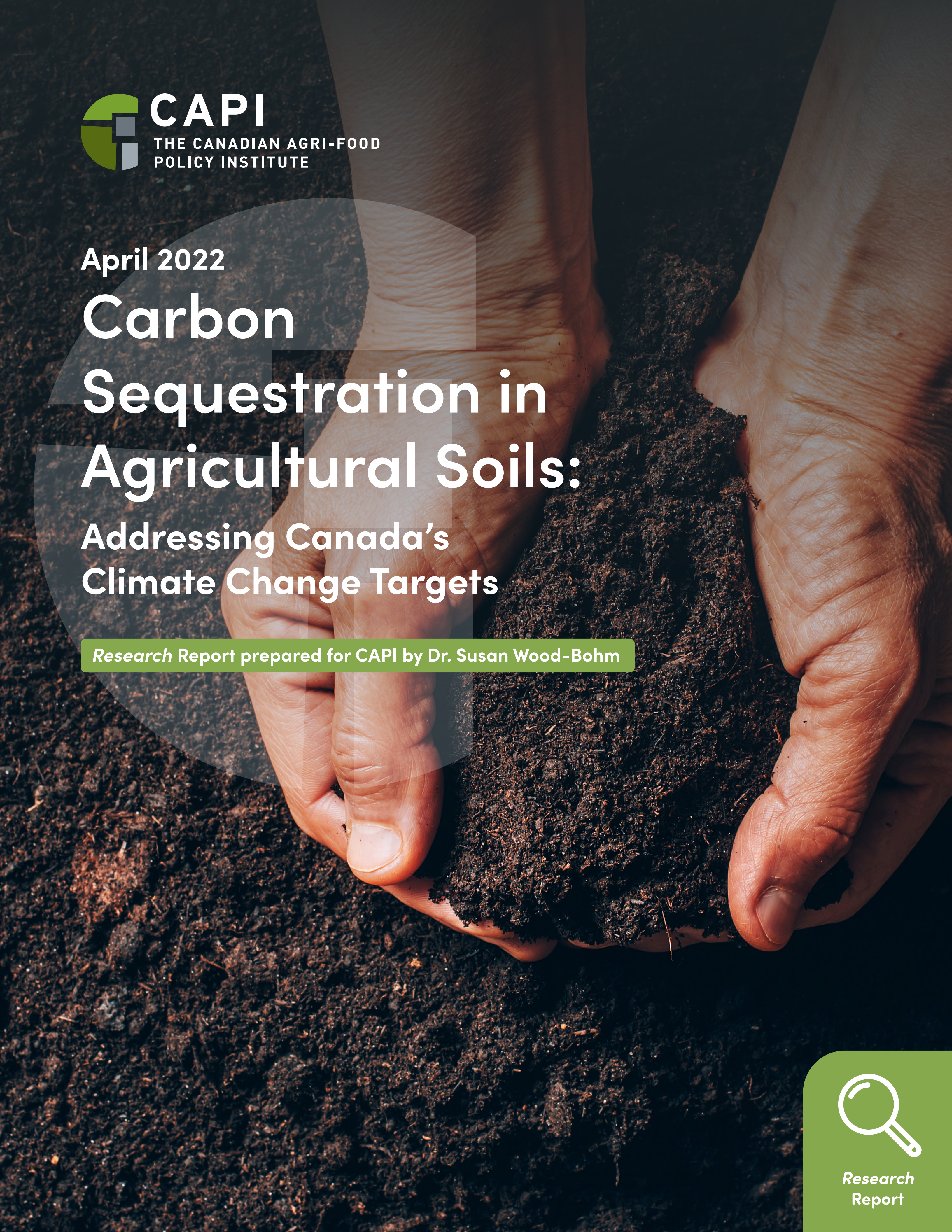

CAPI
THE CANADIAN AGRI-FOOD POLICY INSTITUTE

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Carbon Sequestration in Agricultural Soils:

Addressing Canada's Climate Change Targets

Research Report prepared for CAPI by Dr. Susan Wood-Bohm

Research Report

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This report is sponsored in part by the RBC Foundation and part of CAPI's larger environmental initiative, **Spearheading Solutions: Helping Farmers Operate Better, Smarter and Environmentally Sustainably**. This initiative aims to leverage public and private policies to aid in the rapid adoption of beneficial management practices, increase the implementation of new tools and technologies to maximize environmental and social outcomes.

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A Note from CAPI

This paper presents a segment of the CAPI Distinguished Fellowship work on sustainable intensification, which was led by Dr. Susan Wood-Bohm and sponsored, in part, by the RBC Foundation and part of CAPI's larger environmental initiative, Spearheading Solutions: Helping Farmers Operate Better, Smarter and Environmentally Sustainably.

The paper lays out the essential aspects of how carbon is sequestered in agricultural soils, and goes on to ask, "how much carbon can agricultural soils in Canada sequester?" This paper provides a promising answer: Canada can meet the global 4x1000 challenge for soil organic carbon, and there are a range of approaches through which it can do so. Equally, it lays out a number of challenges, based on agronomic, economic and policy-related stumbling blocks.

This comes at a time of increasing interest in the role agriculture can play in mitigating climate change, and just as a new Organization for Economic Co-operation and Development (OECD) report on the topic has been released — Soil Carbon Sequestration by Agriculture: Policy Options (January, 2022).

