AGRICULTURAL
CLIMATE SOLUTIONS

Soil organic carbon measurements for the BC Living Lab:

Agriculture & Agri-Food Canada's approach

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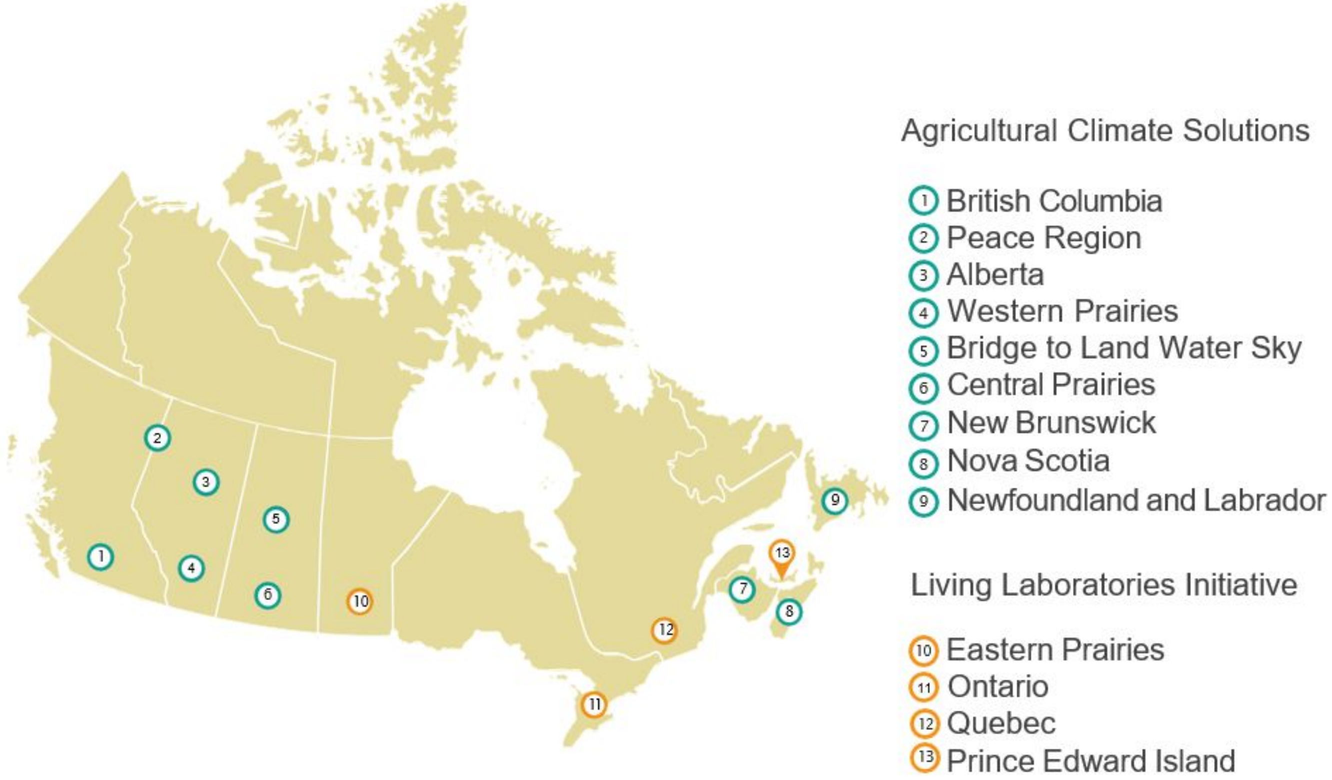
Agricultural Climate Solutions priorities

- Sequester **carbon**
- Mitigate **greenhouse gas (GHG) emissions**
- Provide **co-benefits**, such as biodiversity, water quality, soil health, etc.



