Sustaining Ontario's Agricultural Soils:

Towards a Shared Vision

2016

Ontario

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Minister's Message to Ontarians

Healthy soil is the basis for a strong, sustainable agri-food system. Healthy soils support the production of healthy food which in turn contributes to healthy Ontarians and a strong economy. All Ontarian's benefit from healthy soil through the local foods we all enjoy, the raw materials we need to develop our bioeconomy, and the environmental benefits that farmers provided through their stewardship of Ontario's rich agricultural lands.

That is why I'm pleased to invite you to participate in the creation of a strategy to enhance the health of agricultural soils. *Sustaining Ontario's Agricultural Soils* is a discussion document that begins the conversation on the collective efforts needed by government and stakeholders to support and improve agricultural soil health.

Soil health, climate change, water quality and food security are closely linked and collective efforts are needed to address these issues. Ontario farmers are stewards of the environment — they understand that protecting the health of our soils will help ensure that Ontario has the capacity to feed a growing provincial and world population. The Ontario Ministry of Agriculture, Food and Rural Affairs is working with farmers and other partners to create a soil strategy that will grow and sustain Ontario's strong agricultural sector, protect the environment and address issues around resilience to climate change.

Our government believes that improving soil health can help mitigate the impact of climate change by reducing greenhouse gas emissions and helping sequester carbon. A soil strategy will help the agricultural sector adapt to a changing climate, find more opportunities to reduce greenhouse gas pollution, and lay the groundwork for potential participation in Ontario's carbon offset market. As such, the importance of long-term soil health is featured in our government's recently released Climate Change Action Plan and our government intends to provide up to $30 million in funding to support soil health initiatives.

Your input will help our government determine how to best use resources and work with stakeholders to improve soil health and mitigate and support the fight against climate change.

I look forward to working with you towards a shared vision: healthy soil – it's good for food, it's good for life and it's good for the future.

Jeff Leal
Minister of Agriculture, Food and Rural Affairs

Sustaining Ontario's Agricultural Soils: Towards a Shared Vision

Introduction: Healthy Soil – For Food, For Life, For the Future

Healthy agricultural soil is a living and dynamic ecosystem, and one of the foundations of life. Wise management can ensure the soil is fertile and full of the living organisms that are essential to grow food and other agricultural products, now and for future generations. It takes many years for natural processes to make healthy soil, and very little time to destroy it, so thoughtful stewardship is a must.

Productive soils are critical to the environmental and economic sustainability of Ontario's agri-food industry. In 2014, Ontario's farmers brought in more than $12.7 billion in farm cash receipts - more than 20 per cent of the Canadian total. In the same year, the gross domestic product (GDP) from the industry was $35 billion. Our rural communities support and depend on a robust and thriving agricultural sector - and healthy soil is at its foundation.

Even being so critical to agriculture production and the environment, Ontario's agricultural soil is under increasing stress:

- Increasing demands on soils to grow food for an increasing provincial and global population.
- Changes in cropping, tillage and other practices may be affecting soil health.
- Climate change is bringing extreme wet weather and drought events that increase soil erosion. Extreme temperature swings may also increase stress on soil and crops.
- Water quality issues, especially in the Great Lakes, are linked to contributions from farm runoff (e.g. nutrients and pesticides).

Healthy agricultural soil is the linchpin for producing not only local food and other products, but also to feed a growing global population. Better soil health helps us deal with climate change and weather extremes, and improves our water quality. Healthy soil retains water and nutrients, reducing runoff that can pollute our waterways. Agricultural crops take greenhouse gas from the atmosphere and can build much-needed carbon in soil organic matter. Exciting new research shows that diverse soil ecosystems can often actually increase the number of beneficial insects, fungi and other organisms while sometimes reducing agricultural pests.

Healthy soil is extremely important for all of us. That's why Ontario is committed to working collaboratively with farmers, industry and community partners and

Indigenous communities to develop a strategy that will sustain and support healthy soil so our land can be productive for us and well into the future. The Soil Strategy will build on existing environment stewardship partnerships like the Environmental Farm Plan.

This discussion document is intended to start the process. Part I provides a framework to help guide the public conversation around developing the strategy. Part II provides the technical background and analysis that support the framework laid out in Part I.

Everyone is welcome to provide input into the process. Just visit the Ontario Ministry of Agriculture, Food and Rural Affairs web site, the Environmental Registry or e-mail soilhealth@ontario.ca.

Part I – Towards an Agricultural Soil Health and Conservation Strategy

Taking Action

Like many other jurisdictions, Ontario is taking action to address these issues, so this vital resource continues to grow food and provide ecological benefits. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) is leading the development of an Agricultural Soil Health and Conservation Strategy (the 'soil strategy') with the help of Ontario's farm organizations, soil experts and other organizations with interests in soil health and conservation.

Early this year, OMAFRA announced that it was investing in improvements to its soil mapping. Ontario has some of the most productive agricultural land in Canada. Updated soils mapping and related information will support improved decision-making including the protection of our agricultural land base through the province's land use planning system.

Farm organizations work with governments and universities to understand trends in soil health and the effects of farm practices on the soil. Alongside their members, these agricultural organizations work co-operatively to develop methods for keeping soil healthy. Ensuring the health and conservation of Ontario's agricultural soils is a shared responsibility:

- Farmers are directly responsible for managing soil in their business.
- The agri-business sector provides farm-specific soil, fertility and production-related services to producers.
- Farm and conservation organizations help farmers and other landowners adopt best management practices.