The CAPI and OECD papers pick up many of the same policy issues, in particular the policy challenges and complexities of balancing finite carbon retention capacity, and conversely, the policy incentives needed for greater sequestration of carbon in agricultural soils with untapped potential.

The desire for agriculture to be the conduit through which to mitigate climate change presents great dangers when investigated through a reductionist lens and given a partial analysis. Certain relationships and results can be cherrypicked to the exclusion of others, creating the image of rapid and/or simplistic solutions, and of villains and saints. A recent, widely viewed video published by the New York Times claiming that modern agriculture is "being paid to destroy the planet" illustrates this danger.

CAPI is committed to a balanced dialogue on how a more resilient agri-food system that grows more and better products while being environmentally sustainable, and profitable, can meet the growing demands of consumers in Canada and around the world.

The following from Dr. Wood-Bohm represents an insightful, balanced and realistic discussion of Canada's agricultural soils and the role they play regarding climate change.

Key Takeaways

- Achieving Canada's target of zero emissions by 2050 calls for aggressive progress in every industrial sector and targeted investments to spur innovation and incentivize individual behaviour. Nature-based solutions such as biological carbon sequestration are important in meeting these goals.
- Canadian soils have a huge role to play in securing the Canadian food and feed supply, in enabling global trade, and in stabilizing carbon emissions.
- With aggressive climate targets, Canadian agriculture's future strategies must seek to increase production while reducing emissions and enhancing the amount of carbon sequestered at the same time.
- Understanding the potential impact of strategies and best management practices (BMP) on helping Canada to meet its longer-term climate goals is challenging, given the wide variation in their impact on soils.
- Reducing annual tillage has been confirmed as one of the most successful methods of reducing loss and enhancing sequestration of soil carbons in Canadian agricultural soils. However, since reduced tillage management is already widely adopted where soil characteristics and cropping systems permit, the potential for additional gains is limited.
- Canada has joined the 4x1000 initiative, launched at the Convention of the Parties in Paris (2015) and embraced by over 200 countries, which sets the goal of increasing soil carbons by 0.4%/year, a target considered to be technically achievable in the actively managed agricultural soils in Canada.
- Protocols that use carbon sequestration instead of reductions have been undersubscribed to in Canadian carbon-compliance markets, but voluntary and insetting markets offer future potential.
- Measurement of soil organic carbon (SOC) at the field level throughout the country is often an overlooked element, and it's one that could become critical for validation of sequestration.

In November 2021, Canada committed to reducing carbon emissions by 40 to 45% from 2005 levels by the year 2030. By the end of the decade, Canada must slash some 439 Mt CO_2 eq emissions per year. Ultimately, a net zero emissions goal is projected for 2050[1].

Achieving such ambitious targets will require aggressive progress in every industrial sector — cutting emissions of methane, carbon dioxide and nitrous oxide from the fossil fuel, power production, transportation and heavy industries. Targeted investments are expected to spur innovation and adaptation in other industries and policy tools such as carbon taxes may incent individual behaviour.

As well as emission reductions, a significant role for nature-based solutions (NBS) is envisioned, relying on long-term carbon capture and storage, commonly called biological carbon sequestration.

Biological sequestration occurs when plants and trees take up CO_2 from the atmosphere and store it. In the immediate term, some two billion trees will be planted by 2030[2] to increase atmospheric carbon removals through the photosynthetic capacity of growing trees. This investment will also provide long term sequestration if the resulting forest products are used for dimensional lumber.

[1] Tasker, J. P., & Wherry, A. (2021, April 22). Trudeau pledges to slash greenhouse gas emissions by at least 40% by 2030 | CBC News. CBC News. https://www.cbc.ca/news/politics/trudeau-climate-emissions-40-per-cent-1.5997613

[2] Billion Trees Commitment - Canada.ca. (n.d.). Government of Canada. Retrieved January 30, 2022, from https://www.canada.ca/en/campaign/2-billion-trees.html

So too, an important role for agriculture is envisaged. In the past twenty years, agriculture has fairly consistently contributed about 8% to Canada's total greenhouse gas (GHG) emission profile with approximately 50% attributable to animal agriculture and the remaining 50% to cropping systems[3]. Canadian agriculture is a such vital part of the global food system that production cannot be reduced without impacting global food security, so the future must be dominated by strategies to increase production while reducing emissions. With aggressive climate targets, agriculture will not only need to reduce production emissions, but also to enhance the amount of carbon sequestered in agricultural soils. This paper is intended to explore the science and practical aspects of enhanced soil carbon sequestration and how this may contribute to helping Canada meet its climate change goals while enhancing sustainability.

Soils are complex mixtures of particles that include a mineral fraction of clay, silt and sand, an organic fraction commonly called the soil organic carbon (SOC) made up of decaying plant materials (leaf litter and roots) as well as living organisms (bacteria, yeasts and insects for example), air and water. Soils are formed very slowly over geologic time and are highly influenced by the mineral parent material from which they arise, the type of vegetation (grasslands or forest/tundra) that has historically covered the parent material and the environmental conditions (temperature and moisture) under which the soil has been created. Over time, these processes lead to the formation of typical soil horizons or layers. Horizons are used to classify soils according to a rigorous Canada-specific taxonomic system comprised of ten orders, various great-groups and subgroups[4]. The better soils for agriculture have high mineral and organic content, typical of those produced under grassland cover, and these are most abundant in western Canada. But forest-derived soils can also be highly fertile. The "Guelph series", Ontario's official soil type, has many characteristics beneficial for crop production when combined with Ontario's warmer, wetter climate[5].

