Developing a Field Evaluation of Soil Health (FESH) tool for New Brunswick

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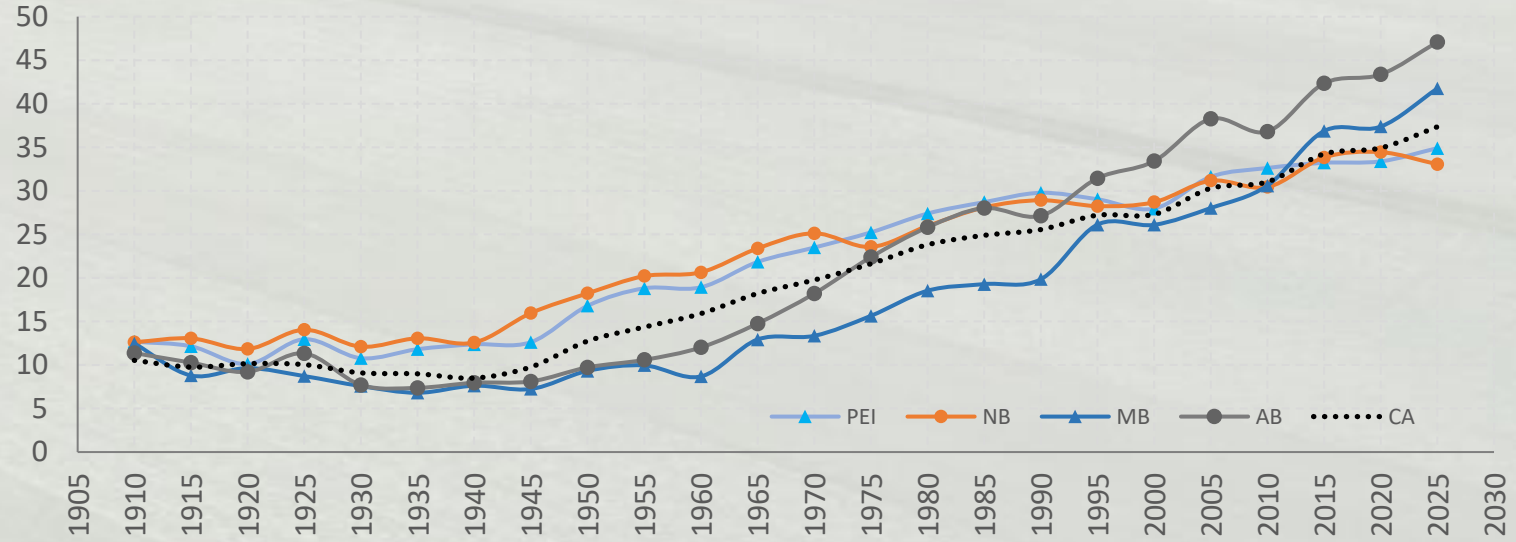
NEPTF 2025
Fredericton, New Brunswick
2025-3-13

Soil health

- Definition (much debated)
  - Soil health refers to the capacity of soil to function as a vital living ecosystem, sustaining plants, animals, and humans, and contributing to clean air and water, bountiful crops, and diverse wildlife.
- Why is it important?
  - Agricultural production
  - Environment
    - Soil, water, air
    - Biodiversity
- The reality in NB
  - Continuous decline
  - Stagnant potato yield

Five year average potato yield (Mg/ha) in major potato production provinces in Canada

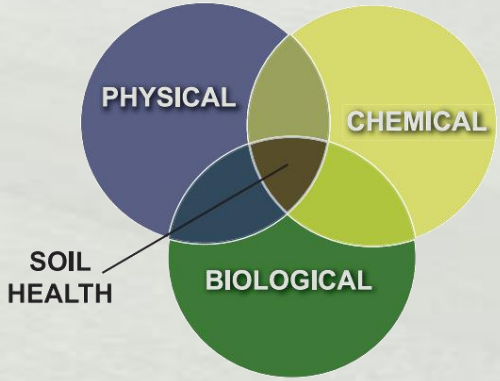


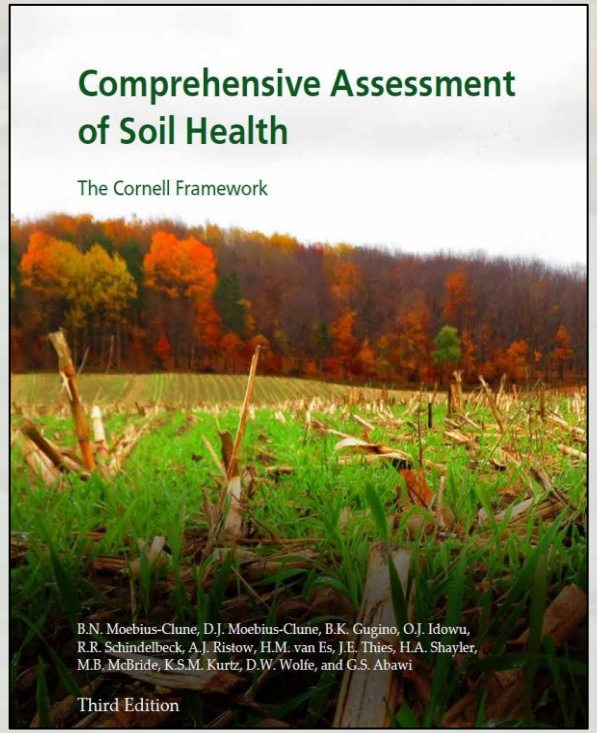
Evaluating soil health

- No standard method
  - Evolving concept
  - Advance in Science
- Most common structure
  - Soil Management Assessment Framework (SMAF)
  - Based on a set of measurable Soil Health Indicators (SHIs) / soil properties

Comprehensive Assessment of Soil Health (CASH)

