# Candidacy Examination

Question 2: How has the understanding of "soil health" changed over time and how has this influenced, or manifested within, a Canadian public policy context?

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*Each soil is an individual body of nature, possessing its own character, life history, and powers to support plants and animals.*

~Hans Jenny, Meeting the Expectations of the Land

## *1. Introduction*

The health of humanity rests on the health of our soils. The language used to describe soils has the power to connect individuals and communities, inspiring action that can regenerate and sustain ecosystems, and be codified in policy and practice (Brevik et al., 2017). Definitions are often a starting point for shared understanding, and for soils, these definitions position the topic for potential consideration as a social, environmental, or economic priority that can be included in public policy. The capacity of soils to deliver ecosystem services (MEA, 2005), including contributions to climate change mitigation and adaptation has raised the profile of soils as a strategic priority for farmers, governments, corporations and communities alike (Equiterre, 2021). Soils are transdisciplinary by nature, and policy paradigms are shifting in real time, with the potential to bridge fragmented interests and communities on regional, national and global scales (Dubé, 2014).

The idea of a relationship between healthy soils and healthy society has been considered for thousands of years (Montgomery, 2012). In 1400 BCE, Moses sent scouts to seek fertile soil for his people (Brevik and Pereg, 2017). It was the fertility of soil that led to an abundance of food above the sustenance needs of the population of Uruk in Mesopotamia in 3000 BCE, from which grew fundamental concepts of society, including private property, the stratification and specialization of roles, the creation of administrative governance bodies (with resulting policies), and the support for militias, wars, and empire building (Montgomery, 2012). In this way, soils have been part of social and policy development for much of human history.

The way soil is described reflects the ways soil is valued, and plays a role in how it is treated, conserved and measured. The opportunity to understand soils as central to systems change in the face of a changing climate is emerging in tandem with a shifting understanding of the meaning and value of the term "soil health" (Janzen et al., 2021). A critical evolution in the definition of soils over the last 150 years is the transition from soils being seen as inert or passive substances with value primarily arising from its role in resource extraction, to soils being considered as a ‘vital living system’ with a broad range of potential values (Appendix A).

The language used to describe soils is evolving on a global stage, as the nature of this complex three-dimensional body is described in increasing detail on micro- and macro-scales. Academics and organizations focused on this subject are sharing new discoveries and new ways of thinking, particularly in regard to the soil biome, discoveries that reshape our understanding of the complexity of these systems, and confirm the interdependence of humans and natural systems through the myriad biotic and abiotic cycles that intersect with soils (Kemper et al., 2017, Sojka et al., 2003, Kibblewhite et al., 2008).

The health of soils is context-dependent, and subjective based on the observer. In the Canadian policy context, soils have been valued for their contributions to a variety of policy objectives over time, from defense and immigration pre-confederation to provisioning, economic trade, and risk management objectives that dominate current policy approaches (Fowke 1945, AAFC, 2022a, Skogstad, 2008). Responsibility for soils is shared between federal, provincial and territorial governments, with activities undertaken in various departments, primarily agriculture, environment, and climate change. Efforts towards soil policy coherence and measurement are challenged by entrenched and siloed economic and industrial interests, alongside divergent regional and commodity specific considerations (Dubé, 2014, Berry, 1977).

This critical analysis presents an overview of the understanding of soil health over time and its manifestation within a Canadian public policy context, beginning with a summary of the history of Canadian soil policies, both nationally and as a result of global influences. This is followed by a summary of changes in soil health concepts over time, and a discussion of how the evolution of our understanding has manifested in the present day policy context including regional approaches and measurement frameworks.

***2. Early policy objectives for Canadian soils relate to defense, provisioning and immigration***

Globally there are deep roots of exploitation, conquerors and victims in our policies and practices relating to soils (Berry, 1977). The concepts, definitions, ideas and understandings of soil's value in the Canadian context have changed dramatically since the *British North America Act* created the Dominion of Canada in 1867 (Fowke, 1945).