- Universities and colleges provide research into soil science and management, adding to the knowledge needed for government and business to meet future soil needs. They also train new experts in soil science who can contribute to its proper conservation.
- Government develops policy, provides information to farmers on soil management, maintains soil data and mapping and monitors the state of soil.

The strategy should be designed and implemented collaboratively to be successful. Together, we will develop approaches that not only improve soil health, but also support the economic viability and environmental sustainability of farms.

OMAFRA is committed to building this important soil health and conservation partnership.

The Agricultural Soil Health and Conservation Strategy will be developed in three stages:

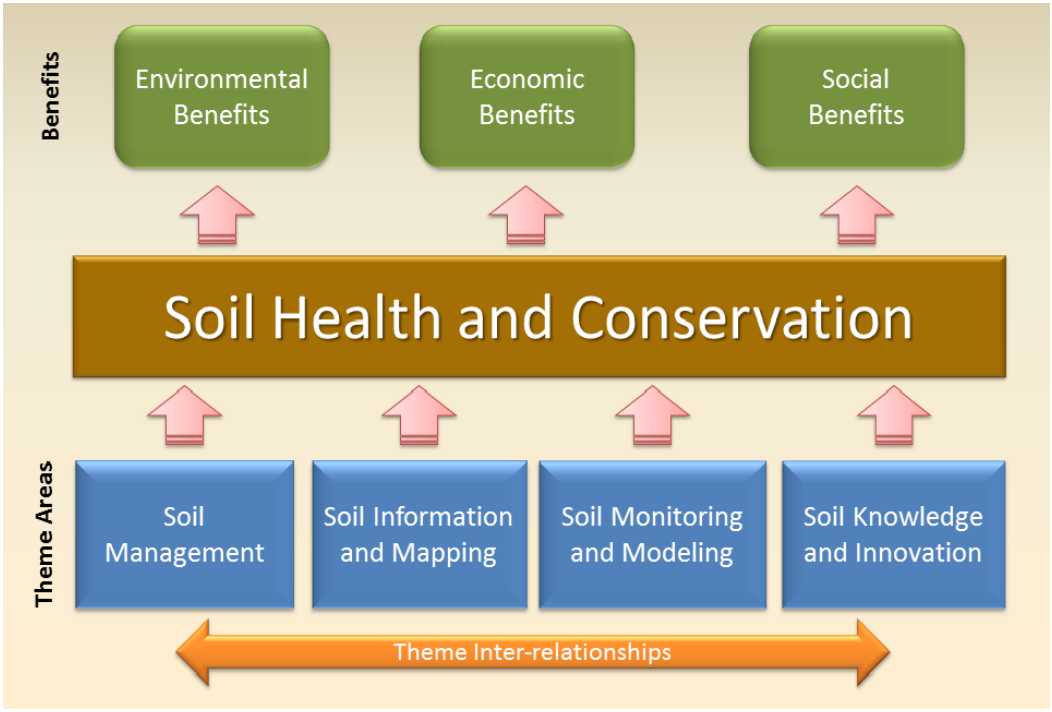
- The first stage includes using this discussion document to provide background to the issues and propose a draft vision, goals and objectives for the strategy. People are being asked to provide input to these elements.
- Stage two comes after comments have been received, OMAFRA will work with a working group (see page 14) with participants from the federal government, farm and commodity groups, conservation authorities, the Soil Conservation Council of Canada and the University of Guelph that will help develop a draft strategy document. The draft document will then be released for comment.
- Following the second consultation, the strategy will be finalized. That strategy will guide actions undertaken on soils by OMAFRA and other partners over the coming years.

How Will Ontario Benefit From The Strategy?

This shared strategy will align the collective efforts of farmers, governments, the agri-business sector, partner organizations and the education sector to build a sustainable future for Ontario's agricultural soils.

Healthy agricultural soils are essential in order to ensure ongoing productivity and competitiveness in Ontario's agri-food sector as well as food security for the province and the world. Both security of food supply and nutritional quality of foods can, in part, be influenced by soil health.

Soil health, climate change, water quality and food security are all linked together. These issues all reflect our need to evolve toward a sustainable and low-carbon economy. The soil strategy will support agricultural soil management practices that provide economic, environmental and social benefits to Ontario (see diagram on page 7). It will be an integral part of achieving the goals set out in other key Ontario initiatives, including Ontario's *Climate Change Strategy, Great Lakes Strategy* and *Draft Strategy for a Waste Free Ontario*. It will also complement but not duplicate other initiatives such as the proposed *Excess Soil Management Policy Framework* and *Biodiversity: It's in Our Nature*. The soil strategy deals exclusively with agricultural soils. Forest, wetland and urban soils are not included.