Figure 1. The importance of soils. Adapted from FAO, 2015[6].

[3] https://agriculture.canada.ca/en/agriculture-and-environment/climate-change-and-air-quality/agricultural-greenhouse-gas-indicator

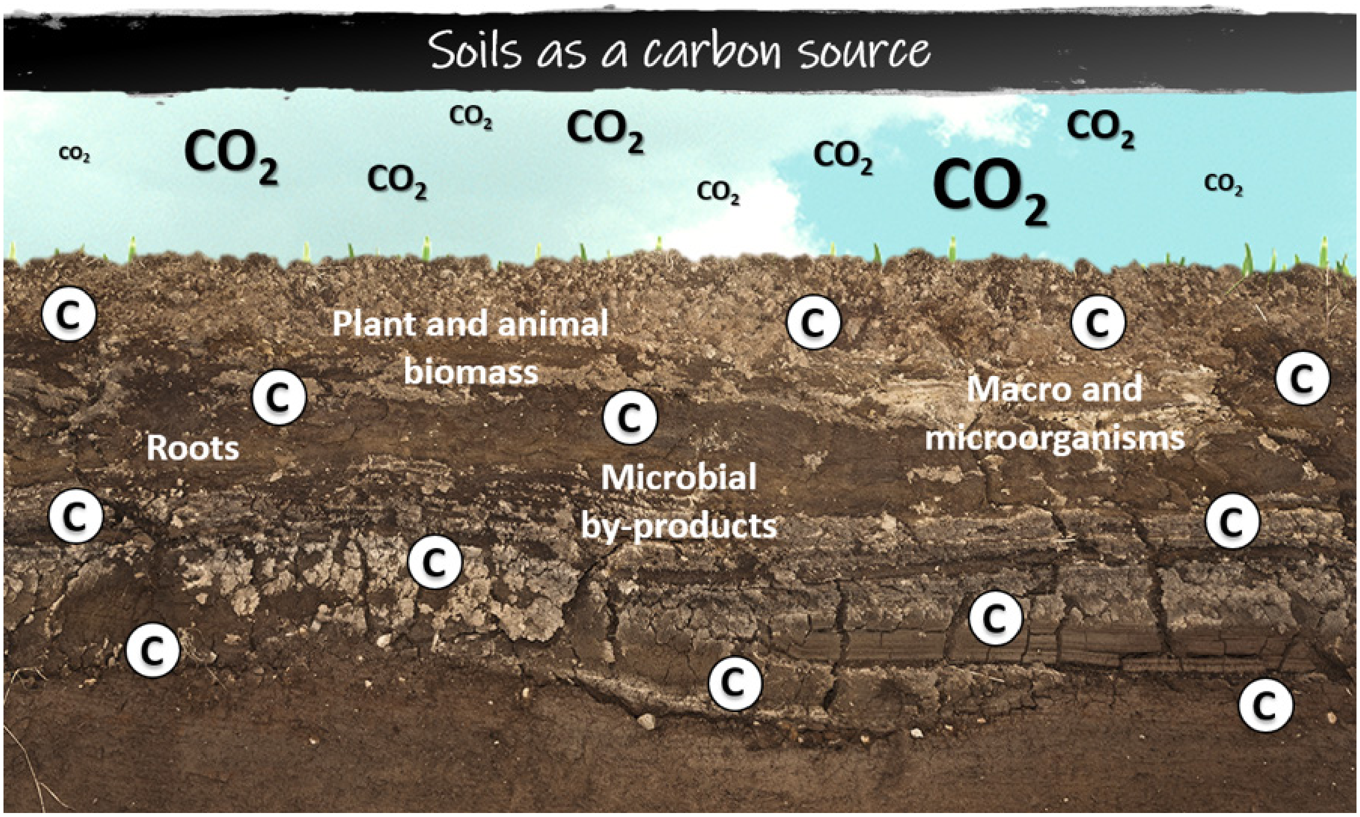
[4] The Canadian System of Soil Classification, 3rd edition. (n.d.). Government of Canada. Retrieved January 30, 2022, from https://sis.agr.gc.ca/cansis/taxa/cssc3/index.html

[5] Provincial Soil. (n.d.). Ministry of Agriculture, Food and Rural Affairs Ontario. Retrieved January 30, 2022, from http://www.omafra.gov.on.ca/english/about/prov-soil.htm

[6] https://www.fao.org/resources/infographics/infographics-details/en/c/284478/

Soils are living, dynamic environments, which host a suite of physical, chemical and biological processes. Plants use the structure of soils to hold them upright, to provide a source of minerals, and to house the microbes that assist plants in gathering nutrients and water. As they grow, plants takes up atmospheric CO2 and, through photosynthesis, combine it with water from the soil to create carbon-based molecules necessary for the structural building blocks and chemical processes of plant growth and development. Plants are comprised of 40 – 50% carbon, which is distributed about equally in above ground (stems and leaves) and below ground (root) tissues[7]. When plants complete their growth cycle, microbes aid in decay, releasing the above ground carbon back to the atmosphere and helping to incorporate the below ground carbon to the pool of SOC. SOC will remain stable unless the soil is disturbed, which permits oxidation to CO2 and release to the atmosphere. Carbon sequestration that permanently removes carbon from the atmosphere occurs when the amount removed from the atmosphere and stored exceeds the amount lost to oxidation.