Until the early twentieth century, soil was primarily considered as an enticement tool to attract European immigrants to pursue and develop agricultural and commercial interests in Canada. In 1841, under the *Public Lands Act*, the governor of the day was authorized to issue 50 acre parcels to new immigrants (Fowke, 1945). Initial responsibilities of the Bureau of Agriculture (est. 1852) were to receive patents for innovation, conduct registration statistics, and collect information to support immigration for agricultural development (Fowke, 1945). Under the 1872 *Dominion Lands Act,* the government authorized 100,000 acre grazing leases in the Canadian foothills for commercial cattle, around the same time that reservation schemes displaced Indigenous peoples from their traditional territories (Fowke, 1945). During this period, soil was valued for its capacity to attract immigrants, provision new colonies and advance old world interests. In part due to its historic role in immigration and regional economic development, Canadian policies related to soils, particularly agricultural soils, lack coherence (Equiterre, 2021, Bradford and Wolfe, 2013, Fowke, 1952).

In its early history, Canadian soils produced wheat and timber for internal and export markets, staples that had economic implications for resource and community development (Innes, 1933, Watkins, 1963). Soils were treated as a substrate on which to achieve productivity and profitability. It was only after the great war of 1914-18, when soldiers were re-established with quarter section parcels of land (160 acres, 65 hectares), that Canada became more selective about their issuance of soil/land grants (Fowke, 1945). A reliance on resource extraction and export of primary resources from soil manifested in a boom and bust cycle for communities and regions at various rates of growth and decline over time (Brannen et al., 2009; Halseth et al., 2009).

Agricultural activities and rural economies in Canada reached their peak policy influence in 1900-1925 (Fowke, 1945), leading to the 1912 *Canada Grain Act*, the 1913 *Agriculture Instruction Act*, and the establishment of the Wheat Board. After this period, industry-based (rather than soil-based) economies began to contribute more to the national gross domestic product (GDP). Rural outmigration along with global trade intensification saw a restructuring of agriculture's role as a support to industrialization of other sectors to grow the economy overall, resulting in a proliferation of trade agreements, and a shift towards market liberalization (Dubé, 2014, Wiebe, 2022, Williamson, 1985). Overall this led to a relative decline in the role and value of soil at a national policy level, and a fragmentation of soils and their relationship to concepts of human health and economic development (Brevik and Saure, 2015, Finnigan, 2019).

### *3. Canadian national soil policy objectives and language are shaped by global influences*

Global influences are relevant to and have shaped Canadian soil policies and concepts of soil health over time. For example, food shortages arising from the second world war united Europe in a common goal of food security, an interest that is integrated into European trade agreements with Canada today, and is central to ongoing strategic agreements (European Commission, 2002, FAO, 2015, Skogstad, 2008).

Global soil health policies and programs are relevant to Canada, including the United Nations (UN) Food and Agricultural Organization (FAO) Global Soil Partnership, which prioritizes the governance of soil as critical to economic, environmental and social outcomes, and the European Union Green Deal, which focuses on the role of soils to achieve climate neutrality by 2050.

In 2015, member countries of the FAO, including Canada, adopted the World Soil Charter. This document calls on nations to manage soils through sustainable agriculture as a lever for climate regulation, ecosystem services and biodiversity (FAO, 2015). These commitments are reflected in a private members bill currently being advanced through the House of Commons of Canada, Bill C-290, to develop a national strategy to promote efforts across Canada to conserve and improve the health of soil, including introducing national reporting requirements (House of Commons of Canada, 2021).

Soils are linked to critical global issues such as producing food for a growing population, ensuring air and water quality in a changing climate, and disease prevention and control, priorities addressed in the 2018 UN Sustainable Development Goals (SDGs). Within the 17 goals, there are multiple sub-objectives, four of which include soil (emphasis added):

> *Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture*
>
> > ***2.4*** *By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and* ***soil*** *quality*
>
> *Goal 3. Ensure healthy lives and promote well-being for all at all ages*
>
> > ***3.9*** *By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and* ***soil*** *pollution and contamination*
>
> *Goal 12. Ensure sustainable consumption and production patterns*
>
> > ***12.4*** *By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and* ***soil*** *in order to minimize their adverse impacts on human health and the environment*
>
> *Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*
>
> > ***15.3*** *By 2030, combat desertification, restore degraded land and* ***soil****, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world*

It is noteworthy that in almost all instances, the word "soil" comes at the end of these statements. The SDGs have been criticized for not sufficiently recognizing the importance of soils to the achievement of the ambitious targets set in this document (Adhikari, 2016), and implementation and measurement of these objectives is a challenge (Bonfante, et al., 2020).