Long-term Benefits of Soil Health & Conservation

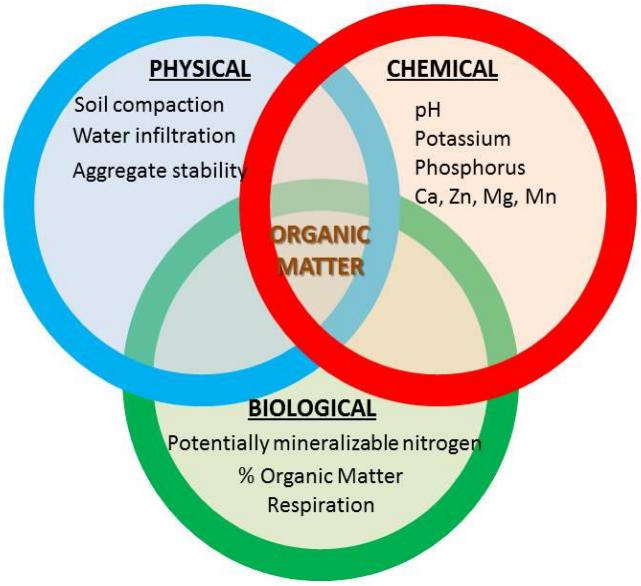
Environmental Benefits	Economic Benefits	Social Benefits
• Better water quality as nutrient and sediment runoff is minimized	• Sustained long-term farmland productivity	• Contribute to long-term security of local and global food supply
• Reduced gas emissions from soil organic matter and nitrogen fertilizers	• Long-term reduced on-farm input needs (e.g. supports pest suppression, nutrient cycling, water retention)	• Contribute to better food quality and nutrition
• Better resilience to climate change and extreme weather	• Contribute to long-term on-farm cost savings and profitability	
• Increased soil biodiversity		

What is Soil Health?

Soil health is an evolving concept defined as the "continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans" (Natural Resource Conservation Service, US Department of Agriculture).

More specifically in agriculture, it is defined as the soil's "fitness to support plant growth without becoming degraded or otherwise harming the environment" (Agriculture and Agri-Food Canada).

Components of Soil Health



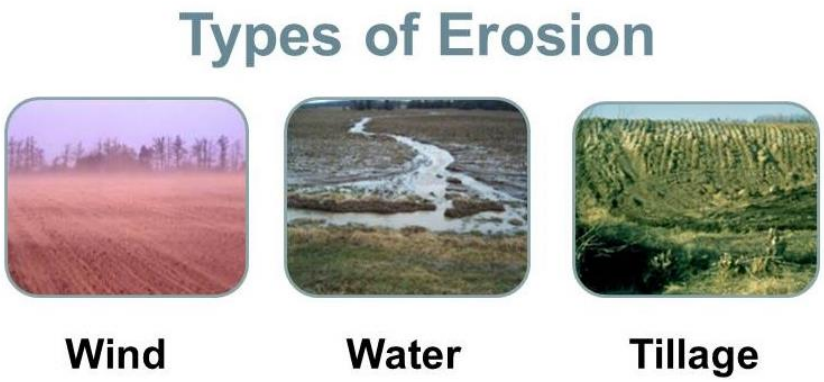
Soil health has physical, chemical and biological components (see illustration and Part II for more detail). It encompasses a soil's ability to:

- accept, hold, filter and release nutrients and water;
- promote and sustain plant root growth;
- maintain soil organic matter (carbon) and a biologically diverse soil life (e.g. worms, microbes, fungi);
- respond to management; and
- maintain its physical structure and resist degradation (for example, by erosion and compaction).

The flipside of soil health is soil degradation. Degradation includes lost soil aggregation, reduced organic matter, lost infiltration and water holding capacity and increased compaction. All contribute to reduced soil health and productivity as well as increased erosion.

What is Soil Erosion?

Soil erosion can be caused by one or more of three factors – tillage, water and wind. It is a key driver in degrading soils and affecting water quality. In Ontario, tillage erosion results in the greatest movement of soil, because of the combined effect of



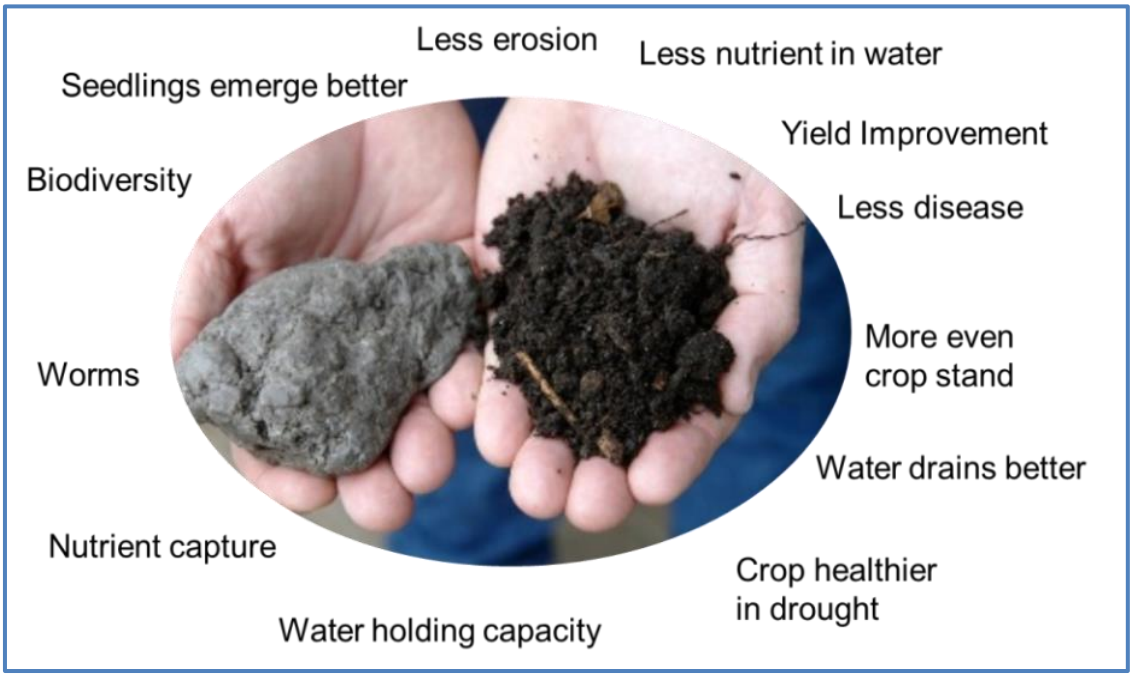
the soil disturbance and Ontario's sometimes gently sloping or hilly farmland. Tillage erosion is often unnoticed and constantly moves soil downslope on much of Ontario's agricultural landscape. Water and wind erosion move much less soil but the effect is more dramatic and water erosion in particular contributes to serious off-site water quality degradation. The erosion potential of Ontario's agricultural soils is significant – an estimated 54 per cent of Ontario's farmland is in an unsustainable erosion risk category (Agriculture and Agri-food Canada, see Resources, page 34).