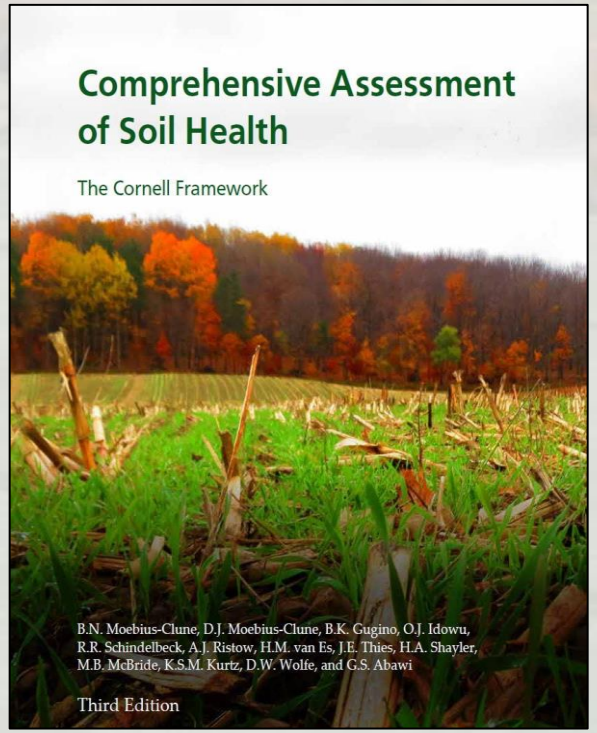
- General characteristics
  - Developed from SMAF
  - Widely used worldwide
  - Integrating three aspects of soil processes
  - Quantitative score system
- Strict protocol
  - Sampling requirements
  - Lab analysis
- Reliability
  - Accuracy
  - Representative
  - Repeatability





Challenges

- Cost
  - Direct cost of materials and supplies
  - Lab charges
  - Labour intensive
  - Personnel training
- Time
  - No instant results
  - May miss optimum measurement time
- Lack of reference
  - What is the norm
    - It is area, soil and crop specific
  - A low score does not necessarily mean bad soil health if that is the norm for that area



Objectives

- To develop a tool for soil health evaluation that
  - Based on low cost and simple field methods
    - A farmer with some training will be able to do it
  - Provide scores for different aspects of soil health
  - Provide regional reference scores
  - Can be used to track changes over time

Framework

- Soil Health Indicators (SHIs)
  - Following the structure of CASH
  - Select SHIs to reflect all three aspects of soil health
    - Indicative and important for soil health
    - Simple evaluation method available
  - Select evaluating methods for SHIs
    - Soil survey methods
    - Visual assessment methods
    - Can be done in the field
      - No lab analysis
    - Low-cost equipment or tools

Physical

Soil infiltration

Slope gradient

Slope curvature

Soil structure

Tillage layer

Soil strength (hardness)

Chemical

Soil carbon

pH

Biological

Emergence rate

Root development

Root coating

Earth worm activity

Mycelium development

Framework

- Scoring system
  - Score for each SHI
  - Average of SHI scores weighted by reliability and importance

Soil Health Indicator (SHI)	Method of measurement	Reliability	Importance	Variation	Best timing for measurement
Physical					
Slope gradient	Inclinometer (mobile app)	5	3	Long term	Any time
Slope curvature (position)	Inclinometer (mobile app)	1	3	Long term	Any time
Tillage layer (Ap) depth	Visual/Ruler				
Depth to restrictive layer	Visual/Ruler	3	5	Long term	Any time
Soil structure	VESS	5	5	Seasonal/long term	Early spring / Late fall
Soil strength (hardness)	Pocket penetrometer	3	3	Seasonal/long term	Early spring / Late fall
Soil infiltration	Infiltration ring test	3	3	Seasonal/long term	Early spring / Late fall
Chemical					
Soil organic carbon	Soil color (mobile app)	3	5	Seasonal/long term	Early spring / Late fall
pH	pH paper and pH meter	5	5	Seasonal/long term	Early spring / Late fall
Biological					
Emergence rate	Count/Visual estimate	3	3	Seasonal	Early growing season
Root length and density	Tape measure/Visual	3	5	Seasonal	Mid growing season
Root coating	Visual	1	3	Seasonal	Mid growing season
Earth worm activity	Count	1	5	Seasonal	Mid growing season
Mycelium development	Visual	1	3	Seasonal	Mid growing season

Framework

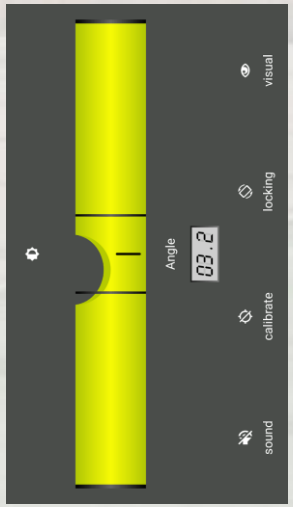
- Reference database
  - A set of maps or reference data tables for each SHI
  - The initial database
    - Based on existing database
      - National, provincial and local soil database
    - Only as a starting point
      - No need to be very accurate
  - Database evolution over time
    - Feedback from users' data - Citizen science
    - Statistical analysis
      - Average
      - Standard deviation
      - Percentiles
      - Maximum and minimum
    - The more it has been used, the better the reference