Valuation of the ecological goods and services (EG&S) of soils to support policy development has been attempted globally. The Millennium Ecosystem Assessment (MEA) released in 2005 describes wide ranging goods and services provided by ecological systems (including soils) as:

(i) provisioning (food, fibre, fuel, biodiversity),
(ii) regulating (climate, gas and water regulation, erosion, carbon sequestration),
(iii) cultural (recreation, sense of place), and
(iv) supporting (soil formation, nutrient cycling, habitat).

Soils provide goods and services in all four categories. The vast majority of research studying soils and EG&S (75 percent of papers between 1975-2014) focuses on regulating and provisioning services of soils (Adhikari, 2015). Soil biology plays a particularly important role in supporting soil functions such as nutrient cycling, biodiversity, and habitat creation, and these are some of the least understood and least measured mechanisms connected to EG&S (Brussaard, 1997, Wall et al., 2012).

Other global classification schemes have emerged to translate the value provided by soils and ecosystem services into languages that are relevant for broader audiences, including policy makers, such as the Economics of Ecosystems and Biodiversity (TEEB, 2010), and the Common International Classification of Ecosystem Services (CICES, 2011). While the language describing the value of soils in terms of their goods and services continues to evolve, soils are underrepresented and overlooked in ecosystem evaluations and policy-level decisions (Daily, Matson and Vitousek, 1997).

The emergence of the concept of soil health forces the valuation of soil's goods and services beyond something strictly economic, although some have described such a valuation as "incalculable" (Daily, Matson, and Vitousek, 1997). Given that economic considerations often drive the systems and structures that rely on soils (e.g. food systems and supply chains), it should not be surprising to see soil referred to as "natural capital" (Dominati, Patterson, Mackay, 2010), and to see economic valuations assessed. Costanza et. al. (1997) used an economic model and literature review to estimate the value of goods and services offered by terrestrial ecosystems at US $12 trillion annually.

Because economic arguments are framed in a language that crosses cultural and jurisdictional boundaries, financial considerations have historically been used to drive policy discussions and soil management decisions for farmers. Social and environmental values lag behind in policy and soil concepts, partly due to the complexity of assessment and valuation (Bünemann, 2018). The ideas of soil valuation and measurement lose shape in the context of complex biological systems, especially when those biological systems include humans, who depending on their context, may require different policy responses and levels of support (Dubé, 2014).

***4. Soil definitions have evolved towards complexity, reflecting changes in purposes and philosophies***

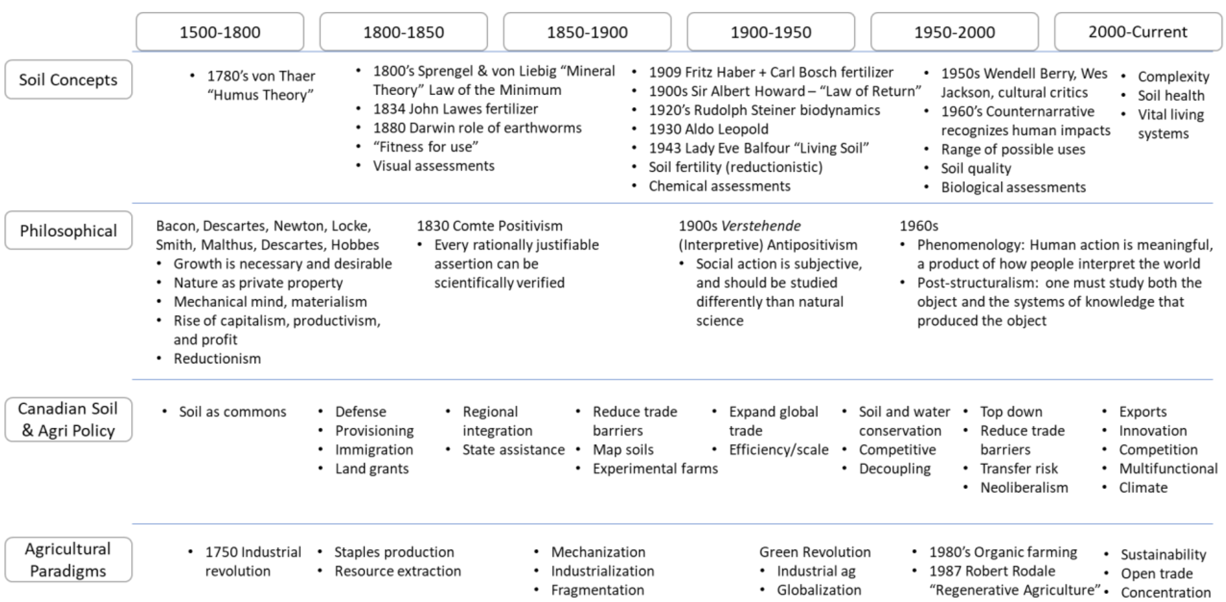
The value placed on soils to support policy objectives has changed over time. This has manifested in different language, definitions and concepts of soil health, which have set the parameters for how to baseline and measure the impact of changing practices over time. In general, the evolution of the concept of soil health has transitioned from "soil as resource" to "soil as vital living system" (Appendix A).