Climate change is bringing more intense weather events to Ontario. Heavy rain storms put soils at an increased risk of erosion. With more potential for runoff outside the growing season, farmers really need to adapt to these new climate extremes. Most water erosion and nutrient runoff occurs during these major events.

Soil conservation has many benefits to the environment and to farm profitability. Soil erosion is estimated to cost Ontario farmers over $150 million annually. Less erosion means a reduction of sediment and nutrients entering nearby streams and rivers. As a result, water quality in rivers and lakes throughout a watershed should improve (e.g. reduced harmful algae, improved fish habitat). Best management practices such as crop rotation, no-till farming, planting cover crops, establishing windbreaks, buffer strips, erosion control measures and regular additions of organic amendments can reduce water erosion as well as maintain a soil's organic matter content.

Healthy Soil Benefits Farms and our Environment:

(Photo: Dan Hudson)



What is the Vision for the Future of Ontario's Agricultural Soils?

A draft future vision for Ontario's agricultural soils was prepared, by government and participants in the working group, to guide the Soil Strategy:

Draft Vision:
Healthy agricultural soils contribute to a productive economy, sustainable environment and thriving society.

Draft goals and objectives are proposed to guide development of the strategy with a focus on four important key theme areas (see diagram on page 7):

1. Soil Management;
2. Soil Information and Mapping;
3. Soil Monitoring and Modelling; and
4. Soil Knowledge and Innovation.

Key Theme Areas

Soil Management

On-farm soil management is a result of decisions farmers make. It is influenced by many factors including:

- cropping practices
- weather
- farm technology
- prices for different crop and livestock commodities
- costs of production
- profitability
- environmental issues
- government programs
- how much they know about best management practices.

These decisions can not only have impacts on soil health but other things such as water quality, climate change mitigation and adaptation.

Soil Management

Draft Long-Term Goal:

Soil management practices sustain and enhance soil health and productivity for societal, economic and environmental needs.

Draft Objectives:

- Soil health is sustained and improved to keep farmland productive.
- Soil erosion from tillage, water and wind is minimized.
- Soil is conserved to support production of, and access to, food and other products.
- Soil health is enhanced to improve water quality, reduce greenhouse gas emissions and address other environmental issues.

Management practices that have been shown to improve soil health include:

- using diverse crop rotations including perennial crops
- reduced-till or no-till practices
- planting cover crops
- using organic soil amendments
- implementing erosion control measures
- reducing soil compaction.

Possible actions:

- Further encourage farmers to assess soil health on their farms and adopt best practices like diverse crop rotations, cover crops and reduced tillage.
- Enhance research and boost technological innovation.

Soil Information and Mapping

Information on soil health is important to farmers for making decisions on crop choice, planting and management. Governments also depend on soil information to identify different areas of Ontario with the potential to produce different crops and livestock. Provincial and municipal land use planners need to know where high quality farmland is so they can protect it.

Soil Information and Mapping

Draft Long-Term Goal:

Reliable soils information and tools are available to allow for informed decision-making and analysis by producers, industry, government and the public.

Draft Objectives:

- Soil inventory data are well documented, replicable and defensible.
- Soil information is comprehensive, accessible, flexible and widely available.
- Accessible soil data provide for a wide range of analysis and decision-making.

Today, data can be collected quickly from on-board computers in farm equipment, smart phones and tablets. However, co-ordinating all that data and getting access to it is a challenge. In addition, many soil information maps are outdated.

Possible actions:

- Update soil inventories using contemporary methods with digital technology and remote sensing data (see Resources, page 34).
- Digitize some of the large amount of soil sample data and make it available for analysis.
- Make soil sampling data available through new open source digital tools for producers to inform their decision-making.

Soil Monitoring and Modelling

Farmers, government and other

Soil Monitoring and Modelling

Draft Long-Term Goal:

The health and status of Ontario's agricultural soils are tracked over time.

Draft Objectives:

- Capacity is developed to track changes in agricultural soil health, erosion and soil organic matter.
- Soil health and erosion monitoring is used to inform and evaluate policies and programs.

stakeholders need to know more about status of soil health in Ontario. Different tests and approaches are available to farmers to assess soil health, fertility and erosion on their land.

Agriculture and Agri-food Canada (AAFC) has developed agri-environmental indicators to assess changes in soil carbon, soil erosion risk and other factors at a national scale (see Part II, page 30). Overall, these indicators suggest that soil health and erosion risk are not improving in Ontario. They cannot be applied at the farm scale and their accuracy at a more detailed regional scale is limited. But these are the best indicators currently available for finding the status of soil conservation and health.

At the farm level, work is well advanced in creating a new suite of tools for soil health monitoring (see page 30).

