The State of Soil in Atlantic Canada and How can it be Improved

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The state of agricultural soils in Atlantic Canada

I have chosen to focus on the soils of Atlantic Canada in my submission as I believe these are the soils that are in greatest peril with the greatest potential to impact the rural economy and the environment. Much of what I will present also has relevance to other areas of Eastern Canada.

Soil organic matter or soil carbon is a critical indicator of soil health. The loss of soil carbon not only represents the transfer of CO_2 to the atmosphere, contributing to climate change, but also a critical decline in soil function resulting in a decline in productivity. As we look for technologies to remove CO_2 from the atmosphere, we should not forget plants. Plants are the ultimate system for carbon removal from the atmosphere and soil the ultimate storehouse for that carbon.

The organic matter contained in soil is critical to physical, chemical, and biological function. Canada's Agri-Environmental Indicator Series (Clearwater et al., 2016) documents the decline in soil carbon in Atlantic Canada, in many cases greater that 1.2 tonnes ha^{-1} over the past 30 years (Fig. 1). Direct measurement of soil carbon over an 18-year period in the PEI Soil Quality Project conform these finding, documenting that over 56% of PEI's landbase has suffered a 1% decline in SOM, corresponding to a loss of 0.5 tonnes C ha^{-1} y^{-1}.

This decline has resulted from the shift from forest to agriculture, perennial to annual crops and increased intensity of tillage. These practices have decreased the length of time plants are actively growing in and on the soil and greater disturbance of their root systems, the primary builders of soil organic matter. Not surprisingly this has translated into a decrease in the productivity of our soils and increased impacts on the surround air and water.

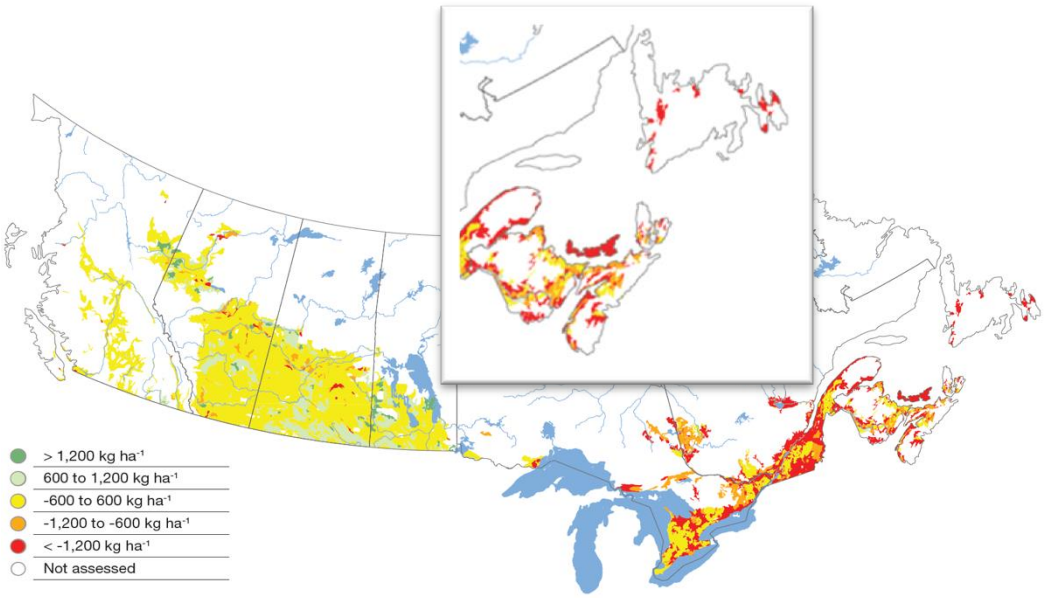


Figure 1: Cumulative SOC change (kg ha^{-1}) from 1981 to 2011 due to land-use changes (e.g. forest to agriculture) and shifts between annual and perennial crops (Clearwater et al., 2016)

The loss of productive capacity of soil due to its degradation and its impact on the environment

The potato industry in Atlantic Canada provides an excellent example of the toll intensive cropping systems can take on soil and the sorts of innovative solutions we need to make these systems more sustainable and resilient to climate change. One of the impacts of declining soil health in Atlantic Canada is that potato yields have stagnated over the past three decades (Fig. 2), placing the Atlantic Potato industry at an economic disadvantage.