Soil is unique among comparable natural substances, such as air and water, whose definitions tend to focus on single parameters such as pollution. The understanding of soils as dynamic and complex has led to conceptual definitions and metaphors that reflect relationships with other parts of the natural world. Soils are part water, part air, part inorganic and organic materials, and part living organisms (Brady and Weil, 2019).

The evolution of language towards soils as complex has not been a linear process (Figure 1). Early concepts of soil described its "fertility", including von Thaer's humus theory. Howard's

Law of Return (1945, 2011), and Balfour, Leopold and Steiner's contributions recognized the inherent cyclical and connected properties of soils and their roles in broader systems (Brevik and Pereg, 2017). These systems-based concepts competed with reductionist thinking (using the same soil fertility term) arising from the Newtonian view of the world, such as von Liebig's Law of the Minimum, and a focus on the chemical and physical properties of soil (Brevik and Saure, 2015). In a broad sense, metaphors and definitions used to describe components of soils have shifted over time from a focus on observable chemical/physical parameters to a broader concept of interconnectedness and vitality (Janzen et al., 2021). This has led some to describe and label various soil definitions as either reductionistic, considering the "fitness for use" of chemical, physical and biological aspects of soil, or "integrated," considering potential emergent properties of complex living systems (Kibblewhite, 2008, Appendix A).

*Figure 1. High level timeline of the evolving paradigms and concepts related to soils, philosophies, Canadian soil and agricultural (agri) policies and agricultural paradigms from the 1500s to present day.*




As the levels of human intervention in soil ecosystems began to manifest in changes to its capacity to produce food, the shift to consideration of a 'range of possible uses' for soils arose in the 1970s alongside a new term, soil quality. This term recognized that soils play a broader multifunctional role in biosphere function and biological productivity, such as nutrient cycling and waste management (Smith et al., 2013, Bünemann et al., 2018). Over time, some criticism of this concept emerged in debates about the terms ability to reflect soil's capacity for simultaneous functions (Letey et al., 2003) and the potential for the term to be misunderstood in policy applications and measurement (Sojka et al., 1999, Sojka et al., 2003).

The term "soil health" emerged near the end of the 20$^{th}$ century (Appendix A), and is often used interchangeably with soil quality. Now ubiquitous, soil health is a conceptual metaphor that draws on the holistic role of soils in broader systems, one which conveys fragility, functionality, vitality, ambiguity, and sustainability (Janzen et al., 2021). It is important to note that despite "health" being included in this definition of soil, research continues to be oriented towards the potential harm created by soils in most investigations between soil health and human health, such as the role of pathogens and toxic chemicals (Brevik and Saure, 2015, Brevik and Pereg, 2017, Kemper et al., 2017).

As shown in Figure 1, the evolution of intensive agriculture mirrors an evolution in soil use concepts and language (Warkentin and Fletcher, 1977). With some exceptions, early definitions of soil fertility were typically reductionistic, and emphasized soil's capability to support agricultural or engineering activities for human benefit. This was especially true as soils became a means to an economic end through the increased use of chemical fertilizers, the Green Revolution and the expansion of global trade, building on policies and philosophies that privileged capitalism, individualism, productivism and profit (Conway, 1997, Montgomery, 2012, Berry, 1977, Monbiot, 2016, Monbiot, 2022).