Figure 2. Soils as a carbon source, courtesy of Marie-Elise Samson.



The amount of carbon in any given soil may be determined accurately by collecting samples and testing these under laboratory conditions[8] or in the field[9], or on a larger scale using techniques such as aerial spectroscopy, LiDAR and modelling on the landscape level[10],[11].

[7] *Manage Carbon . (n.d.). Natural Resources Conservation Service Pennsylvania; United States Department of Agriculture. Retrieved January 30, 2022, from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/pa/soils/health/?cid=nrcseprd1201408*

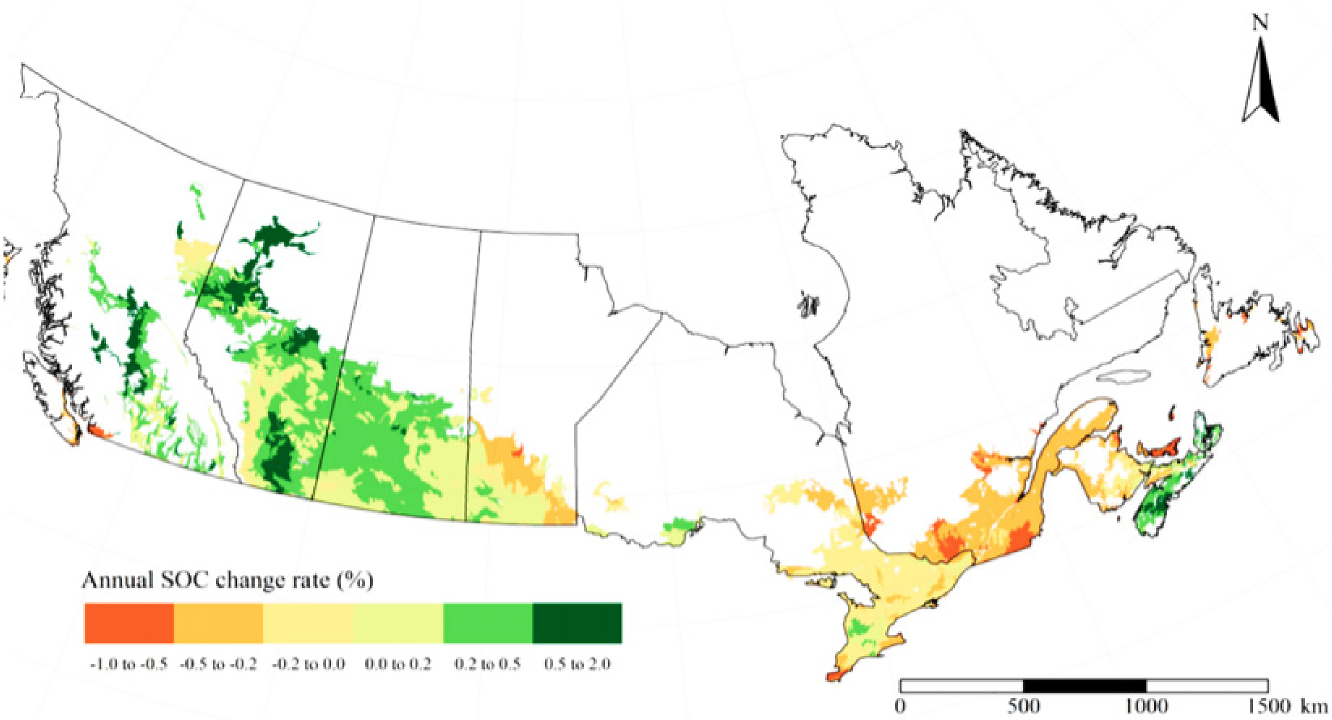
[8] *Soil Survey Standard Test Method: Organic Carbon. (n.d.). Department of Sustainable Natural Resources. https://www.environment.nsw.gov.au/resources/soils/testmethods/oc.pdf*

[9] *Edwards, T. (n.d.). Measuring and reporting soil organic carbon | Agriculture and Food. Department of Primary Industries and Regional Development. Retrieved February 5, 2022, from https://www.agric.wa.gov.au/soil-carbon/measuring-and-reporting-soil-organic-carbon*

[10] *Stevens, A., Udelhoven, T., Denis, A., Tychon, B., Lioy, R., Hoffmann, L., & van Wesemael, B. (2010). Measuring soil organic carbon in croplands at regional scale using airborne imaging spectroscopy. Geoderma, 158, 32–45. https://doi.org/10.1016/j.geoderma.2009.11.032*

[11] *Fynn, A. J., Alvarez, P., Brown, J. R., George, M. R., Kustin, C., Laca, E. A., Oldfield, J. T., Schohr, T., Neely, C. L., & Wong, C. P. (2009). Soil carbon sequestration in United States rangelands. In Grassland carbon sequestration: Management, Policy and Economics.*

Figure 3. SOC stocks in Canada from 1971 to 2015. Adapted from Fan et al. 2019[12]



How much carbon Canadian agricultural soils are able to sequester depends on many environmental and operational factors as well as the amount of land under cultivation.