But there are several gaps and challenges related to soil monitoring and modelling, including coordinating and accessing information, and applying current models to the provincial, regional and farm scales.

Possible action:

- Adapt the federal agri-environmental indicators to regional level.
- Make available a farm-scale soil health test for Ontario farms.

Soil Knowledge and Innovation

Soil knowledge, including training, education, and research, is crucial to the successful management of soil health and erosion at both the farm level and across Ontario. Farmers need access to the best knowledge in order to ensure competitiveness and

Soil Knowledge and Innovation

Draft Long-Term Goal:

Soil knowledge and skills are optimized to meet societal and economic needs and drive innovation.

Draft Objectives:

- Sustain human resource capacity in soils knowledge to meet priorities.
- The education sector supports programs for appropriate soils knowledge and skills.
- Ongoing research supports innovation in soil knowledge and management.
- Industry has access to people with soil-related knowledge and skills to meet client needs effectively and economically.
- Producers have access to the knowledge needed to maintain and enhance soil health.

productivity, while business, the education sector and government need access to well-trained professionals to contribute to and drive innovation in the field of soil health.

But there are challenges in the availability of the right kind of training and enough knowledgeable people to advance a soil health and conservation agenda.

Possible actions:

- New or revised training programs and courses at Ontario colleges and universities.
- New or revised ways to convey soil knowledge to farmers.

Partners Involved in this Initiative

In October 2015, OMAFRA invited a number of knowledgeable individuals from farm organizations, agri-food businesses, academia, conservation organizations and the federal government to participate in a collaborative Agricultural Soil Health and Conservation Working Group. We thank the working group for their efforts and dedication to the future of Ontario's soils.

The Working Group meets regularly and is canvassing the range of agricultural soil health and conservation issues to come to a common understanding of where we are now in terms of knowledge about our soils, their state of health, and where we need to go to ensure healthy and productive agricultural soils in Ontario over the long term. The Working Group participants provided input into this discussion paper and will play a central role in developing the soils strategy moving forward.

Providing Input: Questions to Consider

We are seeking people's feedback on the following key areas related to soil health and conservation:

- The draft vision, goals and objectives (Pages 10-13);
- Soil health and conservation trends, data and information;
- Potential actions to sustain and improve soil health.

As you review this document, please consider the questions outlined in the 'Feedback' box below. For your convenience, the questions are grouped by their associated themes, so you can quickly refer to the pertinent section for more information.

The ministry will engage key stakeholders, partners, the public and Indigenous peoples to discuss the proposals. Remember, comments can be provided through the

- OMAFRA web site,
- Environmental Registry,
- Email soilhealth@ontario.ca .
- Fax to 519-826-3492
- Mail:
  Agricultural Soil Health and Conservation Strategy
  Ministry of Agriculture, Food and Rural Affairs
  1 Stone Road West, 2nd floor
  Guelph, ON N1G 4Y2

Please Note: All comments and submissions received will become part of the public record. Comments received as part of the public participation process for this proposal will be considered by the decision maker for this proposal.

Your personal information may be used in the decision making process on this proposal and it may be used to contact you if clarification of your comment is required. It may be shared (along with your comment) with other Ontario Ministries for use in the decision making process. Questions about this collection should be directed to the address noted above.

Towards an Agricultural Soil Strategy

1. Do you think the draft vision, goals and objectives will lead us in the right direction regarding soils? If not, how might they be improved?

2. What top three actions could government, farm organizations, and the research and education community take to protect and conserve soil health over the long term?

Soil Management

3. What trends have you noticed in agricultural soil management practices over the past 10 years (tillage, cover crops, etc.)?

4. What do you think are the best practices for conserving soil health? How can government and soil experts best assist farmers in adopting best management practices?

Soil Information and Mapping

5. What specific types of information and tools are needed to help farmers, agri-business, municipalities, conservation authorities and governments make decisions about soils?

Soil Monitoring and Modelling

6. What kinds of tools do you think are needed to assess and monitor soil health and conservation in Ontario?

Soil Knowledge and Innovation

7. Beyond what's currently available, what kind of research, education and training should be put in place to produce the expert people and knowledge needed to help improve soil health?

8. What are the best ways to make information available to farmers to help them adopt best management practices for healthy soil and soil conservation?

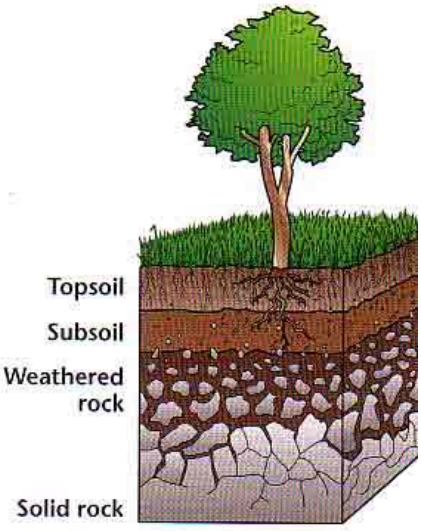
Part II - Technical Background

Part I of this discussion paper presented the framework proposed to guide the development of the agricultural soil health and conservation strategy for public review and comment. Part II provides technical background and analysis in support of Part I.