As human and economic development accelerated population growth and living standards, western-centric industrial patterns and siloed thinking shifted governance and language away from systems approaches where soils were seen as common property, towards empirical, rational considerations to address specific social, political and economic priorities (Dubé, 2014). The foundations for this shift were laid in the 1750s in the industrial revolution and mechanical view of the world described by Newton and Smith, among others. The development of modern chemistry, particularly after the second world war, transformed the value of soil in its use for food production (Sage, 2012), which socially oriented humans towards a position of dominance over the environment, creating competition amongst individuals and nations in a global market

(Berry, 1977). Increases in large-scale mechanised monoculture production for this use combined with a reliance on chemical fertilizers and biocides to resulted in increases in yields and on-farm labour efficiency, further entrenching this reductionistic purpose of soil in social, environmental and economic systems (Sage, 2012, Weis, 2022, Monbiot, 2022, Jackson, 1985, Berry, 1977).

As the broader values of soils have been acknowledged, and the role of humans in the health of soils has been described, philosophies and policies have shifted in parallel ways (Wiebe, 2022). As shown in Figure 1, the evolution of soil health language through time parallels a shift in the emergence of philosophical positions. Positivism, which requires scientific certainty and observations to make an assertion, encourages a reductionistic approach to soil concepts, focusing on observable chemical and physical attributes. Interpretive anti-positivism separated systems of evaluation between social and natural science, mirroring a fracturing of scientific disciplines (Bryman, 2012). Approaches have evolved over time to include phenomenology and post-structuralist recognitions that "to understand an object (e.g., a soil), one must study both the object itself and the systems of knowledge that produced the object", allowing for integrated approaches to soil health assessments to emerge (Bryman, 2012, Raulet, 1983).

***5. Policies of trade and market liberalization have put production pressure on Canadian soils***

The original soil policies of Canada related to provisioning regional colonies and old world interests (Fowke, 1945) have continued in the form of market liberal trade agreements which extract increasing yield from agricultural soils for economic gains (Skogstad, 2008). Primary agriculture is described by AAFC (2022b) as an "economic driver" for Canada, achieved through almost 190,000 farms on 62.2 million hectares (6.3 percent of Canada's total land area).

As of December 2022, Canada was a signatory to 102 trade agreements, and provided exports to over 200 countries (Government of Canada, 2022). According to Statistics Canada, in 2021 Canada exported nearly $82.2 billion in agriculture and food products (including raw agricultural materials, fish and seafood, and processed foods) (AAFC, 2022a), making it the fifth-largest exporter of agri-food and seafood in the world.

The increasing focus on scale and efficiency for global export markets has contributed to the growth of the average size of Canadian farms, from 463 acres in 1971 to 820 acres in 2016 (Statistics Canada, 2017). Larger farms tend to be heavily capitalized and receive the majority of public farm subsidies. Between 1981 and 2021, the number of Canadian farms decreased by 40 percent, and the top 10 percent of Canadian farms generated over two thirds of all farm revenue (Statistics Canada, 2022a, AAFC, 2022b).

The context of global market consolidation and corporate concentration affects all aspects of the agri-business sector and soil policy in Canada, including wholesaling, retailing, processing, farm inputs and transportation (Sage, 2012, Howard, 2016; Magdoff and Tokar, 2009, MacRae, 2020). Competition arising from corporate concentration and trade agreements puts downward pressure on commodity prices, and farmers have absorbed financial losses and risks arising from fluctuating markets, forcing a prioritization of mechanization and efficiency within operations, often at the cost of soil health and environmental priorities (Wiebe, 2022).

Corporate consolidation and concentration associated with reductionistic soil health priorities also shapes federal government policy supports to agricultural producers. Skogstad (2008) describes Canada's shift from a state assistance model of income stabilization and protection to a competitive model that steadily transfers risk from consumers to producers. In the 2001 Doha round of World Trade Organization negotiations, the Canadian national interest in stabilizing farm incomes through supply management programs was criticized as "redistributing wealth from consumers to producers" (Skogstad, 2008).