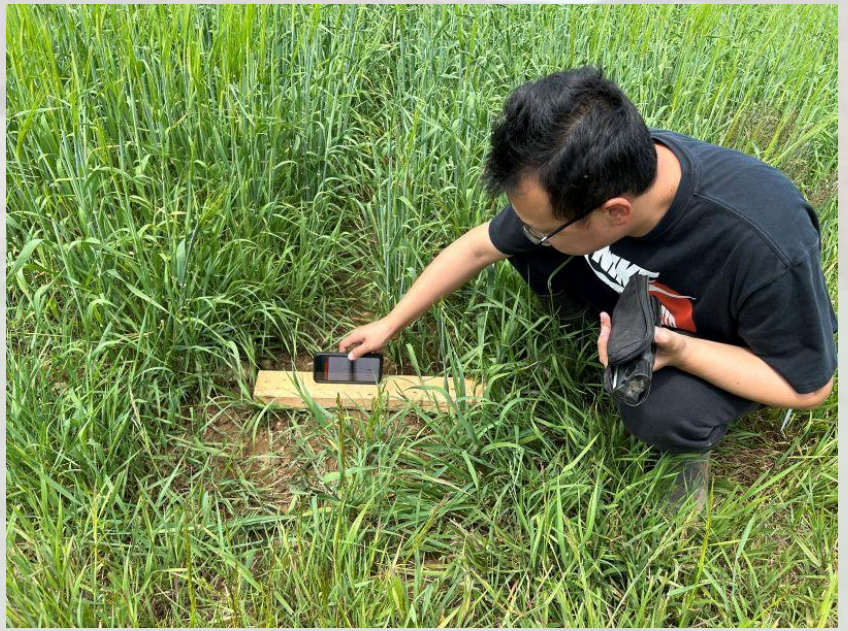
Current method

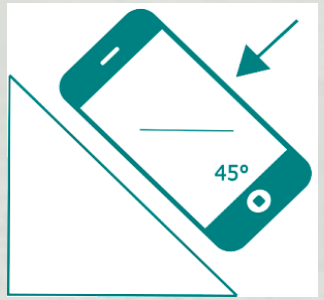
- Package of tools

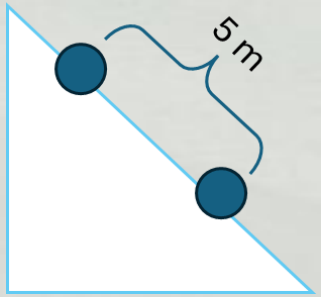
Topography

- FESH method
  - Cellphone app: Bubble Level
    - Android phone (Play Store)
    - iPhone (App Store)
- What is measured?
  - Slope gradient
    - Higher means higher water erosion
  - Slope curvature
    - Higher means higher tillage erosion