As the second largest country in the world, Canada's landmass covers an impressive 9.985 million Km2. But the area appropriate for agricultural endeavours is made considerably smaller by geographic and climatic limitations. For example more than 27% of the landmass occurs north of the tree line in conditions inhospitable for crop production, and a further 890,000km2 are covered with freshwater resources such as lakes and streams[13]. When all of the limitations have been taken into consideration, only about 7% of Canada's landmass is suitable for rearing animals and growing crops; a small additional amount can be used for ranging animals without land modification[14].

Major regions of agricultural activity in Canada are located in the Prairie and Western provinces, which grow vast acreages of grain and oil seed crops and where the largest numbers of beef cattle are raised for much of their lives on rangelands. Larger farms on drier soils dominate this region. In Ontario, southern Quebec and some of the Atlantic region, wetter, warmer soils sustain a variety of annual and perennial crops while livestock are generally raised in confined animal operations with manure spread seasonally on croplands. Farms in this region tend to be smaller and more intensive. In 2016, of Canada's total 93.4 M cropped acres[15], some 86.3% of cropped lands occurred in Manitoba, Saskatchewan and Alberta together, while the remaining 13.7% occurred in Ontario, Quebec and other provinces[16].

[12] Fan, J., B. G. McConkey, B. C. Liang, D. A. Angers, H. H. Janzen, R. Kröbel, D. D. Cerkowniak, and W. N. Smith. 2019. Increasing crop yields and root input make Canadian farmland a large carbon sink. Geoderma 336:49–58.

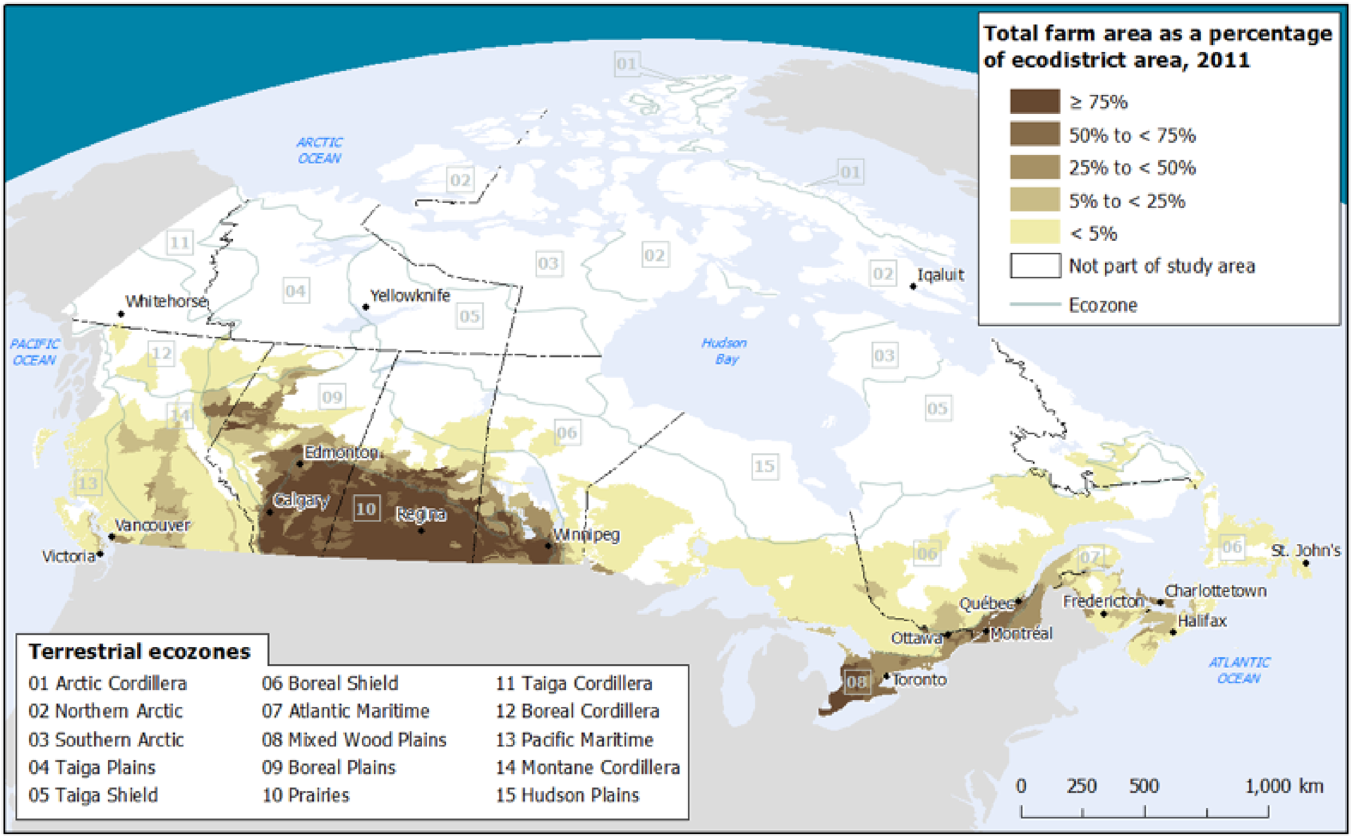
[13] Statistics Canada. (n.d.). Geography. Retrieved January 30, 2022, from https://www150.statcan.gc.ca/n1/pub/11-402-x/2011000/chap/geo/geo-eng.htm

