the information gap that farmers face when considering what BMPs will work for their farm-specific conditions.
- Communication and extension about farm-level soil health information and the role of BMPs in improving soil health is key to increasing BMP adoption. Extension is necessary to make progress towards soil health improvements, climate benefits and other co-benefits.

4. There are many potential sources of data, both historical and current, that could contribute towards a provincial soil health database. The value and accessibility of these sources needs to be evaluated.

- A large pool of BC soil health data, both academic and government data, already exists. But this data is largely inaccessible as it is stored by individual researchers and programs, and permissions may not be in place to use this data for a provincial database.
    - Step 1: Conduct an inventory of data to document what data exists and who owns it.
    - Step 2: Develop methods for sharing these data sets (infrastructure and data sharing agreements/permissions).
    - Some historical data may not be worth the effort of standardizing and accessing.
- Leveraging programs like the Resilient Agriculture Landscapes Program and On-Farm Climate Action Fund can help increase adoption of BMPs (including those tested in the Living Lab) and can be used as opportunities to collect soil health evaluation data.
- There is the potential to add soil health indicators into the requirements of the Nutrient Management Plan.
- In developing a soil health database, questions around what is considered the baseline needs to be addressed as well as how, or if, treatments (e.g., specific BMPs) can be compared against reference practices.

5. The Ministry of Agriculture and Food should dedicate significant funds and staff dedicated to initiating and implementing a provincial soil health evaluation and monitoring strategy.

This has been recognized by the Ministry. It is committed to supporting a strategy with multi-stakeholder engagement (industry, researchers, government).

Breakout discussions: Provincial government role in the BC Living Lab

1. Provincial government support can make BC Living Labs research more robust through replicated trials and/or more in-depth analysis across sites.

- There is an opportunity to develop emission factors for practices being trialled in the BC Living Lab by funding replicated trials. Currently, there is a lack of ground-truthed data on what impact BMPs have on greenhouse gas emissions in BC agricultural/regional contexts. The Living Lab is prioritizing producer engagement rather than replicated trials, and funding is insufficient to do both.

- More funds could support the analysis of additional soil health indicators, for example, conducting metaspectral microbial analysis across multiple commodities and regions or piloting soil health indicators that could later be applied provincially.
- Provincial funding could be provided to conduct a standardized set of soil health evaluations (e.g., using the A&L Canada Laboratory's soil health analysis package) across the BC Living Lab commodities and treatments over the next four years.

2. The Ministry of Agriculture and Food can support additional daughter sites (on-farm BMP trials with less intensive data collection) under the new regional extension model.

- The Ministry can cover the costs of establishing and supporting additional on-farm trial sites.
- These sites can be used for Ministry-supported extension — field days and demonstrations — and to trial BMPs in additional regions.

3. Provincial government support would enable the Living Lab to be an opportunity to create a provincial baseline data set and data sharing system.

- Investment is needed to develop a structure for sharing data, including, but not limited to, soil data.
- There are limitations to which information the Ministry can receive and manage. Funding is needed to develop a system that is outside of government (e.g., via ACARN as a third-party supported by academic institutions).
- A dedicated portal/website is required, as well as funding for maintenance, establishing data-sharing protocols and agreements, and a long-term data steward (a funded position to maintain data and ensure accessibility, quality, etc.).
- There is a need to consider how this data sharing system would/could integrate with existing government online tools, such as the Environmental Monitoring System's database where water quality samples are managed.
- This central data sharing system would maintain the Ministry's soil health evaluation data, including the three SHI recommended indicators and additional indicators of interest.

Through the Living Lab projects, there is an opportunity to demonstrate the utility of data sharing to farmers — if the data can be shown to benefit farmers' management decisions and operations. This could help shift the culture around data sharing from a regulatory requirement to a helpful resource.

