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TO: **Members of the Standing Senate Committee on Agriculture and Forestry**

Subject: **The State of Soil Data in Canada**

Dear Senators, October 13, 2022

I want to thank you and your colleagues for your involvement on the Standing Senate Committee on Agriculture and Forestry. I also want to thank the Committee for recognition of soil as one of our country's vital natural resources, as well as the great efforts and leadership that the committee has taken towards addressing sustainable soil management and recognizing the importance of examining the status of soil health in Canada.

My research expertise is in **digital soil mapping**—a discipline of soil science that leverages novel technologies in computing, remote sensing, and artificial intelligence to predict soil properties and evaluate indicators of soil health. This is an emerging area of research in Canada and the soil mapping community is tasked with modernizing soil data across the country to maximize and inform sustainable agricultural and forestry practices; and to better inform Canadians on the current health status of our soils. With knowledge on the state of our soils, we will be far more effective in ensuring soil security, food security, and water security under climate change. Information about where healthy soils and threats to soil health are is crucial to our ability to tackle some of the greatest existential challenges of our times (e.g., climate change and food security).

I have long been involved with the national soil science community via the Canadian Society of Soil Science (CSSS). I am a member of the Canadian Digital Soil Mapping Working Group (CDSMWG), a national network of soil mapping researchers from Agriculture and Agri-Food Canada, Natural Resources Canada, provincial government agencies, and academic institutions. In 2018, my peers nominated me as Co-Chair of the CDSMWG (with Dr. Angela Bedard-Haughn, University of Saskatchewan). Most recently, we have produced a chapter on digital soil mapping as part of the open access, Canadian introductory textbook on soil science, Digging Into Canadian Soils: An Introduction to Soil Science.

Given my role with the CDSMWG, my commentary will be framed around the importance of digital soil information for providing a comprehensive assessment of soil health.

Soils as a Natural Resource

In 1984, your senate committee (formerly the Standing Senate Committee on Agriculture, Fisheries, and Forestry) produced the "Soil at Risk: Canada's Eroding Future" report. The report included a series of recommendations to address the need to resolve policy conflicts, intensify soil conservation research, facilitate the transfer of technology, and increase awareness and incentivize soil conservation. These recommendations eventually led to the genesis of the Soil Conservation Council of Canada. These outcomes have had a long-lasting impact on sustainable soil management and have led to the recognition of soil degradation as a major threat to Canada's food security.

Scientific research carried out by soil scientists at academic institutions, provincial agencies, and federal agencies (Agriculture and Agri-Food Canada and Natural Resources Canada) have transformed our understanding of sustainable soil management and the development of best management practices. Moreover, technological developments have led to the emergence of precision agriculture, where farmers are now able to increase the efficiency of agricultural inputs (e.g., water, fertilizers, pesticides, seeds) while maintaining or improving productivity and minimizing the impact on ecosystem services.

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However, soil information is the key to fully realizing the opportunities provided by these scientific and technological advances, carrying out sustainable soil management, supporting long-term food security, and mitigating the ongoing impacts of climate change.

International Demand for Soil Data

To put an international spotlight on the importance of soils, the FAO established the Global Soil Partnership (GSP) in 2012 and the Intergovernmental Technical Panel on Soils (ITPS) in 2013; furthermore, it designated 2015 as the International Year of Soils and 2015–2024 as the International Decade of Soils. These initiatives were designed with the vision of improving the governance of soil resources to "***guarantee healthy and productive soils for a food secure world, as well as support other essential ecosystem services***"[1] through sustainable soil management and productivity.