[14] Snapshot of Canadian agriculture. (n.d.). Statistics Canada. Retrieved February 5, 2022, from https://www150.statcan.gc.ca/n1/ca-ra2006/articles/snapshot-portrait-eng.htm

[15] 2016 Census of Agriculture. (n.d.). Statistics Canada. Retrieved January 30, 2022, from https://www150.statcan.gc.ca/n1/daily-quotidien/170510/dq170510a-eng.htm

[16] Saskatchewan remains the breadbasket of Canada. (2017, May 10). Statistics Canada, Farm and Farm Operator Data. https://www150.statcan.gc.ca/n1/pub/95-640-x/2016001/article/14807-eng.htm

Figure 4. Total farm area as a percentage of ecodistrict area, 2011[17]



At the Convention of the Parties in Paris (2015), France launched an initiative to encourage the sequestration of carbon in the soil through the use of regionally appropriate beneficial management practices (BMPs) in agriculture. A BMP is considered to be a production technique that is different from the conventional approach and which confers an environmental or production benefit. The 4x1000 initiative sets a goal of increasing soil carbons by 0.4%/yr, which on a global level, could offset the new annual GHG emissions from all sources. More than 200 countries and partners, including Canada have joined the effort[18]. As an aspirational goal, the 4x1000 initiative has sparked considerable discussion on the potential role for agricultural soils, and debate on the practicality of such a plan[19]. Much work has now been completed to determine if there is a technical capability to reach this goal, and also to assess the policy tools necessary to enable such a strategy. It is estimated that the actively managed agricultural soils in Canada the stable pools of carbon are about 4,140 Mt of C in the top 30 cm of soil and 5,500 Mt to a depth of 100 cm[20]. Management practices yield gains of 0.1 to 0.5 t C/ha/year, so the 4 x 1000 target is technically achievable in Canada[21].

[17] *https://www150.statcan.gc.ca/n1/daily-quotidien/141113/mc-a001-eng.htm*

[18] *Welcome to the "4 per 1000" Initiative . (n.d.). 4 Pour 1000. Retrieved January 30, 2022, from https://www.4p1000.org/*

[19] *de Vries, W. (2018). Soil carbon 4 per mille: a good initiative but let's manage not only the soil but also the expectations: Comment on Minasny et al. (2017) Geoderma 292: 59–86. Geoderma, 309, 111–112*

[20] *Minasny, B., Malone, B. P., McBratney, A. B., Angers, D. A., Arrouays, D., Chambers, A., Chaplot, V., Chen, Z.-S., Cheng, K., Das, B. S., Field, D. J., Gimona, A., Hedley, C. B., Young Hong, S., Mandal, B., Marchant, B. P., Martin, M., McConkey, B. G., Leatitia Mulder, V., … Winowiecki, L. (2017). Soil carbon 4 per mille. https://doi.org/10.1016/j.geoderma.2017.01.002*

[21] *VandenBygaart, A. J., McConkey, B. G., Angers, D. A., Smith, W., de Gooijer, H., Bentham, M., Martin, T., & Gooijer, de. (2007). Soil carbon change factors for the Canadian agriculture national greenhouse gas inventory*

Historically, the activity of growing crops involved "working" or tilling the soil to break up large, hard clods into smaller particles so that seeds were able to germinate and grow. At the same time, these processes incorporated additional air, permitting oxidation of soil carbons and facilitating their release to the atmosphere, as a loss to the SOC pool. Estimates at the global level have shown very significant contributions to atmospheric carbon attributable to land cultivation and suggest that those historic losses now offer an opportunity for significant carbon sequestration[22]. Rebuilding the pools of SOC will necessarily take some time, and are easily disrupted, but some techniques have already been proven effective.

One of the most successful methods of reducing loss and enhancing sequestration of soil carbons is to reduce annual tillage, or as crop production allows, to eliminate this step altogether. Canadian scientists modelled the loss of SOC under conditions of conventional or reduced tillage using data from 180 sites and confirmed a significant reduction in losses[23]. The adoption of "no-till" methodology has had a dramatic impact on carbon losses in the west, moving the western provinces from a net loss of carbon to a net gain position since 1981 with large geographic areas improving the amount of soil carbon by as much as 1200kg/ha/yr[24]. Because no-till management also reduces the need for equipment on the land and hence fossil fuel emissions, a reduction of GHG impact of 71% has been estimated[25]. Opportunities for continued carbon sequestration in the west do exist because SOC pools will continue to increase over time, albeit slowly; a new balance, when continued gains level off is expected within the century. Over the same 30 year period from 1981 to 2011, no-till has not been widely adopted in the eastern provinces. To date in this region, SOC pools lack stability and continue to release more carbon than they store. Nevertheless, this trend to limit reduced tillage management may continue because untilled soils are slower to warm and dry, thus delaying spring planting and germination and ultimately impacting yield. Additionally, some crops, like corn, present the challenge of significant above ground biomass after the crop is harvested, which can create a barrier to germination of next crops unless some of this residue is first removed.