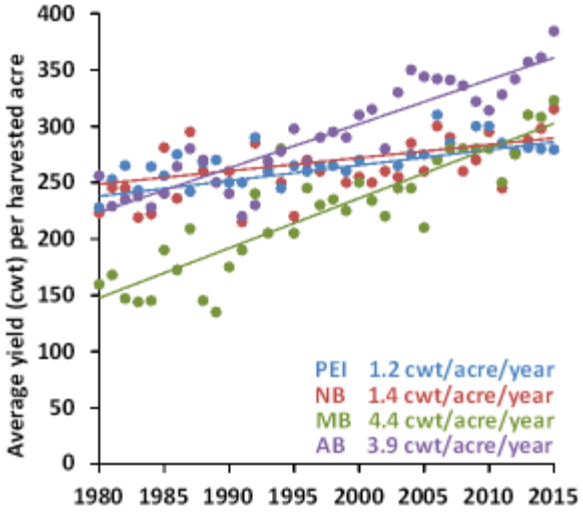


Figure 2: Change in potato yield by province over the past 35 years (Statistics Canada).

Another symptom of the poor health of the soils in Atlantic Canada is the accumulation of nutrients, particularly nitrogen. In Atlantic Canada the majority of nitrogen losses occur during the non-growing period – from October to May. Nitrogen management practices that limit the amount of nitrate that remains in the soil following the growing season (Residual Soil Nitrogen) will reduce both overwinter nitrous oxide emissions as well as nitrate leaching to groundwater. Residual soil nitrogen has been increasing and is high to very high through much of Atlantic region (Fig. 3).

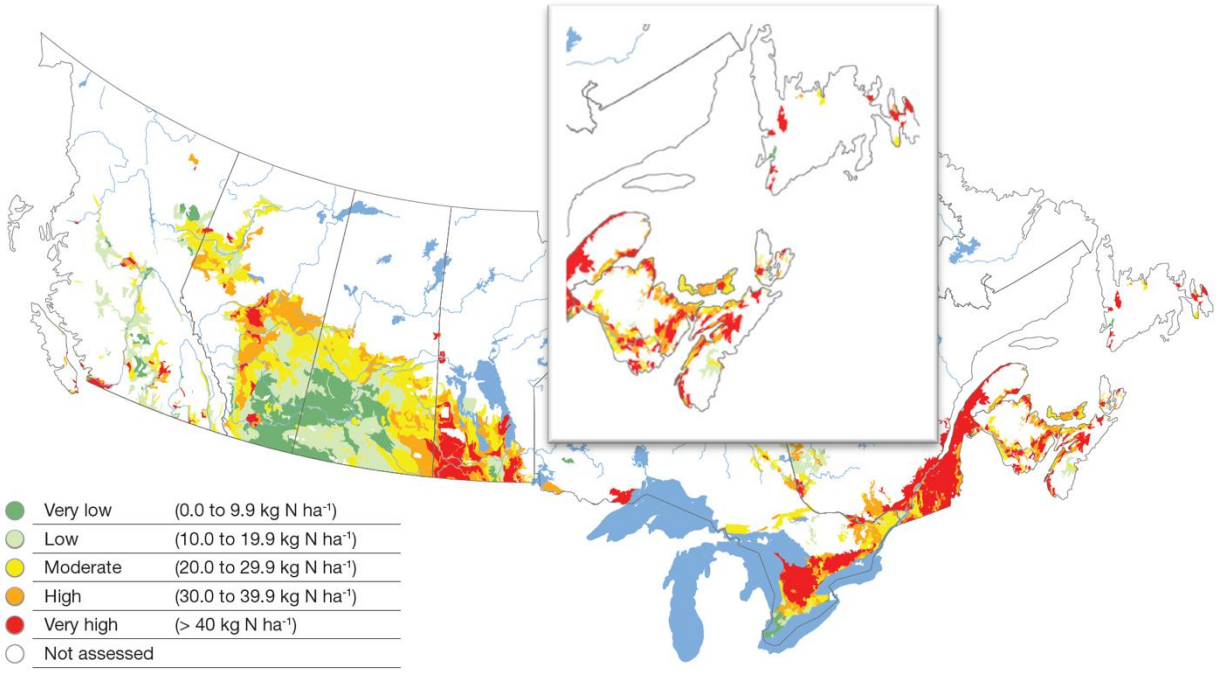


Figure 3: Residual Soil N (RSN) levels on Canadian farmland in 2011 (Clearwater et al., 2016).

Cropping Systems and Soil Health

Over the past several years at Dalhousie we have been surveying health of soils in Atlantic Canada to determine their current state and to identify management practices that can improve soil health. Some of the cropping practices which can lead to increased soil organic matter include:

- Keep the soil covered – Soil should never be bare. There should always be a plant growing, taking up nutrients, releasing root exudates, feeding microbial populations, slowing water runoff, holding soil aggregates together. The use of extended rotations with more frequent perennial crops improves soil health.
- Reduce or eliminating tillage – Tillage disrupts soil aggregates and exposes soil organic matter to decay by microorganisms. Reducing the frequency or intensity of tillage will reduce the decay of existing soil organic matter and therefore reduce its rate of decline.
- Return organic matter to the soil – Soil organic matter contents can be increased by practices that return organic residues to the soil such as crop residue management, choice of crops with extensive root systems, the application of animal manure, compost and other organic wastes.