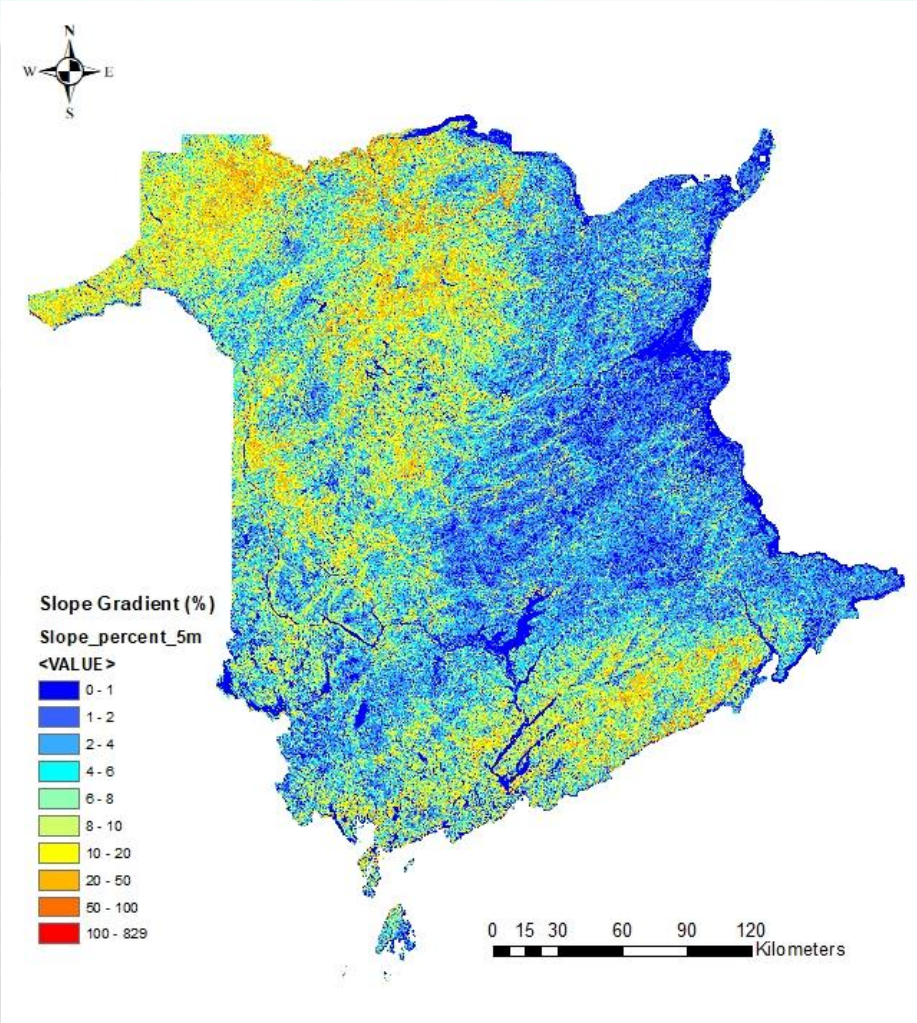






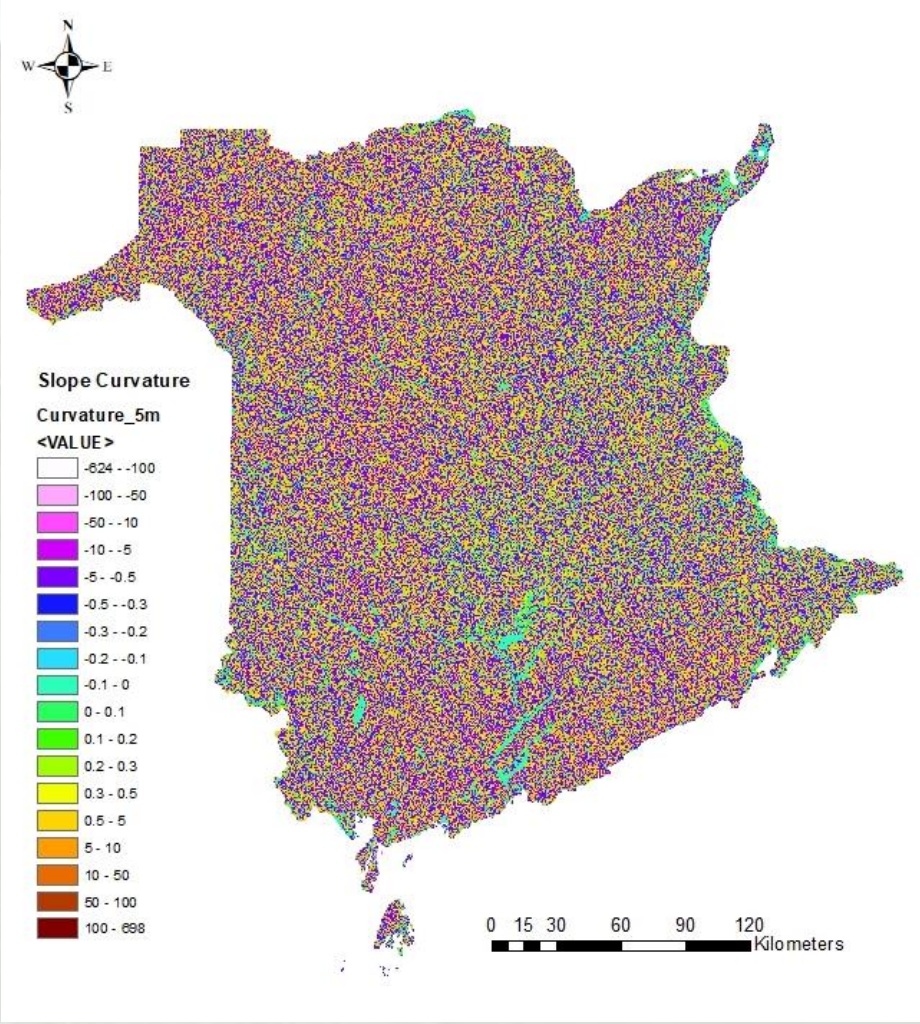
Slope gradient map

- Slope gradient Database
  - Slope gradient along the steepest slope direction
  - 5 m resolution
- Source
  - NB provincial GeoNB Lidar data
- Processing
  - Lidar DEM
  - ArcGIS slope tool



Slope curvature map

- Slope curvature Database
  - Slope curvature along the steepest slope direction
  - 5 m resolution
- Source
  - NB provincial GeoNB Lidar data
- Processing
  - Lidar DEM
  - ArcGIS slope tool

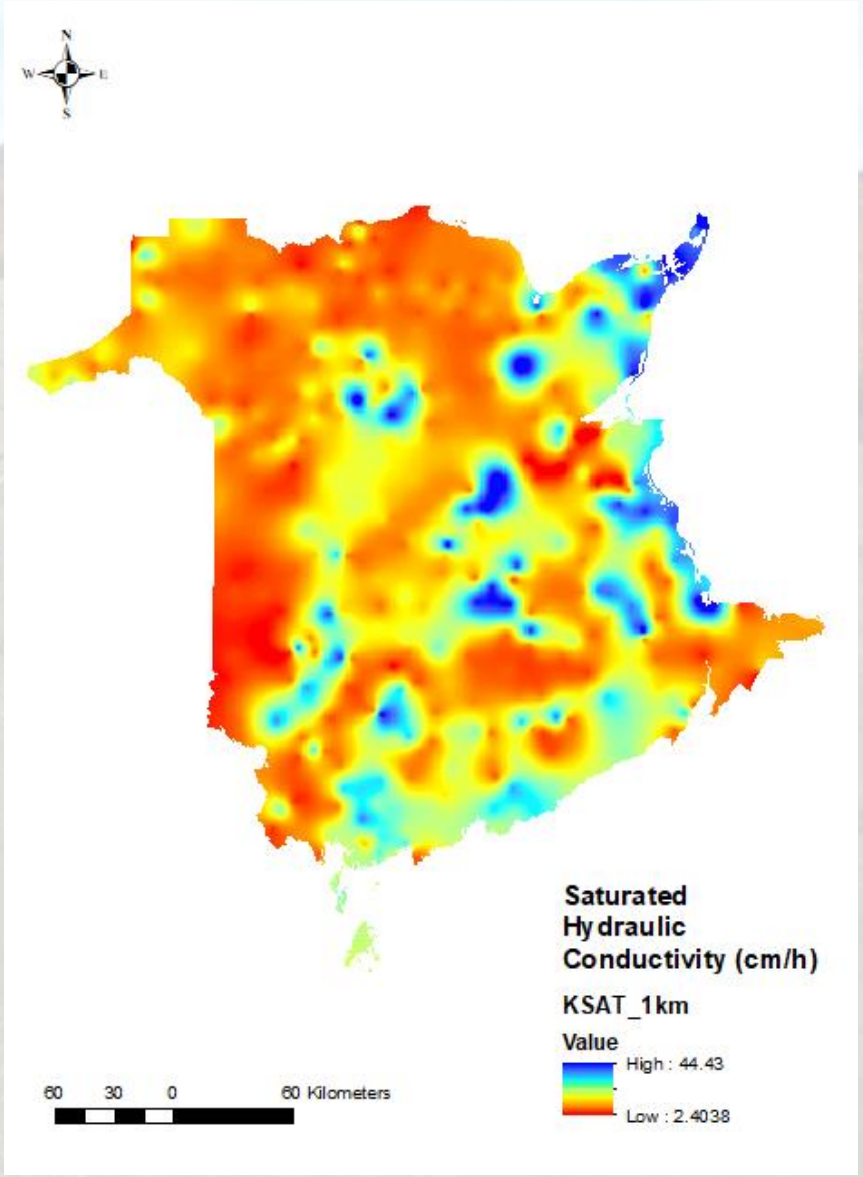


Soil infiltration

- FESH method
  - Single ring infiltrometer
  - Diameter of about 8.5 cm
  - 10 cm underground
  - Filling water until the infiltration rate is stabilized
- What is measured?
  - Infiltration capacity
    - Higher means better soil structure and lower risk for water erosion

Soil infiltration map

- Ksat Database
  - Hydraulic conductivity for saturate flow
  - 1000 m resolution
- Source
  - CanSIS (National Soil Database)
- Processing
  - Polygon based
  - Kriging interpolation