During the establishment of the GSP, the scientific community held the wide consensus that, despite the abundance of soil knowledge and data worldwide, soil data is often "dispersed and partial, not harmonized and not accessible to the broad range of stakeholders," whereby "mechanisms are needed to enhance the wide sharing of knowledge, data, methods, [and] technologies."[2] Subsequently, the "Status of the World's Soil Resources,"[3] which provided the first global assessment of soils and highlighted the many threats to soils (e.g. erosion, salinization, compaction, and pollution) and global food security, identified several major knowledge gaps and research needs with specific linkages to soil information. These included the development of realistic and high-resolution representations of soils in global-scale models (e.g. climate change and crop suitability models) and the need to establish a distributed observational and soil monitoring network for model validation.[3] If these needs are addressed, the soil science community will be far better equipped to provide accurate, precise, and spatially-explicit estimates of soil properties by using *location-specific* and *measurement-based* soil information. Soil scientists will be able to provide digital soil information that are in accordance with international standards, such as the Intergovernmental Panel on Climate Change (IPCC) guidelines for greenhouse gas inventories using Tier 3 (i.e., highest-quality) approaches.[4] Canada, as required by the United Nations Framework Convention on Climate Change (UNFCCC), is obligated to report the sinks and sources of carbon in managed lands. Furthermore, in 2018, the FAO report, "The State of Food Security and Nutrition in the World," clearly articulated the need for detailed and accurate soil information to understand and predict the impact of climate change on agricultural crop suitability and food security at global scales.[5] The availability of spatial soil data is critical towards our ability to monitor, verify, and report on the state of our soils and ensure our international commitments are met.

To address the needs for fulfilling information gaps, the international soil science community has established initiatives such as *GlobalSoilMap.net*, *SoilGrids*, and ISRIC – World Soil Information. These initiatives have the goal of producing digital soil maps (DSMs) of key soil properties at multiple depth intervals, in order to facilitate soil modeling and monitoring activities at the global-scale using cost-effective and time-efficient approaches.[6-7] At a continental scale, the European Soil Data Centre of the Joint Research Centre (European Commission, EU) has been effective in distributing continental-scale maps of soil threats and functions as well as providing open-access to a comprehensive database of soil observations to assist modeling activities. Using cost-effective and time-efficient approaches, these initiatives leverage technological advances, such as remote sensing, geographical information systems, "Big Data" sciences, and machine learning, to produce DSMs. Furthermore, other initiatives such as the *International Soil Carbon Network* have focussed on establishing soil monitoring networks that are designed to track changes in soils thus facilitating long-term assessments and management of soil organic carbon and soil health.[8-9] The success of these initiatives largely hinges on a *community-based model* whereby participants are able to effectively communicate with each other; to contribute to the

development of a data-sharing framework that ensures data harmonization and interoperability from the various data-sources; and to create a common modeling platform.[9]

Recognizing the Need for Soil Information in Canada

On May 2, 2019, your committee held a hearing and invited expert witnesses to report on the topic of "The matter of soil conditions in Canada, how soils are used and what steps are being taken to protect them." Expert witnesses included Dr. David Lobb (Professor, University of Manitoba), Dr. David Burton (Professor, Dalhousie University), Ms. Gabrielle Ferguson (Agronomist), Mr. Don Lobb (Farmer), and Mr. Cedric MacLeod (Executive Director, Canadian Forage and Grassland Association). Each expert witness clearly communicated the need for soil information and its management. In my capacity as Co-Chair of the CDSMWG and as a dedicated advocate for improving the state of soil information for Canadians, I was very excited to hear the discussions that took place.

Several of Ms. Ferguson's statements particularly resonated with me. For example:

> *To understand how agriculture can make a difference with good land management, we need to know what is happening where and when. A coordinated process to collect and synthesize accurate place-based data can help. Entering the site-specific information into predictive models can provide the foresight necessary to prioritize and target actions toward those with the greatest ability to reduce or reverse soil degradation and protect water quality.*

Given the need for site-specific information, one would expect that accurate and precise soil information would be available to Canadians; however, she also indicated, "The Canadian Soil Information Service [Agriculture and Agri-Food] exists, but it is in need of updating." I am convinced that the soil science community fully agrees with Ms. Ferguson. This system must be completely modernized using 21st century science and technologies.

We have made many advances during this Digital Era, such as machine-learning and artificial intelligence, remote sensing technologies, and Big Data analytics to name a few. Yet, much of our country still relies on provincial soil survey maps—some of which had not been updated since the 1940s when they were first created; by the 90s, the remaining provincial soil survey programs were effectively terminated. Furthermore, large swaths of land have yet to be mapped, including the forested and northern landscapes.