NOTE: SOC stock increases when additions of plant-derived organic C into the soil are greater than losses of CO_2-C out of the soil

Soil organic C stocks – 4 main steps:

- Sample collection
- Sample extraction from cores
- Sample processing & analysis
- Soil organic C calculations

…and, repeat…

NOTE: This guidance is focussed on sample for SOC stocks; sampling will be different for, e.g, some soil health parameters!

Chapter 3
Measuring Change in Soil Organic Carbon Storage

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3.1 INTRODUCTION

Organic carbon (C) must be among the most commonly analyzed soil constituents, starting with the earliest soil investigations. Already in the nineteenth century, chemists were routinely analyzing soil C (e.g., Lawes and Gilbert 1885). Initially, these analyses were done to investigate pedogenesis and to assess soil productivity, both of which are closely linked to organic C (Gregorich et al. 1997). But more recently, scientists have been analyzing soil organic C (SOC) for another reason: to measure the net exchange of C between soil and atmosphere (Janzen 2005). Indeed, building reserves of SOC has been proposed as a way of slowing the rising atmospheric CO_2 concentrations caused by burning fossil fuel (Lal 2004a,b).

Measuring SOC to quantify soil C "sinks" requires more stringent sampling and analyses than measuring SOC to evaluate productivity. Where once it was sufficient to measure relative differences in concentration over time or among treatments, now we need to know the change in amount of C stored in Mg C per ha. Reviews of SOC measurement typically focus on the chemical methods of determining the SOC concentrations after samples have been brought to the laboratory. Here we emphasize soil sampling procedures and calculation approaches to estimate temporal changes in SOC stocks. Uncertainties along the entire chain of procedures, from designing the soil sampling plan, to sampling in the field, to processing and storing the samples, through to chemical analysis and calculating soil C stocks need to be considered (Theocharopoulos et al. 2004).

Sample collection

Ideal:

- Prior to visit, review site information, (e.g., slope, soil type, crop history)
- Walk site to identify relatively uniform area (~0.5 - 1 ha)
- Use prior knowledge (e.g., pre-existing data) to calculate number of samples required to obtain ‘minimum detectable difference’
- Select appropriate sampling pattern (e.g., grid system, ‘W’)
- Record GPS coordinates of each sample location, to facilitate re-sampling

NOTE: Let’s assume here that ‘control’ & ‘treated’ areas with similar soil properties, management histories have already been designated.

Sample collection


A.J. Midwood

Reality:

- Site may not be sufficiently homogenous
  **stratify area, e.g., based on slope position*
- Pre-existing data may not exist; the number of samples required for MDD may be humongous
  **select ~10 sample locations per area, accommodating stratification, if needed*
- SOC is distinctly different in crop vs. drive rows of woody perennial crops
  **collect representative samples from both areas*

Sample extraction

Soil Sampling SOP (Beaverlodge) – Heather and Jacy (2019)

Ideal:

- Use a truck-mounted hydraulic corer equipped with a soil coring tube (internal diameter ~7 cm)
- Cut the core into sample depth (e.g., surface litter; 0-15 cm, 15-30 cm, 30-60 cm, 60 cm+) in the field and place in labelled sample bags
- Use the same samples for SOC and bulk density determination

Sample extraction

A.J. Midwood

Reality:

- Site may not be accessible by truck; coarse fragments may prevent the use of a hydraulic sampler; soil structure may not be preserved (e.g., sandy, wet, dry or poorly aggregated)

  ** sample by hand using an auger or soil probe; collect separate samples for bulk density*

- Soil may fall out when using hydraulic corer

  **try a smaller (e.g., 5 cm internal diameter) sampling tube*

- Insufficient sample may be obtained by collecting soil in 15 cm increments

  **collect more samples for shallow depth increments*

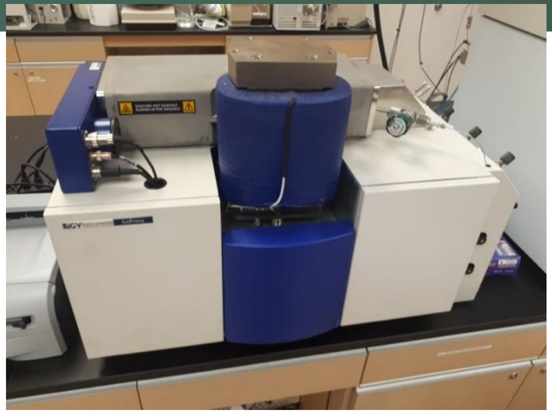
Sample processing & analysis

A.J. Midwood

Ideal:

- Dry, grind and sieve (2 mm) soil samples
- Use a riffle box or centrifugal sampler to extract aliquot of soil for SOC analysis
- Determine SOC using dry combustion; determine total N at the same time

Sample processing & analysis



A.J. Midwood

Reality:

- Coarse fragments & large roots (> 2 mm) are present
  **remove these during sieving, and record mass of both fractions*
- A riffle box or centrifugal sampler is not available
  **use 'cone and section' method*
- Not all carbon in the sample is organic:
  **pre-test sample pH (~6.5 cut-off) to identify samples where SIC is likely; determine SOC & SIC separately (e.g., acidification, two-stage combustion, calcimeter)*

Soil organic C stock calculations

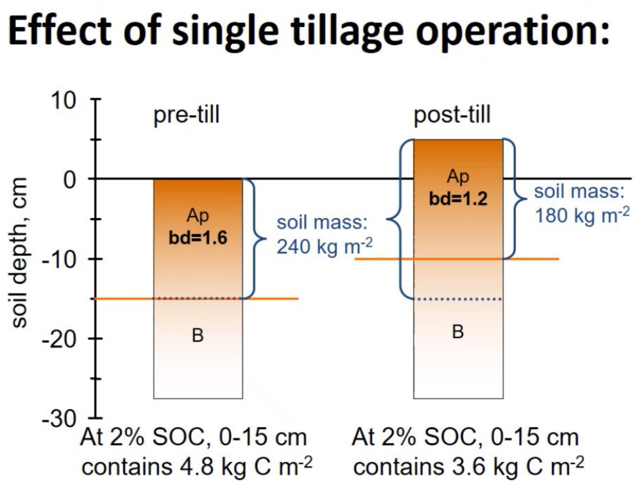
Ideal:

- Calculate SOC content (kg/ha) as bulk density (g/cm^3) x concentration of SOC (g/kg) for each depth increment
- Calculate SOC stock as the sum of the SOC contents for all depth increments

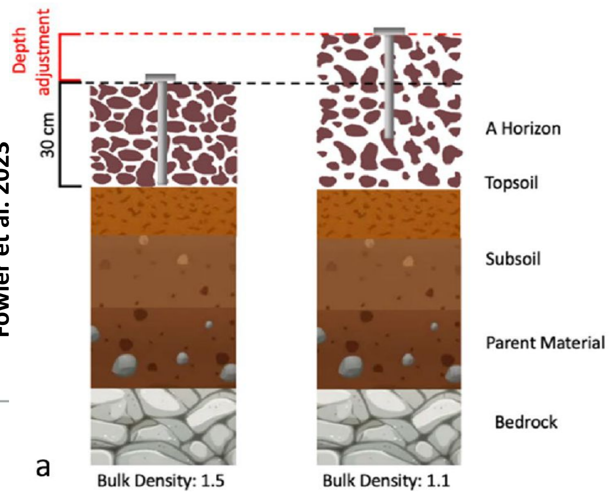
Soil organic C stock calculations

Reality:

- Coarse fragments & large roots (> 2 mm) can lead to over-estimation of SOC stock
  ** account for their presence during bulk density calculations*
- Differences in bulk density introduce inconsistency in soil sample mass
  ** use ‘equivalent soil mass’ calculation*