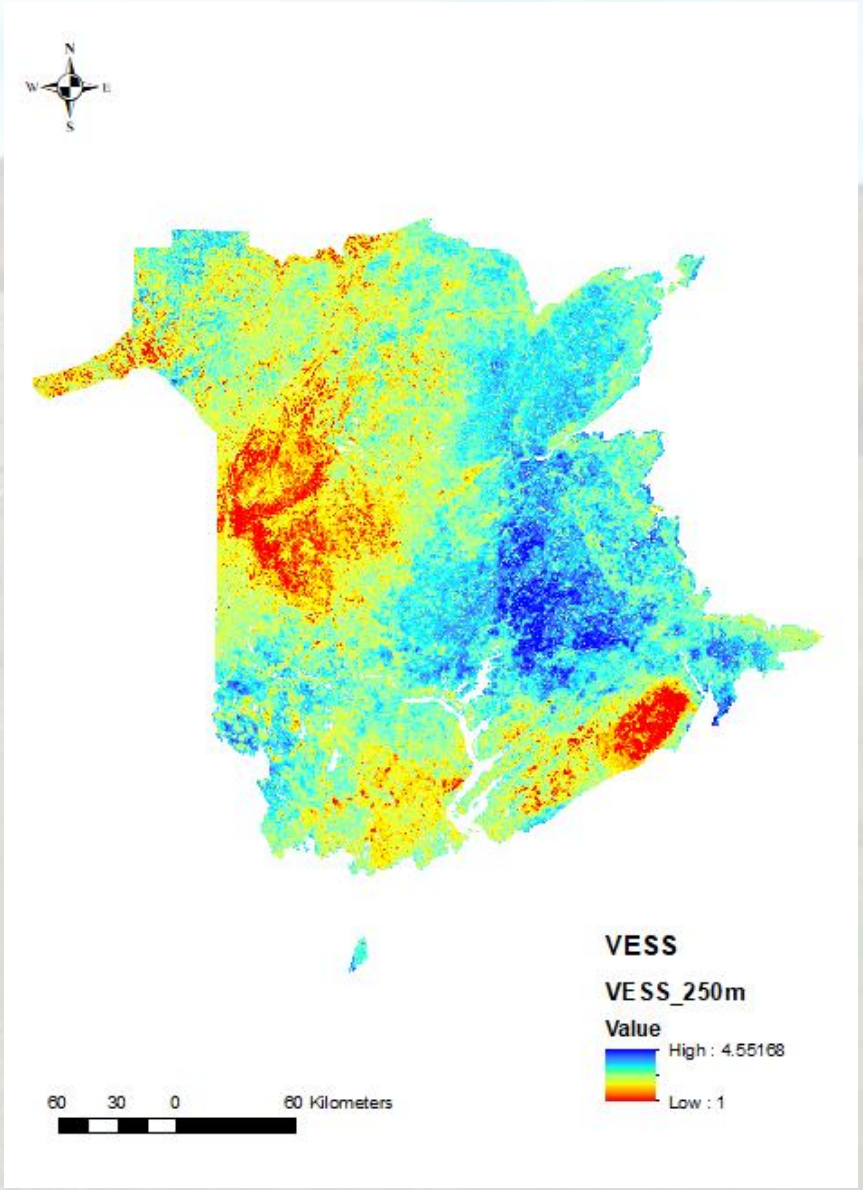
Soil structure

- FESH method
  - Visual Evaluation of Soil Structure (VESS)
    - Used widely in Europe
    - Visual assessment
    - Aggregate size, shape, strength
    - Pore size and distribution
- What is measured?
  - Soil structure score
    - Five classes
    - Higher score (lower class #) means better soil structured

VESS2020 version 09.06.2020	Layer appearance Aggregate/clod size	Appearence of intact aggregate/clod: Size	Appearence of intact aggregate/clod: Shape	Resistance [observe only in optimal moisture conditions, if not optimal refer to appearance after opening]	Opening (breaking) the clod	Appearance of opened aggregate/fragment size and shape	Appearence after "opening": Shape	Appearence after "opening": Porosity	Roots and color [root observation only possible on established crop]
Sq1 Very good (friable)		Mostly < 6 mm. [not relevant if recent tillage --> refer to shape instead]	**Crumbly.** Small rounded aggregates	readily crumble with fingers	porous clod: The whole clod can be colonized by roots. When 'opening' the clod, it does not break exactly where you want and for Sq1-2 seems to be composed of smaller aggregates.	1.5 cm	Large aggregates are composed of smaller ones, held by roots.	High intra-aggregate porosity	Roots within aggregates
Sq2 Good (intact)		From 2 mm to 7 cm [not relevant if recent tillage --> refer to shape instead]	Rounded aggregates. No clods present.	aggregates easy to break with one hand		6 cm	Opening reveals some smaller agregates and faces with rough structure	**High intra-aggregate porosity**	Roots within aggregates
Sq3 Moderate (firm)		From 2 mm to 10 cm. Less than 30% are <1 cm.	Mixture of various sizes of rounded aggregates. Possibility of some angular non-porous clods	most aggregates break with one hand	non-porous clod: massive structure, roots cannot grow freely, they are restricted. When 'opening' the clod, it breaks exactly where you want or along cracks and reveals flat faces.	rough faces	Opening reveals faces which are **more or less rough**. Possibly some areas with flat faces	Low intra-aggregate porosity. Some macropores and cracks may be present.	Few roots but mostly within aggregates.
Sq4 Poor (compact)		Mostly large >10 cm. Less than 30% are < 7 cm.	Sub-angular clods. With posible sharp edges.Horizontal/platy structures or cracks also possible.	requires considerable effort to break clods with one hand		13 cm; distinct macropores; flat face	Opening a clod reveals rather flat faces.	Very low intra aggregate porosity. Distinct macropores	**Roots usually clustered in macropores and cracks**. Or around non-porous clods
Sq5 Very poor (very compact)		Mostly large >10 cm.	Angular clods. Sharp-edged and non-porous.	difficult to break up		angular edges; 15 cm; restricted roots	Opening a clod reveals flat angular faces. **Possible to make sharp edged cubes**	No intra-aggregate porosity.If some pores present, then restricted to a few macropores	Anaerobic zones with **grey-blue color possible**. Few roots, if present restricted to cracks