My colleague Dr. Burton also offered similar sentiments to Ms. Ferguson's:

> *We need to increase the direct measurement of the state of our soils so that information can inform our management of those soils. Information will be critical to identify areas of concern and document solutions.*

We need to gather information about the location and properties of our soils in order to assess the threats to this valuable resource, which include salinization, organic matter loss, soil health degradation. This information will also allow us to identify new opportunities, such as enhancing soil carbon sequestration and assessing crop suitability.

Lastly, your colleague, Senator Rosemarie Moodie made one of the most important comments:

> *I think we need a **paradigm shift** and I think that moving the accountability of this [soil information] resource to a new area might help achieve some of the rethinking at a system level of how we can actually fix some of the breakdowns in the linkages that we need: getting*

information translation out to the front-liners; understanding how the metrics can guide us and how the data can guide us.

Yes. Absolutely. We need a paradigm shift. And we need ways to communicate that information to people who will require it the most—from individual farmers and foresters to the politicians that draft our national climate change policies. The unfortunate truth, however, is that while our country is still developing our expertise in digital soil mapping and our capacity to communicate soil information to stakeholders, the paradigm has already shifted—long ago—in other developed countries. Soil information must be democratized, and Canada is behind.

Canada within the International Context

Take for example, the European Union and its Joint Research Centre, which established the European Soil Data Centre (ESDAC) in 2006. Through international collaboration, this centre has made incredible achievements:

1. It established a **centralized** soil data platform that is **interoperable** with other data provision services; it is **open access** and **updateable** (here and here).

2. It carried out a continental-scale, soil survey campaign and produced a dataset with more than 250,000 sample points (LUCAS Topsoil Survey), which is **freely available**.

3. It produced a suite of digital soil map products for Europe, which is **also freely available**.

Using the soil mapping products derived from the LUCAS dataset, ESDAC now has the capacity to evaluate the threats to soil (e.g. soil erosion, landslide susceptibility, desertification) and soil functions (e.g. soil carbon sequestration, biomass productivity, food security). Australia shows a very similar story with the Soil and Landscape Grid of Australia.

Building a Community to Develop and Provide Digital Soil Information in Canada

Canada has a rich history in soil surveys; however, the need for high resolution information to address climate change and sustainable soil management has led to a search for novel methods to predict soil properties and to provide updated and more accurate and precise estimates than what is currently available. To address these needs, **Pedometrics**—**a branch of soil science that aims to develop soil maps and provide knowledge of soil variability over space using statistical techniques**—has been an emerging field of research, globally. This developing area of research has evolved over the past ten years in Canada and within the agricultural, forestry, and environmental sectors. With great success, the soil mapping community has provided valuable information at multiple spatial scales to various stakeholders, including landowners, farmers, governments, and forest managers.

To address the challenges indicated by the GSP, the Pedology Committee of the Canadian Society of Soil Science (CSSS) established the CDSMWG in 2016. This cross-country, cross-sector research network coordinates national-scale soil mapping initiatives, disseminates digital soil information, and delivers educational workshops. All products developed by the CDSMWG are designed to meet international DSM standards of *GlobalSoilMap.net* and the FAO. To date, the CDSMWG has been successful in its mandate; it was instrumental in developing and delivering a preliminary Canadian Soil Organic Carbon Map (CSOCmap) as part of Canada's contribution to the Global Soil Organic Carbon Map (GSOCmap) compiled by the ITPS and FAO in 2017.

Dedicated volunteers in the project clearly demonstrated the network's ability to effectively communicate and collaborate in the daunting task of developing the CSOCmap. However, the scope and scale of the activity and the lack of centralized resources, combined with Canada's enormous land mass and diverse ecosystems, created additional challenges in the map's development. Sourcing soil data from various academic, provincial, and federal agencies and the lack in harmonization and interoperability amongst those datasets present some of our greatest challenges. To address this problem, our network developed the CSOCmap from eleven regional submissions provided by CDSMWG volunteers familiar with the datasets from their respective jurisdictions.