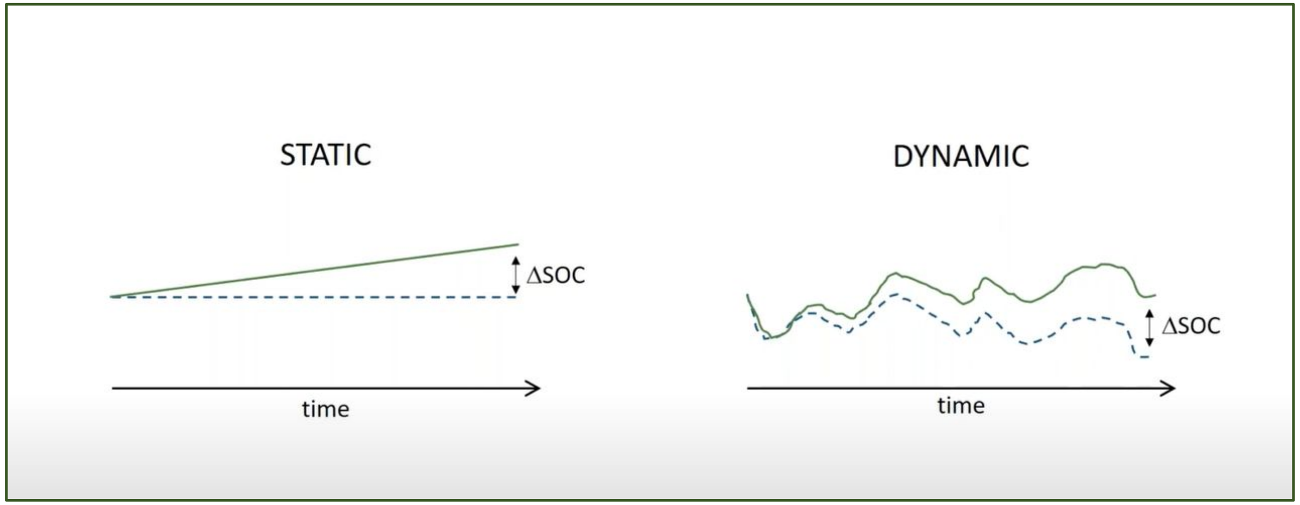
B.H. Ellert, pers. comm. 2022



Fowler et al. 2023

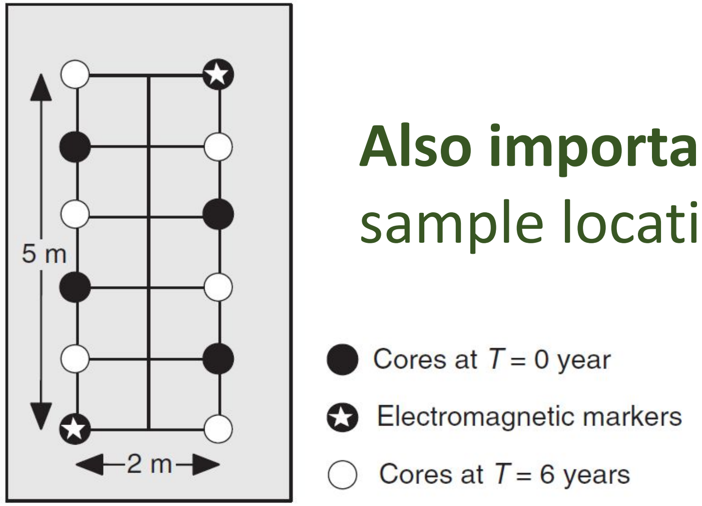
…and, repeat…

J. Sanderman, 2021



Important: Must re-measure both ‘control’ and ‘treated’ areas

Ellert et al. 2006



Also important: Sample close to original sample locations, but not too close…

An very incomplete list of great resources…

- Ellert et al. 2006. Measuring change in soil organic carbon storage. In: Carter and Gregorich (eds.) – Soil Sampling & Methods of Analysis. 2nd. Edition. CRC Press Taylor & Francis, Boca Raton, FL, Chapter 3.
- So many international protocols!!!
- Jonathan Sanderman Youtube: Measuring soil C: Emerging Approaches – YouTube

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.

Let’s discuss!