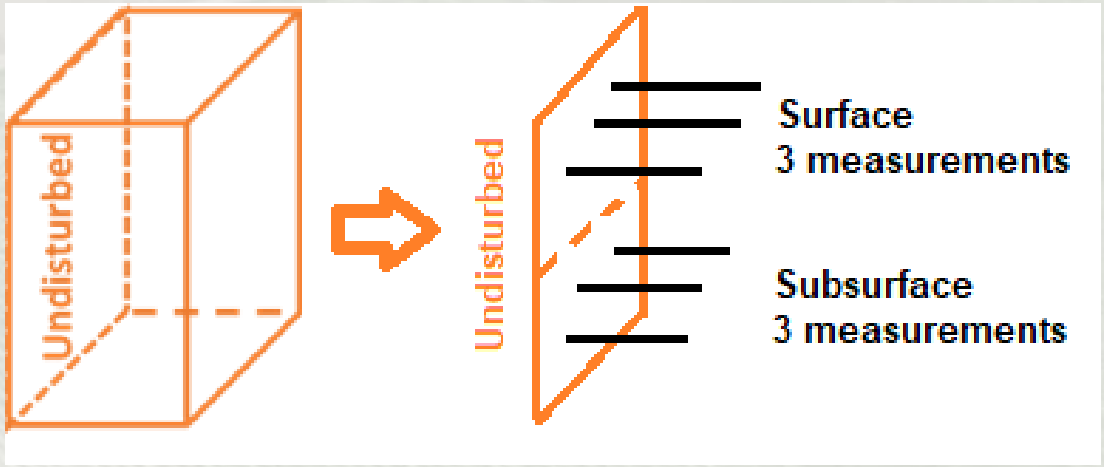
Soil structure score map

- Soil structure score database
  - Calculated from soil bulk density using a pedotransfer function (PDF)
  - 250 m resolution
- Source
  - Bulk density data
    - CanSIS_PSM_2024
  - PDF from Guimaraes et al., 2013
- Processing
  - ArcGIS tool (Raster calculator)



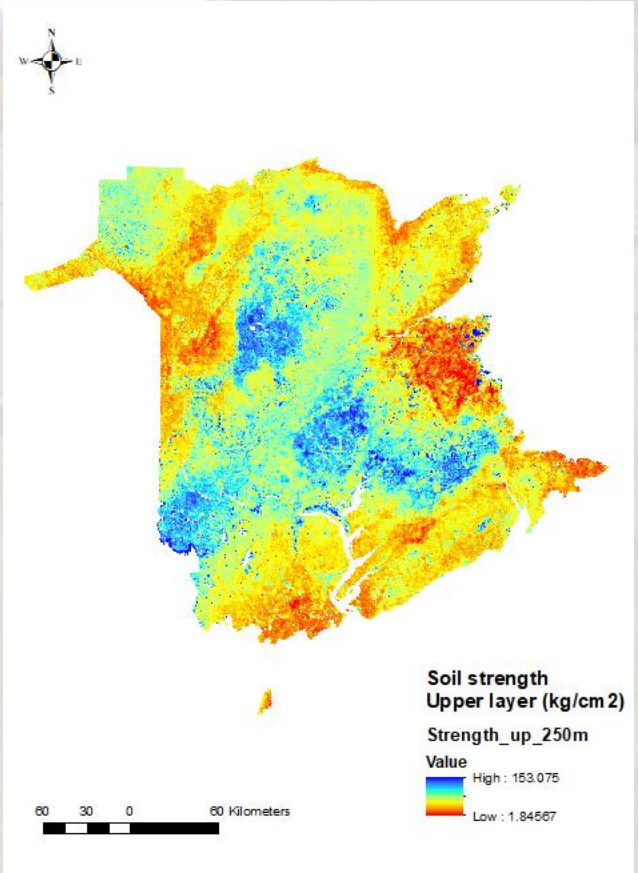
Soil strength

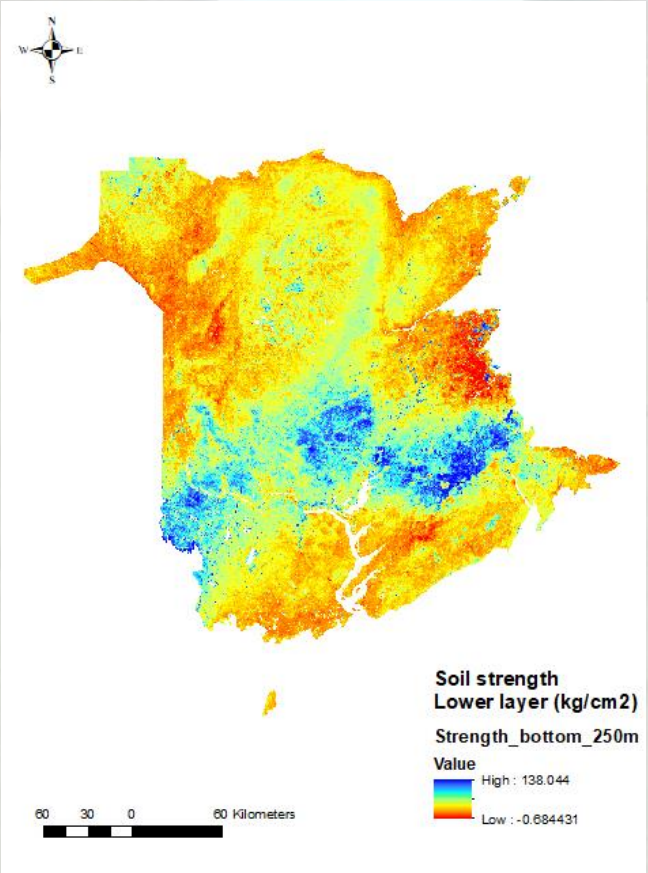
- FESH method
  - Pocket penetrometer
- What is measured?
  - Soil resistance to penetration
    - Higher value means more compacted soil and thus more difficult for root growth



Soil strength map

- Soil strength database
  - Calculated from SOC, soil bulk density and texture using a pedotransfer function (PDF)
  - 250 m resolution
- Source
  - Soil data
    - CanSIS_PSM_2024
  - PDF from Lardy et al., 2022
- Processing
  - ArcGIS tool (Raster calculator)





Soil organic carbon

- FESH method
  - Cell phone image with a reference color plate
  - Method developed in house
- What is measured?
  - Soil color
    - Mussel soil color value is higher for soil with higher organic carbon content
    - Soil organic carbon is one of the most important indicators for soil health