Agricultural Soils: A Global Perspective

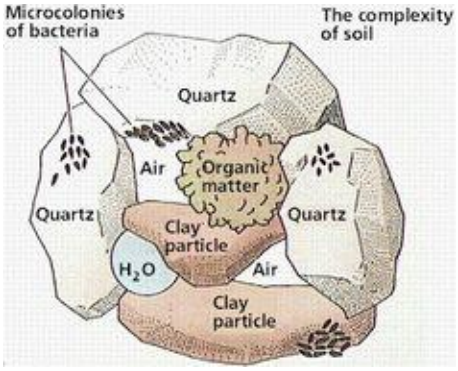
In its 2015 report, *The Status of the World's Soil Resources,* the Food and Agriculture Organization of the United Nations (FAO) found that overall, the world's soils are rapidly deteriorating due to soil erosion, nutrient depletion, loss of soil organic carbon and other threats. The state of soils is particularly serious in some developing countries, while in most developed countries, including Canada, soils are in better shape comparatively—but action is still needed.

The report also states that the negative trends can be reversed if governments take the lead in promoting sustainable management practices.



Source: Alaska Independent Distance Education

What is Soil? Soil typically has several layers. The top layer, topsoil, is a mixture of mineral and organic particles with air and water. Topsoil contains sand, silt and clay, and usually more organic material than lower layers. Topsoil sustains most of the soil's biological life. Organic matter is essential for soil ecosystems and greatly influences the soil structure. The subsoil below topsoil is usually of greater depth than the topsoil but has little organic matter. Below the subsoil, the substrate soil is mostly mineral, including "parent" material derived from the underlying geological deposits.



Source: Home Garden Journal

In North America, the terrible drought and erosion in the 1930s triggered widespread concern and action on sustainable land use and soil management. A later crisis emerged in the 1970s and 1980s, with the large-scale conversion of perennial forage crops to annual crops and excessive tillage that led to soil erosion

and degradation. Governments and farm organizations then focused on reducing tillage and erosion. The 1980s and early 1990s saw the introduction of numerous federal and provincial programs aimed at soil conservation.

In the late 1990s and 2000s, interest in soil science and soil conservation programs waned. Even the UN's commitment to soil resources was dramatically scaled back. In Canada and Ontario, other priorities took precedence, like nutrient management. The food price rises of 2007-2008 were a reality check that affordable food and a steady supply of it could not be taken for granted. Everyone started re-examining how global soil resources could support sustainable agricultural production.

A renaissance of interest in soil health and conservation has emerged globally over the past decade. The United States, the United Kingdom, France, the European Community, Australia and other jurisdictions have embarked on new soil initiatives of various sorts. For example, France has launched the voluntary 4 in 1000 initiative to build soil organic matter (see Resources, page 34). International agencies such as the Food and Agriculture Organization and World Bank have taken a renewed interest in soil issues. 2015 was designated as the International Year of Soils by the Food and Agriculture Organization and the United Nations.

Scientists are again focusing on soils, examining the interactions between physical, chemical and biological soil properties, and the role of micro-organisms in shaping the structure and functions in healthy soil. In Ontario, many farm organizations including the Ontario Soil and Crop Improvement Association, the Innovative Farmers Association of Ontario and the Grain Farmers of Ontario work with OMAFRA, the University of Guelph and conservation authorities to sponsor events on soil health and cover crops.

Agricultural Soils: The Ontario Context

Ontario soils originated from the geological materials deposited from the last ice age. These soils developed as a result of underlying geological material and its minerals, local climate, vegetative cover and fauna, local topography and time. Ontario's agricultural lands are concentrated in southern Ontario and several regions in northern Ontario with favourable soils and climate.

Stewardship, partnerships, and collaboration have been the foundation of agricultural soil health and conservation in Ontario for over a century. Since farmland is predominantly privately owned, soil management is dependent on practices and decisions by individual farmers who own or rent the farmland.

The Science of Soils

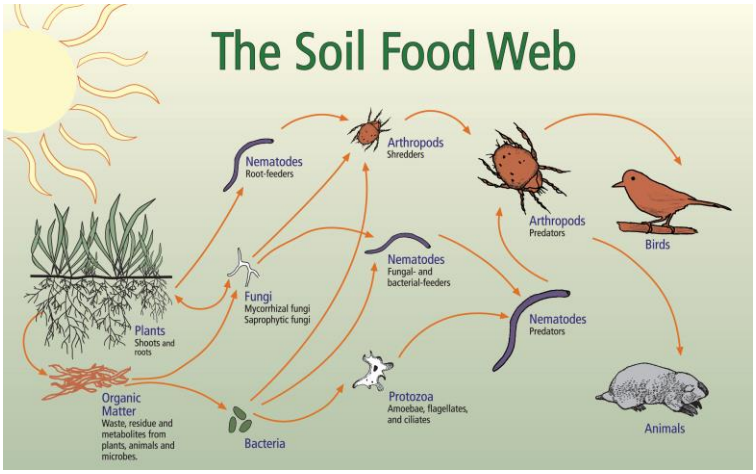
Soil Health

Soil health has physical, chemical and biological components. The physical component includes soil structure and the movement of water and air through the soil. The chemical component refers to the availability of nutrients and other conditions for plant growth (pH for example). The biological component consists of all the living and dead organisms associated with the soils. It is this last component that drives many soil processes. Measuring soil health involves determining indicators for all three components:

- Physical: loss of surface soil horizons, aggregate stability, available water capacity, bulk density, surface crusting, subsurface compaction

Soil Organic Matter – Why It Matters

The amount of organic matter in most agricultural topsoils ranges from one to ten per cent (muck soils are higher). The optimum percentage varies with soil type, but more is generally better. Soil organic matter ranges from raw plant residues (less than 10 percent) to a stabilized portion (40-60 percent) which is fairly resistant to further breakdown. Between these stages is "active" organic material (10-40 percent) being decomposed by microorganisms, particularly fungi. These microbes produce organic glues and fungal threads that bind soil particles to produce good topsoil structure (especially arbuscular mycorrhizal fungi, see Resources, page 34). In soils with adequate organic matter, the microbial "food web" and soil structure provide numerous benefits – improved water retention and infiltration, improved nutrient availability, slowly released plant nutrients, resistance to leaching, and increased soil biodiversity. Loss of soil organic matter is a serious concern in Ontario – of all Ontario's farmland, 82% is estimated to be losing organic matter (Agriculture and Agri-food Canada).