Since reduced tillage management is already widely adopted where soil characteristics and cropping systems permit, the potential for no-till to address climate goals is limited. Other BMPs however, may be useful. Of these, cover cropping may provide an opportunity across a broad range of soil types and crop cycles.

Cover crops are those seeded for their non-harvest benefits and may be grasses, legumes, brassicas or non-legume broad-leaf plants. These are typically seeded after the harvest and may be incorporated or used as a foundation for no-tilling. Cover crops contribute to SOC but also have very positive impacts on reducing erosion, improving soil fertility, retaining water stocks, reducing pests and weeds and aiding in biodiversity. Cover cropping can have a direct and immediate impact on near-surface carbon stocks; soils in Ontario showed a greater than 10% increase in SOC when cover crops were used for 9 consecutive years[26]. But cover cropping has highly variable impacts depending on soil type, cropping practices and cover crop chosen and may not provide consistent positive impacts in every situation[27].

In addition to reduced tillage and cover cropping other management practices may have significant impacts on carbon sequestration. These include incorporating more perennials and forages such as alfalfa, use of fertilizer to increase biomass production, intercropping and better use of crop rotations chosen for positive soil impacts[28].

[22] Sanderman, J., Hengl, T., & Fiske, G. J. (2017). Soil carbon debt of 12,000 years of human land use. Proceedings of the National Academy of Sciences of the United States of America, 114(36), 9575–9580. https://doi.org/10.1073/PNAS.1706103114

[23] Smith, W. N., Rochette, P., Monreal, C., Desjardins, R. L., Pattey, E., & Jaques, A. (1997). The rate of carbon change in agricultural soils in Canada at the landscape level.

[24] Soil Organic Matter Indicator - agriculture.canada.ca. (n.d.). Government of Canada. Retrieved January 30, 2022, from https://agriculture.canada.ca/en/agriculture-and-environment/soil-and-land/soil-organic-matter-indicator

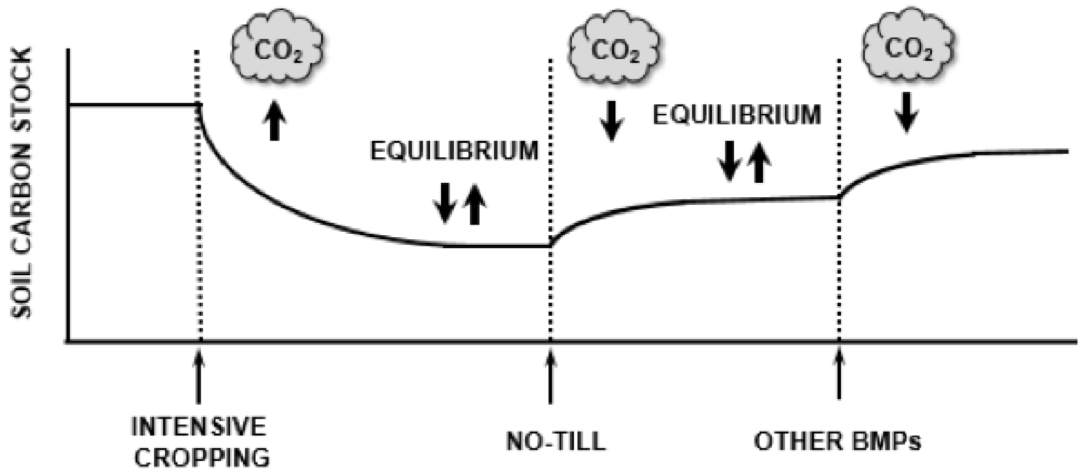
[25] Sainju, U. M. (2016). A Global Meta-Analysis on the Impact of Management Practices on Net Global Warming Potential and Greenhouse Gas Intensity from Cropland Soils.

[26] Chahal, I., Vyn, R. J., Mayers, D., & van Eerd, L. L. (2020). Cumulative impact of cover crops on soil carbon sequestration and profitability in a temperate humid climate. Scientific Reports, 10(1). https://doi.org/10.1038/S41598-020-70224-6

[27] Abdalla, M., Hastings, A., Cheng, K., Yue, Q., Chadwick, D., Espenberg, M., Truu, J., Rees, R. M., & Smith, P. (2019). A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. Global Change Biology, 25(8), 2530. https://doi.org/10.1111/GCB.14644

[28] Vandenbygaart, A. J., Gregorich, E. G., & Angers, D. A. (2003). Influence of agricultural management on soil organic carbon: A compendium and assessment of Canadian studies.

Figure 5. Impact of different BMPs on carbon sequestration. Adapted from Fan et al. 2019[29]



Understanding the potential impact of these strategies and BMPs on helping Canada to meet its longer term climate goals is challenging, given the wide variation in their impact on soils. Permanence of the stored organic carbon pool is fragile at best and newly stored carbon is easily lost if a cultivation cycle is deemed necessary, for example to manage an invasive weed infestation. Because initial carbon sequestration occurs in the active agriculture zone (top 30cm of soil), it is subject to weather, disturbance and the immediate impacts of climate change. Climate change impacts that disrupt the typical moisture cycles, such as through flooding or drought, or increasingly rapid snow melt in the spring may alter the carbon cycle dramatically in the upper soil horizons. Over time, microbes assist in the movement of SOC to deeper soil horizons where carbon pools are more stable[30].