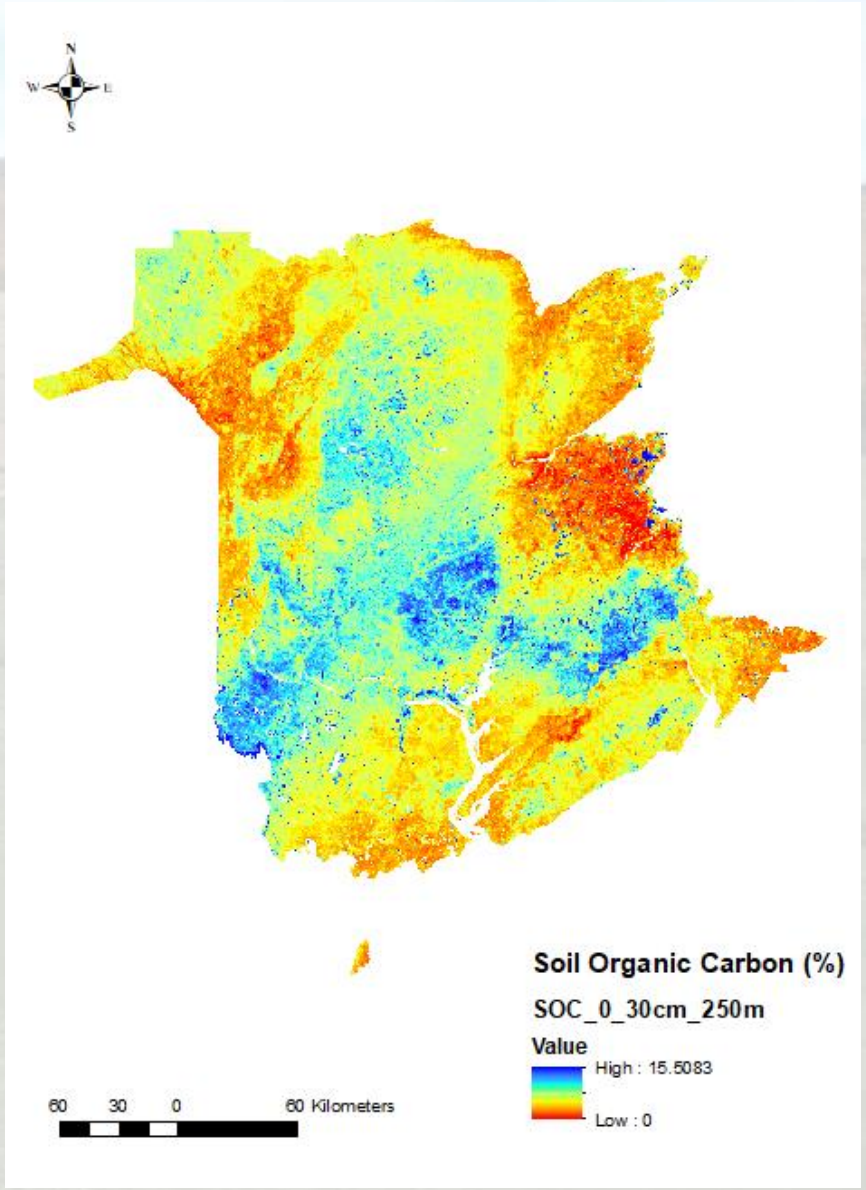
Color Parameters

Established Regression

Soil Organic Carbon

Soil organic carbon map

- Soil organic database
  - Existing database
  - 250 m resolution
- Source
  - CanSIS_PSM_2024
- Processing
  - ArcGIS tool (clip for NB)

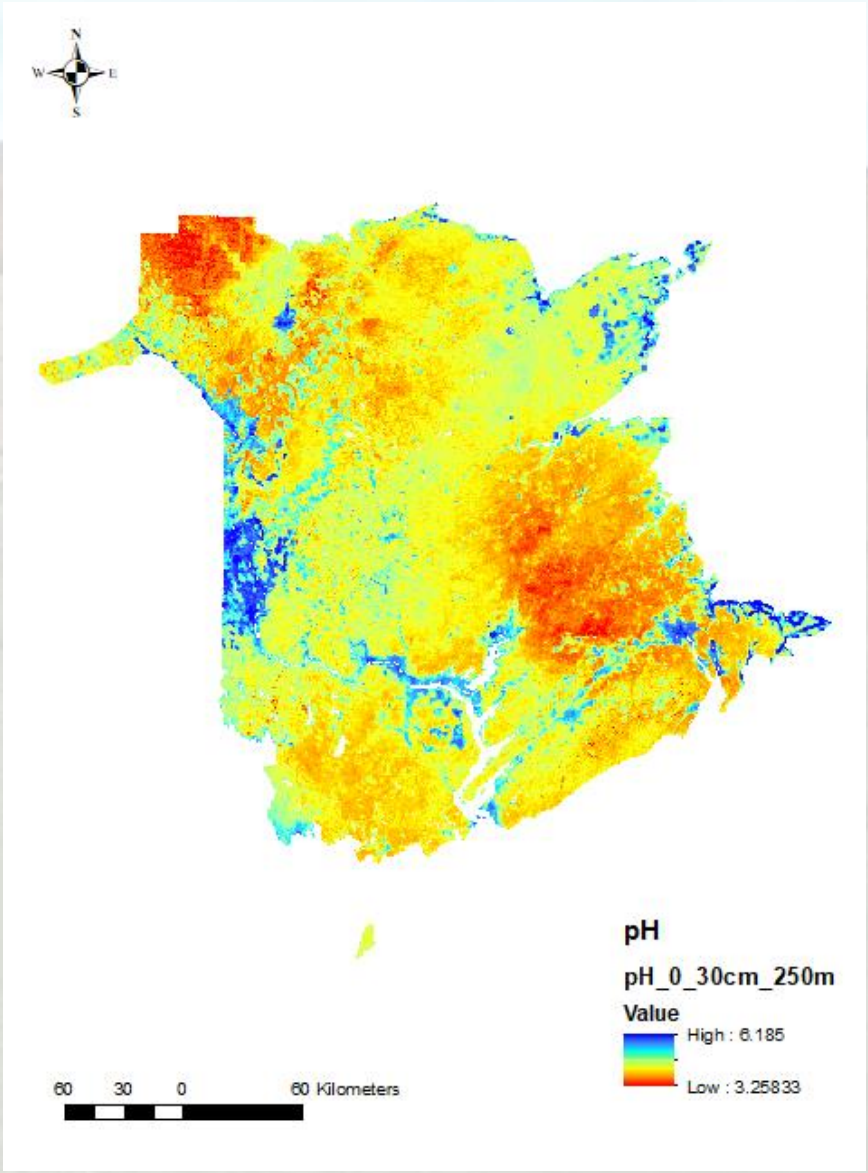


Soil pH

- FESH method
  - Soil pH sensor
    - Tested multiple soil sensors
    - S-1
    - SONKIR and TAKEMURA not good
- What is measured?
  - Soil pH
    - 6.0 – 7.0 suitable for most crops
    - Potato likes acidic soil: 5.5 – 6.0
    - Soil are getting more acidic due to natural processes and farming practices such as the use of fertilizer
    - Liming may be needed with soil pH lower than 5.5