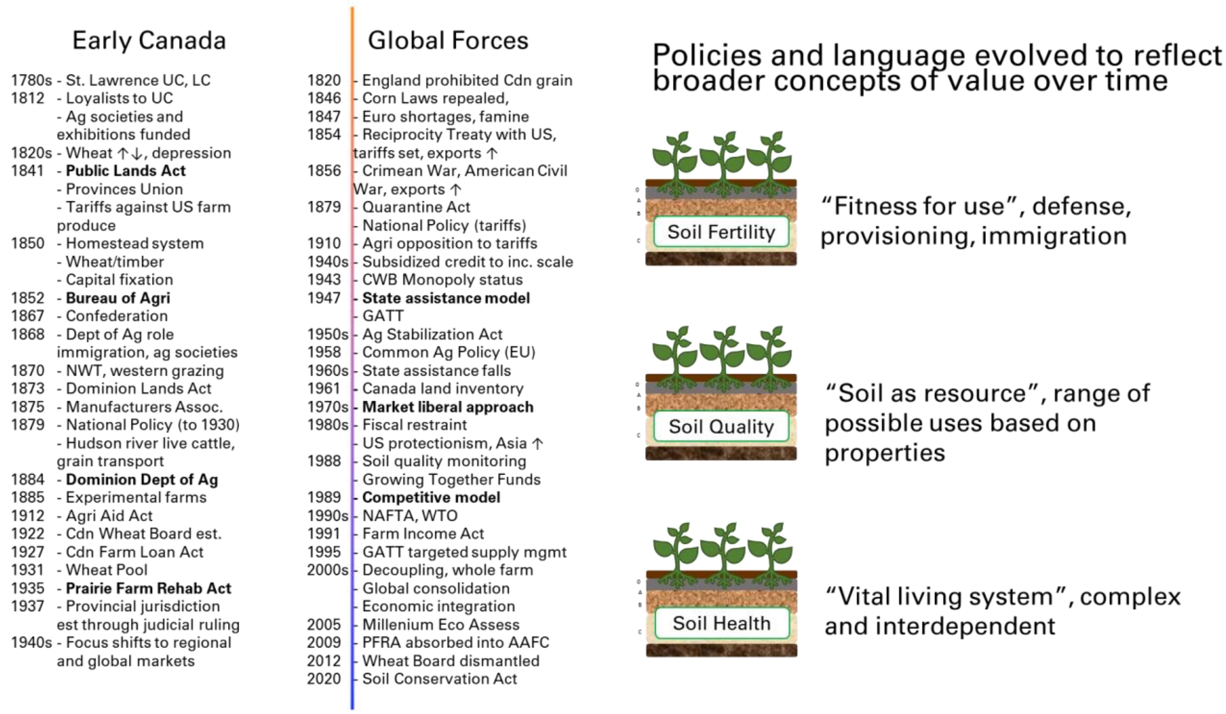
The market orientation of Canadian agricultural policies has prioritized "self-reliant" aka "market-responsive" agriculture in trade agreements, which has steadily eroded supply managed commodities such as wheat and barley, and reduced social supports for farmers and communities (Skogstad, 2008, Berry, 1977, Monbiot, 2022). This has included the elimination of income stabilization tools, export subsidies for grain and industrial milk, the closure of the branch lines of the Canadian Pacific Railway and the Canadian Wheat Board, and the decoupling of risk management and safety net programs to the farm level (Skogstad, 2008).

At times, soil health has taken centre stage to achieve economic objectives for Canada. In 1935, the *Prairie Farm Rehabilitation Act* was passed, resulting in the creation of the federal Prairie Farm Rehabilitation Administration, with responsibility for improving soil health in response to drought and the subsequent dust bowl that affected North American producers. In 1984, the Standing Committee on Agriculture, Fisheries and Forestry created an influential report titled Soil at Risk: Canada's Eroding Future (Canada, 1984). The report clarified the national importance of agricultural soils, including risks of degradation across all regions of the country. Soil health was recognized as a driver of economic yields and ecological services, and as a result, vast regions of the Prairie provinces adopted soil building practices such as reduced tillage.

Despite this example, alongside market liberalization efforts in the 1990s, provincial agricultural extension resources and research stations were closed, limiting access to variety trials and practical information on soil health for farmers across the country. A fragmented suite of private sector certifications and extension resources for soil health do exist, although access and support are not accessed equally, and resources are often designed to achieve commercial ends, rather than environmental, social, or public health goals (Equiterre, 2021).