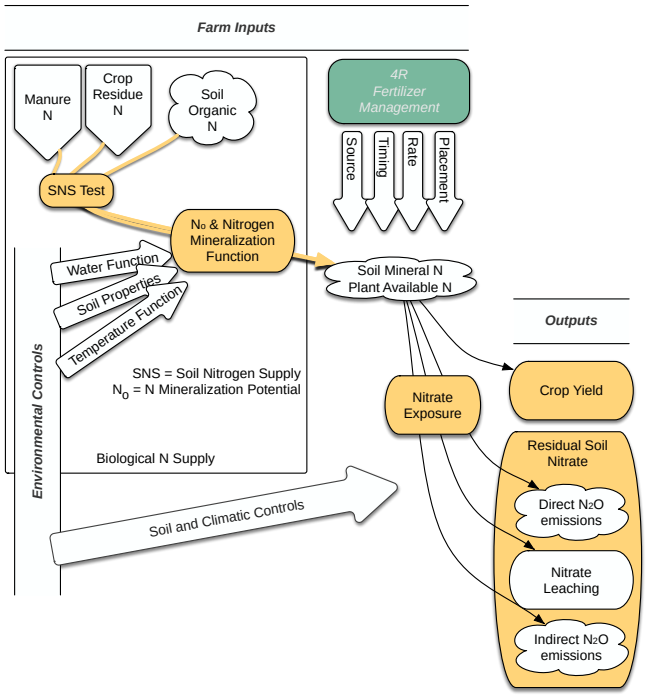
Nutrient stewardship

Increasing nutrient use efficiency in agriculture is of agronomic and environmental importance. The fertilizer industry has shown leadership in their development of "4R Nutrient Stewardship". This approach focuses on the selection of the **R**ight product, applied at the **R**ight rate, at the **R**ight time in the **R**ight place to increase nutrient use efficiency.

The emissions of N_2O from agricultural soils in Atlantic Canada are closely tied to the accumulation of nitrate (Burton et al., 2008; Zebarth et al., 2008). Providing for plant N requirements while limiting nitrate accumulation in soil requires an understanding and quantification of soil N supply. Over the past decade we have been developing tools to measure the N supplying capacity of soils and to predict the impact of climate on soil N supply (Dessureault-Rompre et al., 2015; Dessureault-Rompre et al., 2011; Dessureault-Rompre et al., 2012; Nyiraneza et al., 2012).

The Need to Measure

One of the reasons why we find ourselves in this situation is that we are no longer measuring and reporting the state of our soil resources. A focus on the commodities produced by agriculture resulted in a neglect to ensure that the resources producing those commodities are being sustained. The agri-environmental indicators presented here are largely the result of simulation modeling based on activities reported in the Agricultural Census and not a result of direct measurement. We need to increase our direct measurement of the state of our soils and use that information to inform our management of those soils. This



information will be critical to identify areas of concern and documenting solutions. As an example, we have developed a means of assessing the biological soil nitrogen supplying capacity of soils in Atlantic Canada. Our approach involves three elements:

1. *Soil Nitrogen Supply Test* – Measurement of the soil's ability to supply nitrogen and the status of the soil resource
2. A *nitrogen mineralization function* that considers the impact of climate on nitrogen mineralization
3. Measuring of the risk of nitrogen loss (*nitrate exposure*) that tracks how well nitrogen supply and plant nitrogen demand are synchronized.
4. Measurement of residual soil nitrogen
[5]

These four elements are integrated into an overall framework that considers all N sources and climatic factors in influencing crop yield and potential environmental impacts (Fig. 4).

Figure 4: Framework for developing site-specific, right rate N recommendations (Burton, 2011).

It is not enough to know what we s*hould be doing* – we need to ensure that producers have the *means to do* them. The international market for agricultural commodities does not reflect the value soil stewardship and thus it is difficult to past the costs of soil conservation on to the consumer. Various food industry lead initiatives such *Field to Market* have to the potential to provide this mechanism but is not clear that primary producers have a strong voice in their development. The costs of the sustainable management of our soils cannot be borne solely by the producer. Society at large and consumers in particular must embrace the true cost of sustaining our food production system. There is a need for government policies to support producers in these efforts. Policy tools such as the Nitrous Oxide Emissions Reduction Protocol (NERP) create tradeable credits for practices that reduce nitrous oxide emissions and they are critical in encouraging the adoption of this innovative approaches and must be recognized in "carbon" policy.

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