A recent study on Canada's stored terrestrial carbon stocks used a variety of data acquisition tools and a series of models to determine the relative stocks in above ground biomass, below ground biomass and deep soils. While much of the data and analysis focussed on the boreal forest and peatland stocks, the analysis of deep carbon stores is particularly interesting. Agricultural soils, which are assessed by soil samples taken in the active agricultural zones show the impacts of disturbance, but perhaps overlook the potential of stable deeper pools, which go unmeasured by traditional sampling techniques[31]. This work supports the idea that more carbon may be stored below the agriculturally active layers than previously thought.

Canadian researchers seem to have reached the consensus that the 4 x1000 initiative is technically feasible for Canadian agricultural soils with implementation of reduced tillage, recognizing that only limited additional capacity remains in western soils. To increase the SOC on active agricultural soils by 0.4% would add an additional 16.6 Mt C in the top 30 cm of soil by sequestering 60.8 Mt CO2/yr which is about 14% of Canada's target for 2030. Presumably the adoption of additional BMPs could augment this number.

[29] Fan, J., B. G. McConkey, B. C. Liang, D. A. Angers, H. H. Janzen, R. Kröbel, D. D. Cerkowniak, and W. N. Smith. 2019. Increasing crop yields and root input make Canadian farmland a large carbon sink. Geoderma 336:49–58.

[30] Ontl, T. A., & Schulte, L. A. (2012). Soil Carbon Storage . Nature Education Knowledge , 3(10), 35. https://www.nature.com/scitable/knowledge/library/soil-carbon-storage-84223790/

[31] Sothe, C., Gonsamo, A., Arabian, J., Kurz, W. A., Finkelstein, S. A., & Snider, J. (2021). Large soil carbon storage in terrestrial ecosystems of Canada. Earth and Space Science Open Archive. https://doi.org/10.1002/ESSOAR.10507117.2

This technical feasibility may be enabled by complimentary policy tools. Carbon credits are one way in which producers could be incented to take up practices that improve SOC pools. Compliance carbon markets are focussed on measuring and reducing emissions through the development and use of a compliance protocol, for which a carbon credit is allocated. These credits are purchased by regulated industries who are permitted to use credits to comply with at least a portion of their obligation. Voluntary carbon credits are not eligible to meet regulated obligations but can be used to meet environmental claims. In both cases, the carbon offset is generated by the reduction of carbon emissions; protocols which use carbon sequestration instead of a reduction have been undersubscribed in Canadian compliance markets because of issues with permanence and the associated expense to validate and verify.

The concept of insetting, or making change that results in a carbon benefit either upstream or downstream within a supply chain may be useful in incenting changes leading to carbon sequestration and ultimately a value for achieving the goal[32].

Adoption of BMPs is most directly rewarded by improvement of the yield or quality of the harvested crop. Activities such as reduced tillage lower the cost of labour and fuel, but typically come with higher costs, or weaker pest control. In particular, chemical herbicides are an essential substitute for destruction of weeds through tillage and the associated disturbance of the top layer of soil. Herbicides can be expected to become even more critical as climate change permits invasion of weedy species; without the use of herbicides reduced tillage strategies are difficult to successfully implement.

Adoption of some BMPs comes at the cost of expensive new equipment; access and affordability of equipment is a huge barrier in many parts of Canada. Policy tools to enable the purchase of essential agricultural inputs could have multiple benefits, including enhancing carbon sequestration over the longer term.

Some producers have adopted "regenerative agriculture" techniques to systematically combine reduced tillage, cover cropping, introducing perennials and agroforestry, encouraging biodiversity, integrating livestock and using organic inputs with the goals of improving soil health and consequently yield[33]. Using these techniques has demonstrated benefits for some[34], but are not fully possible in all regions of the country and have yet to demonstrate widespread adoption or economic benefit for all[35].

When carbon sequestration is considered an essential part of the climate change strategy, a key element that is often overlooked and which could become a critical enabling policy tool is the measurement of SOC at the field level throughout the country. Simple soil sampling, and more sophisticated analysis and modelling would identify locations where the application of BMPs could be most helpful and profitable and such measurements could validate positive changes over time. Canadian soils have a huge role to play in securing the Canadian food and feed supply, in enabling global trade, and in stabilizing and balancing carbon emissions.

[32] What is Carbon Insetting? (n.d.). My Climate| Shape Our Future. Retrieved February 5, 2022, from https://www.myclimate.org/information/faq/faq-detail/what-is-carbon-insetting/

[33] Régénération Canada. (n.d.). Retrieved February 5, 2022, from https://regenerationcanada.org/en/about-us/

[34] Newton, P., Civita, N., Frankel-Goldwater, L., Bartel, K., & Johns, C. (2020). What Is Regenerative Agriculture? A Review of Scholar and Practitioner Definitions Based on Processes and Outcomes. Frontiers in Sustainable Food Systems, 4, 194. https://doi.org/10.3389/FSUFS.2020.577723/BIBTEX

[35] Regenerative agriculture. (n.d.). Retrieved February 5, 2022, from https://ellenmacarthurfoundation.org/articles/regenerative-agriculture