As shown in Figure 2, the shift from a state assistance model of policy assistance to a competitive model in support of global trade agreements has persisted despite a changing understanding of soil concepts and valuation over time. The paradigm of export-oriented agricultural policy embraced by the Canadian government is resilient, in part because the policy failures of this approach are not obvious (e.g. environmental issues occur in remote and rural areas) (Skogstad, 2008). This approach is also enabled by global trade agreements, which uphold traditions of statist trade liberalization, and are slow to adapt to emerging concepts and priorities.

*Figure 2. Overview of the soil related policies influencing the Canadian context both regionally and internationally, alongside a description of the changing language to describe soils over this period.*




## *6. Regional opportunities for soil health integration in policy and practice*

The diversity of geographies and commodities in Canada necessitates a soil policy environment that enables context-and subject-specific actions. The regionality of the Canadian political economy, in combination with the development of secondary industrial staples such as power and metals, has steadily shifted power to provinces and territories to manage their unique soil resources and economic development priorities (Fowke, 1952, Bradford and Wolfe, 2013). This regional distribution is administered through five-year federal-provincial-territorial agreements for agriculture, established within a broad strategic framework of national priorities called Canadian Agricultural Partnership (CAP), valued at over $3 billion from 2013-2023.

Under CAP, most regions deliver some form of an Environmental Farm Plan (EFP) and Beneficial Management Practices (BMP) cost-share program, encouraging the adoption of soil building practices that draw on common principles and guidance developed by Agriculture and Agri-Foods Canada (AAFC). With the exception of EFP/BMP programs, the focus of CAP is economic growth and technical innovation, rather than environmental and social objectives (AAFC, 2022). The AAFC Agricultural Strategy Discussion Paper (2022) for the next round of CAP funded agreements with provinces and territories starting in 2023 uses the term soil fertility interchangeably with soil health, suggesting that language and understanding of soil concepts are continuing to evolve and not yet consistently applied within the federal policy context.

Agriculture is not the only department with an interest in soil health. Canadian climate policies and programs are guided by the Environment and Climate Change Pan Canadian Framework on Clean Growth and Climate Change (Environment and Climate Change Canada, 2016) and the new climate change mitigation plan “A Healthy Environment and A Healthy Economy” (Environment and Climate Change Canada, 2020). While agricultural soils are noted in these documents for their potential in supporting climate adaptation and mitigation priorities, and high level activities are provided, strategies and programs for agricultural soils and climate change are lacking, at both the federal and provincial level (Equiterre, 2021). Other departments that often hold responsibility for policies and programs that relate to soils include forestry, mining, water and waste management. There are opportunities to align and integrate these approaches.

### *7. Measurement as a means of understanding how soil health is prioritized in policy*

Shifts in measurements of soil health tend to reflect an evolving understanding of the perceived value of soils and a translation of soil health concepts in practical terms. The earliest official measurements and classifications of soil in Canada were made in 1873, when the Department of the Interior established the Dominion Lands Branch survey to support soil mapping for immigration and defense purposes. Before 1970, visual assessments of soil were common, and were primarily conducted to assess the suitability for crop growth and productivity.

The methods for soil assessment proliferated in the 1980s and 90s, and soil quality test kits became widely available and used to inform management decisions. The focus of these measures expanded slightly to include the environment, plant and human health (Bünemann et al., 2018). In 1988, Canada was one of the first international jurisdictions to institute a national soil quality monitoring program, in part to assess risks to soil, including erosion, salinization, and loss of organic matter (Acton and Gregorich, 1995). From 2010 onwards, the focus of measurement has shifted from minimum data sets to novel indicators based on high-throughput digital assessment methods, and interactive design and end user engagement (Bünemann et al., 2018). Given the diversity of soils and production practices across Canada, creating a comprehensive set of "reference soils" has been a persistent challenge (Bünemann et al., 2018).

It is tempting to reduce the definition of soils to a single or simple metric, but this necessitates assumptions about the ability of this metric to reflect the complexity of the broader system. How exactly does one measure a 'vital living system?' Classification according to physical and chemical parameters is a functional exercise, and measuring complex systems is challenging. Traditional scientific approaches that focus on single variables in quantitative analysis tend to provide meaningful data within a limited range, and the cross-disciplinarity of soil health challenges communication (Brevik and Saure, 2015). In order to simplify the definitions and discussions around measurements, a recent review of the methods and techniques to assess and describe soil health specifically excluded any measures related to non-ecological functions, such as acting as a source of biodiversity and cultural heritage (Bünemann, 2018).