Source: Soil and Water Conservation Society. 2000. Soil Biology Primer. Rev. ed. Ankeny, Iowa.

- Chemical: pH, extractable phosphorus, extractable potassium, minor elements
- Biological: Diversity and abundance of soil organisms, organic matter, active carbon, potentially mineralizable nitrogen, root health

Important scientific concepts in soil health are soil aggregate and aggregate stability. Soil aggregates or "clumps" are groups of soil particles bound together. Aggregate stability is the ability of soil aggregates to resist breakdown by water or wind erosion, or compaction. Soil organisms are especially important in producing biological compounds to create and maintain aggregate stability (see Resources, page 34).

Soil Erosion and Conservation

Soil forms at the rate of about 3 tons of soil per acre per year (6.7 tonnes per hectare per year), and this figure is used as the tolerable soil loss in much of North America. That figure is debated by scientists, many arguing that it is too high. The underlying goal is that farmland should not lose more soil each year than is replaced by natural processes. This threshold is set using an international standard equation.

Climate change is bringing more intense weather events to Ontario. Our soils are at an increased risk of erosion with heavy rain storms and increased potential runoff outside the growing season, making it ever more essential that farmers adapt to these new climate extremes. Average erosion rates between March and August have increased 10 to 20 percent per decade over recent decades. A single intense storm in summer or winter can now account for 60 percent of annual erosion.

Soil Management

Soil best management practices can contribute to conserving, sustaining and improving the health of Ontario's agricultural soils. To ensure maximum benefits to soil health, these practices should be used together in a 'systems approach' to management rather than in isolation. These BMPs generally follow key principles, such as disturbing the soil as little as possible and keeping the soil covered at all times, preferably with living plants and preferably a diverse variety of plants.

Examples of soil best management practices include the following.

- **Diverse crop rotations including perennials**: Growing multiple crops in rotation over many years helps build soil organic matter, improve soil structure, diversify soil biota, reduce pest pressures and optimize nutrient use. Inclusion of perennial crops in the rotation gives a significant boost to

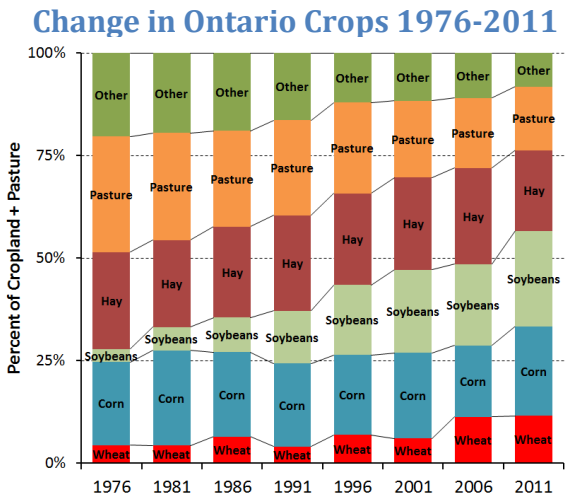
soil health.

- **Reduced-till or no-till practices and crop residue management**: Planting crops directly into crop residue from previous years or into narrow strips with less cultivation helps reduce soil disturbance, build soil aggregate stability and maintain soil ecosystems.
- **Cover crops**: These crops are planted amidst the commercial crop or after crop harvest primarily to maintain soil cover protecting the soil and may provide some production benefits. Livestock can sometimes consume cover crops, one way of allowing integration of crops and livestock on farms.
- **Organic soil amendments (e.g. manure, compost)**: Application of manure, compost or other organic materials to soils helps maintain and build soil organic matter and feed soil ecosystems. Better integration of livestock into crop production can provide sources of manure as an organic soil amendment.
- **Reducing soil compaction**: Reduced axle-weight of farm machinery, low-inflation tires, track systems on farm equipment used in combination with other BMPs can reduce soil compaction.
- **Erosion control measures and structures** (e.g. buffer strips, windbreaks, berms, sediment control basins, drainage management): Vegetative and structural measures can control the quantity, energy and movement of water or air to reduce erosion.

Employing these practices can achieve environmental benefits – reducing runoff of nutrients to the Great Lakes and other waterways, reducing greenhouse gas emissions, and building resilience to climate change.

The status of these practices and trends in adoption in Ontario are discussed below.

Changing Crops: Crops grown in Ontario have changed over time (see diagram, data from Statistics Canada), as they have across the globe. In the last couple of decades, soybean acreage has grown until it became the crop occupying the most cropland in Ontario in 2011 (27 percent), similar to soybean increases around the globe. Corn acreage expanded in earlier decades, 1960s-1980s. The percentage of Ontario cropland in the three main annual crops has increased from 28 percent in 1976 to 57 percent in



2011 as shown in the graph. This is similar to trends in other jurisdictions, responding to market demand. For many decades, hay and pasture acreages have decreased because beef and dairy herds have decreased. Science has shown perennial crops like hay and pasture benefit soil health, by reduced disturbance, increased soil organic matter and soil aggregate stability.