Soil pH map

- Soil organic database
  - Existing database
  - 250 m resolution
- Source
  - CanSIS_PSM_2024
- Processing
  - ArcGIS tool (clip for NB)



Plant emergence rate

- FESH method
  - Visual assessment
- What is measured?
  - Portion of sown seeds that successfully develop into seedlings and emerge from the soil
    - Better soil health will result in higher emergence rate
- Reference
  - No data yet
  - Plant type and variety dependent
  - May be obtained when purchasing seeds

Crop yield

- FESH method
  - Farmers records
- What is measured?
  - Crop yield
    - Better soil health will lead to higher yield
- Reference
  - No data yet
  - Crop dependent
  - Can be estimated based on long term farm record

Earthworm activities

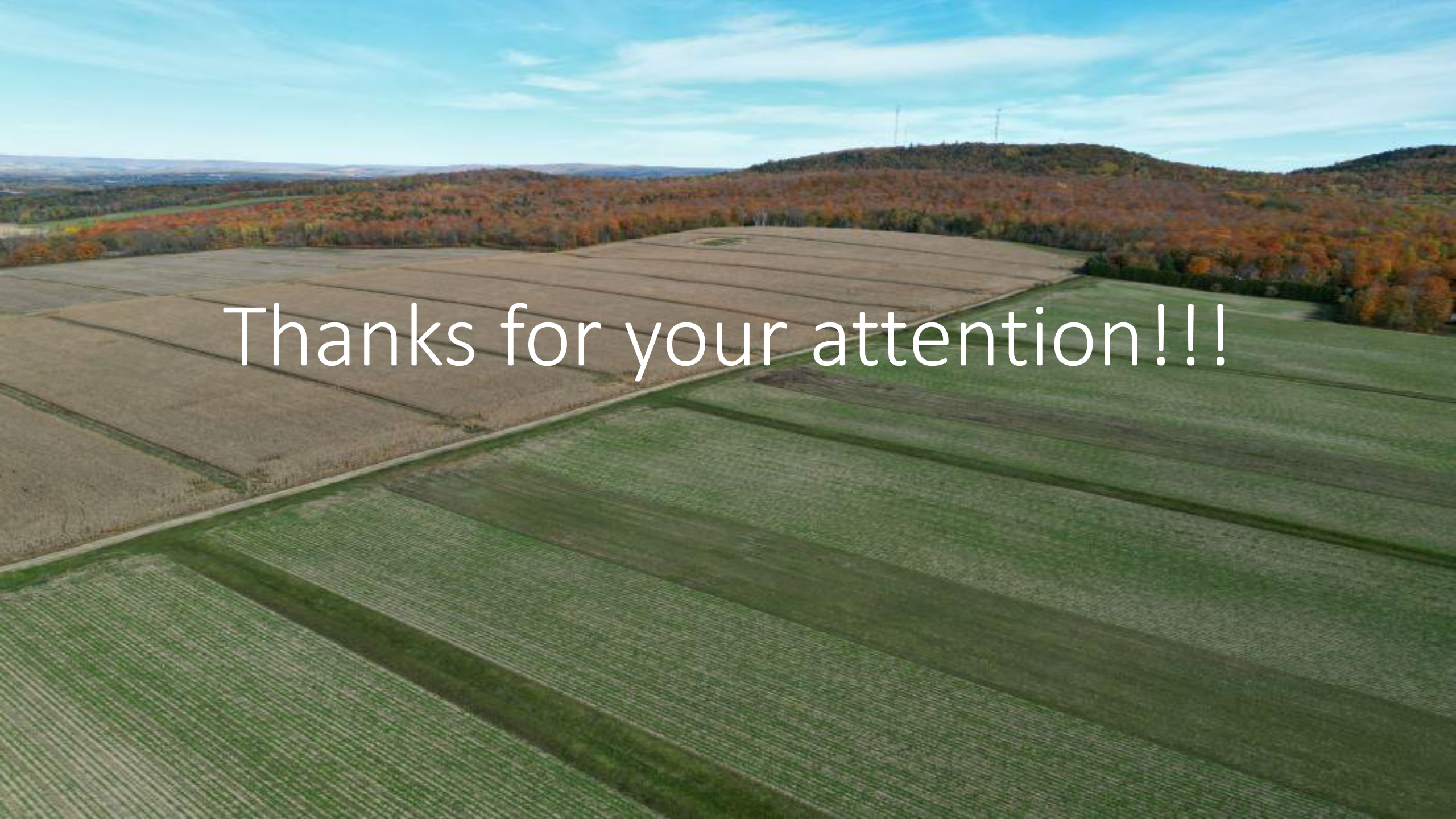
- FESH method
  - Visual assessment
- What is measured?
  - Number of earthworms in a soil block
  - Signs of earthworm activities
    - Better soil health will lead to more earth worm activities
- Reference
  - No data yet
  - Can be estimated using a pedotransfer function on soil bulk density and soil organic carbon and pH

Next steps

- Method verification and validation
  - Testing in different areas
  - Standard Operation Procedures
- Reference databases and maps
  - Enhance and complete the initial maps and databases
  - Update the data with data from field measurement with the FESH tool
- Develop an online tool or cell phone app for collecting user data

Acknowledgement

- Funded by the EARI program of NB-DAAF
- Other contributors and collaborators
  - Sylvie Lavoie
  - Alex Koiter
  - Louis-Pierre Comeau
  - Ray Carmichael
  - Cedric MacLeod
  - David Lobb
  - Charles Karemangingo


Thanks for your attention!!!