With the fragmentation of academic disciplines (Berry, 1977, Monbiot, 2022), many of the systems that have been created to describe and seek insights into the complex inner workings of soils, soil organisms, plants, foods, ecosystems, and human health require the student to immerse themselves within the minutiae of each individual subject independently. The language and measurement systems within each of these disciplines is often fragmented, inconsistent, and human centric (Dubé, 2014). The translation of these understandings across disciplines remains a barrier to common policies and valuations of soil for policy and measurement purposes.

Finally, national policy interests remain regional and commodity specific, and as a result, Canada lacks a common voice to clarify and advance policy intentions and measurement frameworks on the global stage (Skogstad, 2008). Soil mapping, modelling and inventory initiatives are relatively common in the European Union, and seen as a starting place to enable future soil policy discussion and development (Maes et al., 2012).

**Appendix A**: Consolidated list of soil terminology and definitions over time.

| Date | Author | Name | Definition |
|---|---|---|---|
| 1971 | Mausel | Soil quality | The ability of soils to yield corn, soybeans and wheat under conditions of high-level management. |
| 1987 | Soil Science Society of America (SSSA) | Soil quality | The inherent attributes of soils that are inferred from soil characteristics or indirect observation. (described in Bünemann et al., 2018). |
| 1991 | Larson & Pierce | Soil quality | The ability of the soil (i) to accept, hold, and release nutrients and other chemical constituents; (ii) to accept, hold, and release water to plants and surface and ground water recharge; (iii) to promote and sustain root growth; (iv) to maintain suitable soil biotic habitat; and (v) to respond to management and resist degradation. |
| 1993 | Lal | Soil quality | Inherent attributes of soil and characteristics and processes that determine the soil's capacity to produce economic goods and services and regulate the environments. |
| 1994 | Larson & Pierce | Soil quality | The capacity of a soil to function within its ecosystem boundaries and interact positively with the environment external to that ecosystem. |
| 1994, 1996 | Doran and Parkin | Soil quality | The capacity of a soil to function within ecosystem and land use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health. |
| 1995 | Acton & Gregorich | Soil health/ quality | The soil's fitness to support crop growth without becoming degraded or otherwise harming the environment. |
| 1997 | Karlen et al. | Soil quality | The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain or enhance water and air quality, and support human health and habitation. |
| 1997 | Doran & Safley | Soil health/ quality | The continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal and human health. |
| 2000 | Doran and Zeiss | Soil quality | Capacity of the soil to function as a vital living system to sustain biological productivity, maintain environmental quality and promote plant, animal and human health. |
| 2008 | Kibblewhite et al. | Soil health | A healthy agricultural soil is one that is capable of supporting the production of food and fibre, to a level and with a quality sufficient to meet human requirements, together with continued delivery of other ecosystem services that are essential for maintenance of the quality of life for humans and the conservation of biodiversity. |
| 2017 | Bouma et al. | Soil capability | The intrinsic capability of a soil to contribute to ecosystem services, including biomass production. |
| 2019 | Brady & Weil | Soil health | The state of self-regulation, stability, resilience, and lack of stress symptoms in a soil as an ecosystem of living organisms that supports the growth of plants. Sometimes |

| Date | Author | Name | Definition |
| --- | --- | --- | --- |
| | | | used synonymously with soil quality, but usually focused on the plant growth supporting function of soil. |
| 2020 | United Nations Inter-governmental Technical Panel on Soils | Soil health | The ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems. |
| 2021 | Janzen, Janzen and Gregorich | Soil health | The vitality of a soil in sustaining the ecological functions of its enfolding land. |
| 2022 | United Nations Global Soil Partnership | Soil fertility | The ability of a soil to sustain plant growth by providing essential plant nutrients and favorable chemical, physical, and biological characteristics as a habitat for plant growth. |
| 2022 | United States Department of Agriculture, Natural Resource Conservation Services (USDA NRCS) | Soil health/ quality | The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. |

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