Canada is expected to contribute national maps of soil erosion, soil salinity, and soil carbon sequestration potential, as well as an updated soil carbon map to the FAO in the future. Without a centralized national soil database with a common data structure, this task will be challenging. Our country's ability to fully contribute to future FAO-led soil mapping initiatives, provide regularly updated maps, and develop national assessments of soil health are hindered. Despite these challenges, the CDSMWG remains the **only** research network with the capacity and expertise to improve and update the national-scale DSMs and address the national and international demand for SOC information. To do so, however, it will require substantial resources.

Moving Forward & Recommendations

In my view, several major hurdles will need to be addressed before we are able to evaluate the threats and functions of soils at a national scale:

1. **Data Sharing:** The soil science community will need to develop a **data sharing framework** that meets the requirements of academia, government, and industry while respecting **privacy rights**. Also, I believe that the government must take a leadership role in this and should explore the different policy tools (i.e., 'carrots' and 'sticks') at their disposal to encourage the sharing of data by industry. Ideally, there would be mechanisms in place to acquire data from environmental consulting and other related companies as they are contracted out by industry to do environmental impact assessment; and as such, they are the largest source of private-acquired soil data—however, they are not the owners of the data.

2. **Industry Engagement:** Industry data is a valuable resource if the country intends to improve our mapping products and reduce uncertainties. So far, the CDSMWG has shown its effectiveness in collaborating between its members due to the willingness of provincial and federal agencies and university researchers to share data. The private sector is diverse with diverse needs (e.g., agriculture, forestry, energy, and mining) and industry cooperation for data sharing requires there to be a clear business case during engagement activities.

3. **Updating and Harmonizing Soil Datasets:** Like the ESDAC, we need to ensure that our datasets share **a common structure**, are **open** to researchers, are **easy to update**, and are **interoperable** with national and international soil repositories. Many legacy datasets (i.e., soil surveys) need to be digitized from paper. While this data may be out of date, they are still a valuable resource. For example, my research has shown that these legacy soil surveys can be improved using digital soil mapping approaches. Furthermore, we can learn lessons from existing data repositories (e.g. ESDAC and Soil and Landscapes Grids of Australia). The CDSMWG has taken great steps in developing a national framework for harmonizing soil data.

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4. **Long Term Data Management:** Digital soil information must be stored in a place where it will be maintained and updated. My colleagues and I believe in a federated data model whereby data should be made redundant across several nodes across the country by universities and government agencies. However, **financial resources** will be required to ensure that soil data is properly managed. Ideally, such data would be managed by an independent body, comprised of experts from academic institutions and government (provincial and federal)—the discussed National Soil Health Institute may provide a home for this data. **Independence is critical to ensure that our national soil data infrastructure is not put at risk of changing governments and priorities**.

5. **Sustainable Funding:** We do not have the financial resources to sustain our efforts; yet, the soil science community and the senate have identified the modernization of soil information as a high-priority area. While the CDSMWG has the technical expertise in producing digital soil maps, most of the research funding that we receive are usually for one- to five-year projects. **Sure, we can use short-term funding as a springboard to develop a digital soil information platform but sustaining it over the long term will be impossible.** The CDSMWG will certainly take a leadership role in all scientific aspects, but we need government support. Developing map products for future FAO requests should not be considered as "side projects" carried out by the dedicated volunteers of the CDSMWG. Currently, the CDSMWG are developing the Canadian Soil Data Portal—a centralized soil data repository; however, this is being financed, over the short term (1-3 years), via funding from Sustainable Development Technology Canada, to a private sector partner, Terramera. **A long-term funding plan is critical.**

My colleagues and I are very passionate about developing a digital soil information platform. We believe Canada will be able to meet the high bar that has already been set by Australia and the European Union. I am very optimistic but there is no shortage of work to be done. I believe in my Working Group colleagues, but we require substantial resources and investments.

I hope that this rather lengthy brief provides you with a better understanding of the tremendous efforts Canadian soil scientist have already invested and our collective desire to promote sustainable soil management and ensure food security.

Thank you for your attention. Members of the CDSMWG would be more than willing to meet with you and members of your staff to showcase our achievements in digital soil mapping from across the country.

Please do not hesitate to contact me should you have any questions or require further information.

Sincerely,

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