Digital soil mapping of changes in active and total soil carbon (soil organic matter) in Truro, Nova Scotia

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Key points

- The study was conducted in the $37km^2$ landscape, surrounding the Dalhousie University Agricultural Campus farm.
- The goal was to digitally model/map (10m spatial resolution) and monitor the changes in soil total organic carbon (TOC) and active carbon (POXc) from 2015 to 2019.
- Crops were comprised of pastures, forages, corn, soybean, and small grain cereals; and soils ranged from sandy to silty (dykeland).
- Remotely-sensed data (LiDAR for topography and Landsat imagery for soil and vegetation) was combined with AAFC crop inventory data to develop the predictive model.
- Targeted soil samples were collected and analyzed to develop and validate models.
- Compared to the cropping system, soil texture and topography did not influence TOC or POXc.
- TOC ranged from 1.2% to 4.2% (~2% to 7% organic matter) and active carbon (POXc) from 310 to 892 ppm and both were highest under pasture and forages.
- Over time, losses in TOC and POXc (27% and 65% of the study area, respectively) were usually associated with annual cropping fields.

Background

Soil organic carbon (soil organic matter) plays a vital role in climate change mitigation and adaptation. However, the levels of soil organic carbon are declining across many agricultural sectors in Eastern Canada due to the increasing intensity of cropping. Perennial crops, such as forages are less frequently included in rotations, and important cash crops, such as potatoes and soybeans, leave behind very little residue to sustain soil organic matter levels.

Soil carbon is also the keystone element to sustaining soil health as it influences many soil physical, chemical, and biological properties. Changes in TOC, however, can be challenging to detect in the short term, and measurements of the more-dynamic 'active' soil carbon pools are useful additional approaches in soil health assessment.

New tools are needed to efficiently characterize the spatial patterns and track the changes of soil carbon and soil health across farm-scale landscapes. Digital soil mapping (DSM) is an important new tool for predicting the spatial patterns of soil properties (including soil carbon) at various spatial and temporal scales. By leveraging advancements in computing technologies, DSM combines data from remote sensing (e.g. topography, land use, and crop inventories) along with georeferenced soil samples to efficiently produce soil maps that are more accurate and precise than what is currently available.

Study objectives:

- Digitally map (at 10m spatial resolution), and model, the changes in soil organic carbon and active carbon from 2015 to 2019 across the $37km^2$ landscape centered around the Dalhousie University Agricultural Campus farm (Fig. 1)

- Identify the relative influence of soil type, topography, and crop management history on soil organic carbon and active carbon.

Figure 1. Satellite image of the $37km^2$ study area near Truro, Nova Scotia (Image source: Google Earth).

The Approach

Several types of remotely sensed data were collected including:

LiDAR data. Light detection and ranging (LiDAR) topography mapping at a 10m resolution provided data on local elevation, slope, aspect, etc.

Landsat data. Landsat satellite data on soil and vegetation was collected from multiple time steps (pre-, during-, and post-growing season in both years)

Crop Inventory. Data on crop rotations from 2012 to 2019 were taken from Agriculture and Agri-Food Canada's Annual Crop Inventory (30m resolution)

Soil sampling and lab analyses. Soil samples (0-15cm) were collected across all crop types in 2019, and again in 2020 (Fig. 2).

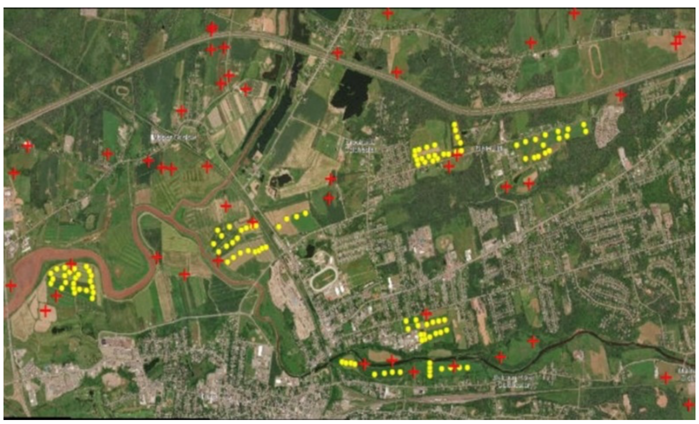

Figure 2. Soil sampling locations in 2019 (yellow) and 2020 (red).

Soil samples were analyzed at the Atlantic Soil Health Lab, Faculty of Agriculture, Dalhousie University for total organic carbon (by automated dry combustion) and active carbon (POXc; by mild oxidation with potassium permanganate).

Active carbon (POXc) is considered a sensitive soil carbon fraction (and soil health indicator) that can respond more readily to management practices in comparison to TOC.

The soil data was used to train and validate the digital maps of TOC and active carbon. The temporal changes in both soil parameters were then calculated.

Results

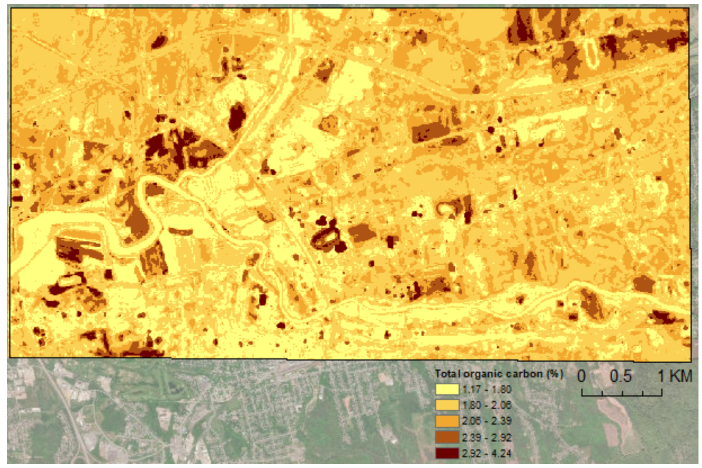

Figure 3. Distribution of total organic carbon in 2019

- Compared to cropping history, soil texture and topography did not influence TOC or POXc.
- TOC ranged from 1.2% to 4.2% (~2% to 7% organic matter) (Fig. 3) and POXc from 310 to 892 ppm, and both were highest under pasture and forages.
- The TOC predictions were more accurate than the POXc predictions.
- 72% of the study area observed no-change in TOC during the study period, while 27% lost and 1% gained TOC. In contrast, POXc was more dynamic with losses and gains of 65% and 33%, respectively.
- Annual crop fields exhibited the most losses in TOC and POXc.
- The findings highlight that POXc is more sensitive to changes in land use and agricultural management—even during a short period.
- The study demonstrates the application of DSM techniques for monitoring both TOC and POXc and the maps will facilitate effective soil organic matter and soil health management.

Author Affiliations and Funding Acknowledgements

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Funding for this project was provided by the Agricultural Greenhouse Gases Program of Agriculture and Agrifood Canada.