RESOURCES

» Draft recommendations from the technical working group on regenerative soils (PDF)

7 Technological Tools to Improve Data Collection, Analysis & Access

7.1 Remote sensing for evaluating health of agricultural ecosystems

[7.1 presentation slides (PDF)]

BING LU, SIMON FRASER UNIVERSITY

Dr. Bing Lu, Assistant Professor, Department of Geography, Simon Fraser University, leads the Remote Sensing of Environmental Change (ReSEC) Lab. He works in the agricultural sector monitoring blueberry plants and scorch virus, mapping the amount of crop residues as part of soil health evaluation and investigating ecosystem health by quantifying landscape fragmentation.

Remote sensing offers numerous advantages for agricultural research:

- Spatial coverage from small to large: canopy, field, landscape, regional
- Repeated data collection: daily, weekly, monthly, yearly, decadal
- Retrieval of various ecosystem features: crop, soil, water
- Images collected by different platforms/ sensors are more and more available

RESOURCES

» Wang et al., 2023. Cross-scale sensing of field-level crop residue cover: Integrating field photos, airborne hyperspectral imaging, and satellite data. Remote Sensing of Environment Volume 285.

However, there are also limitations with remote sensing technologies:

- Remote sensing cannot provide all of the information needed for agricultural research (e.g., soil microbiological features)
- Image collection can be limited by weather
- Some images/technologies are free; some are very expensive
- May generate a large volume of data that creates a large computational load

7.2 LiteFarm: Tools for farmers

[7.2 presentation slides (PDF)]

KEVIN CUSSEN, LITEFARM/UBC

LiteFarm is a free and open source farm management tool made for current and aspiring sustainable farms.

It was built by farmers and researchers coordinated by UBC to address many of the challenges in farm management. It's currently being used to manage farm operations in more than 125 countries.

LiteFarm follows a three-pronged approach:

- Focus on usability and utility for farmers
- Help farmers make a living
- Connect farmers with expert knowledge and tools to improve their practice

Farmers have the option to make the data they upload accessible to researchers. That data is collected in real time and in a way that is useful for farmers and keeps researchers from making separate requests for data.

Over 300 farms in BC have entered data into LiteFarm, including:

- Detailed cost of production data
- Records of BMP adoption and detailed farm input usage data
- Qualitative and quantitative satisfaction ratings for BMPs
- Whole farm sustainability indicators

RESOURCES

» LiteFarm website

7.3 Agrilyze: i-Open agri data and ethical use

7.3 presentation slides (PDF)

JONATHAN MCINTYRE, I-OPEN/ AGRILYZE

Agrilyze is a BC-based data analytics portal for precision agriculture.

Developed by the i-Open Group of Companies as a hub accessible from any mobile device, the Agrilyze platform uses a data commons framework that fosters innovative data reuse, integration and visualization to characterize fields, farms, machinery, soil, water, terrain and weather.

Locally, it is focused on berry, livestock, greenhouse, dairy and poultry farms and will be the first agricultural information platform in BC to allow for predictive analytics to be applied to a farm business operation without the need for extensive research legwork by the user.

Agrilyze makes existing data accessible to farmers to aid farm management decisions and can also increase data availability by deploying weather data sensors at the farm level. The data is analyzed and made accessible to farmers through reports, images and visualizations.

Agrilyze can provide accurate performance insights that demonstrate clear return on investment by improving the precision of agriculture management. Agrilyze offers a flexible data management, data analysis and data visualization platform that can be customized for farm business, research and government clients.

RESOURCES

» Agrilyze website

8 Data Stewardship & Governance

8.1 Data stewardship and data governance options for BC agricultural data

8.1 presentation slides (PDF)

HANNAH WITTMAN, UBC

Dr. Hannah Wittman, Professor (jointly appointed), Institute for Resources, Environment and Sustainability and the Faculty of Land and Food Systems; Member, Centre for Sustainable Food Systems and Biodiversity Research Centre, UBC. Her research projects include community-based research on transitions to agroecology, organic agriculture and more diversified agroecosystems, and the synergies between biodiversity conservation, food security and food sovereignty in diverse global contexts.

- There is significant polarization around data: a lack of consensus around what it is and how it should be managed.
- Those with power do influence policy and practice.
- Farmers (and researchers) are concerned about which entities have ownership and control over agricultural data.
- There is a need to create conditions for trust between all actors in a data collective.
- Information is powerful to farmers, valued and protected.
- To build trust, tools that return data to farmers can be used to make research data valuable for farmers, e.g., FarmOS enables them to use data for their own benchmarking.
- Farms may lack tools to integrate data, therefore, it's difficult to assess the whole picture of farm sustainability.

UBC Farm data governance example

Open data framework

Open data is data that anyone can access, use and share. In practice, that means making data accessible online, putting it in standard digital forms which are machine readable and having terms or licences that allow anyone to reuse the data for anything. It does not mean sharing private data.

Why promote open data?

- To unlock the power of data-driven solutions for agriculture
- To better understand the diversity of challenges faced by farmers
- To design and disseminate context-adapted solutions
- To make it easier for farmers to access data related to, among others:
  - Weather
  - Agricultural inputs (fertilizer, water, insurance, mechanization, crop protection)
  - Soil
  - Market price

CSFS Dataverse portal

- Open-source academic data repository
- Includes research and operations data
- Allows for version control across datasets
- Includes complete metadata for each dataset

Some data concerns shared by BC farmers

- **Data sovereignty**: Control over access to use of data, especially by government or entities that wish to sell farmer data
- **Privacy**: Potential identification of individuals within open data sets

RESOURCES

» Ethical data governance for agriculture project, ACARN and UBC Centre for Sustainable Food Systems

» UBC Farm Dataverse protocol

- **Interoperability**: Can data be accessed and utilized via multiple platforms or used in different kinds of analysis/use cases?

BC Living Lab considerations

A transparent and open process for data governance and stewardship — for both ecological and socio-economic data — is needed to build trust and enable cross-sectoral research for climate solutions.

We know technical challenges exist, so there's an opportunity to build trust and transparency. Some considerations include:

- Transparent clarification and communication relationships of the data management
- Data controllers: farmers or potential collectives of farmers
- What capacity do producer groups have to manage datasets?
- Who are the people that are going to make the decisions? Who are the data stewardship participants within the Living Labs?
- Who will be responsible for cleaning, managing, storing and sharing data?
- Unclear what data needs to be / can be uploaded to federal Living Labs portal
- Could the project use another data repository such as Dataverse at UBC

BC Living Lab governance plan considerations

- **Responsibilities**: Who is managing the data in the short/long term?
- **Data sharing**: Who has access and for what purposes?
- **Consent**: How are farmers providing consent?
- **Privacy**: What is personal and sensitive data? (With so few farms for the Living Lab, how do we protect privacy if that is their preference?)

Plenary discussion themes

1. Look to other sectors for data management models (e.g., health).

Other sectors have decades of experience managing sensitive data.

2. The data governance plan needs to include quality assurance measures.

- Include metadata on the methodologies used to give the data context
- Support a data steward role that will manage the data and ensure metadata and verification measures are completed and create an accountability mechanism for data quality
- Avoid data gaps by including unpublishable data (failed experiment data) in the repository
- Use confidence scores as a tool for curation and quality assurance (but resolution matters)

3. Research ethics processes and approvals need to be considered in the data governance plan, particularly with socioeconomic data.

4. The BC Living Lab, the Ministry of Agriculture and Food's interest in a provincial soil health database, and improved data management tools make this a good time to develop an agricultural data sharing strategy.

Infrastructure is important, but other necessary components include:

- Developing an agreed-upon data sharing and data governance agreement
- Building trust between farmers and other partners (e.g., academic and government)
- Demonstrating the value of data sharing to farm managers