Annual crops like soybeans and corn often involve tillage or cultivation with ploughs or other equipment, unless managed in a no-till system. Science has shown that excessive tillage has a negative effect on soil health, reducing aggregate stability, organic matter and biological activity in the soil. Minimizing disturbance of the soil is a soil health principle.

Tillage: During the 1980s and 1990s, more and more Ontario farms reduced tillage intensity. In 2011, 33.1 percent of cropland was reported as planted using reduced-till or no-till seeding. Cropland reportedly receiving spring tillage that retains most crop residue on the surface was at 29.8 percent. Finally, 37.1 percent of cropland reportedly received spring tillage where most crop residue was tilled into the soil. Good statistics on fall tillage do not exist. Fall tillage on soils then left bare during winter lead to erosion and runoff. Most observers believe that tillage has increased in recent years, especially during the recent period of high commodity prices (2007-2013). But solid data are lacking. Farm decision-making regarding tillage can be challenging depending on weather, pests, diseases and other factors.

Crop Rotation: Crop rotation means growing different crops in succession over time. More complex rotations with more crops over a given period of time are generally better for soil health than simpler rotations. The challenge is often finding crops to add to a rotation that will generate profits annually. In 2011, 66 per cent of Ontario farmers reported using some kind of crop rotation. Agricultural scientists believe the most common rotation in Ontario is a limited, two-crop rotation of corn and soybeans, and corn-soybeans-wheat is also common. Fewer crops dominate Ontario's cropland today compared to past decades (see graph on previous page). This is similar to crop rotation trends in other parts of Canada and the United States. Complex rotations are challenging with respect to managing a larger variety of crops with specific needs related to planting, pest management and harvest.

Cover Crops: Cover crops are planted in among the commercial crop for several purposes including improving soil health. Cover crops may cover the soil during the winter or grow between the rows of the commercial crop during the growing season. Cover crops have a direct cost for farmers but generally have little direct commercial value, except as livestock feed in certain circumstances. Benefits

Ontario Leaders in Soil Management

Bill and Earl Elgie (Dresden)

Photo: Soil Conservation Council of Canada

The Elgie mixed farm (steers, vegetables, field crops, maple syrup) has nearly 700 acres in cover crops – rye, oilseed radish, buckwheat, and red clover. Manure is purchased off-farm and applied to fields beyond the home farm to maintain soil health. Bill and Earl use a reduced-tillage system. As a result of these practices, their soil is very healthy – it requires little addition of mineral nitrogen fertilizer.


Photo: Ontario Soil and Crop Improvement Association

Vollmershausen Farms (Innerkip)

The Vollmershausen family received the 2016 Soil Champion award from the Ontario Soil and Crop Improvement Association. The family has been farming near Innerkip in Oxford County for six generations. "Our focus is on soil health. As farmers, it is our responsibility to manage the land and look after soil," says Tyler Vollmershausen of their soil conservation efforts that include strip till, no till, and cover crops. It all started several years ago with a presentation by soil expert Dr. Jill Clapperton where she explained how fall tillage destroys earthworm populations. "In one presentation, she completely changed the way we view agriculture," Tyler admits.

generally include long-term production improvements. Interest in cover crops is increasing among Ontario farmers. Cover crops were reportedly used by 15-20 per cent of Ontario farmers in 2011. Picking successful combinations of cover crops for different commercial crops in different soils and geographic locations can be challenging – it requires patience, knowledge and experimentation.

Soil Organic Amendments: Adding organic matter to soils through soil amendments like manure or compost is another important practice to maintain and improve soil health. Only about 20 per cent of Ontario cropland reportedly received manure in 2011. Manure, compost or other organic amendments are not always

available or economical to acquire in all locations. Increased farm specialization in livestock or crops has often led to separation of sources of manure from cropland needing organic amendments.

Erosion Control Measures: Installing windbreaks, buffer strips and grassed waterways helps reduce gully erosion and filter runoff. In recent years, many existing fencerows and windbreaks have been removed as many farmers sought to increase their crop acreage at a time of higher commodity prices. Installing water and sediment control basins and controlled drainage are measures that can help manage runoff and drainage to reduce negative impacts when used with other BMPs. The cost and complexity of installing structural measures can be significant.

Reducing Soil Compaction: Compacted soil leads to reduced water infiltration, reduced root penetration and soil structure breakdown. There is more threat of compaction because farm equipment has become larger and heavier over time. Reducing the axle-weight of machinery used for an operation and using lower tire inflation or tracks rather than tires can reduce the downward force on the soil.

Supporting Best Management Practices (BMP) Adoption: OMAFRA and other partners use a variety of tools to help farmers adopt soil-related BMPs, including risk assessment, planning, education and incentives. The Environmental Farm Planning process helps farmers identify risks to soils and match BMPs with the issues identified. Growing Forward 2 offers funding for planning and implementation of soil BMPs, such as cover crops and erosion control. The new Great Lakes Agricultural Stewardship Initiative (GLASI) also offers support for advice and planning for soil health actions through the Farmland Health Checkup. GLASI also provides financial support for adopting all the major soil-related BMPs for farms in the Lake Erie and Lake Huron watersheds. The knowledge, education and research-related programs are outlined in a later section (see page 32).

Potential role of soil organic matter in climate change mitigation

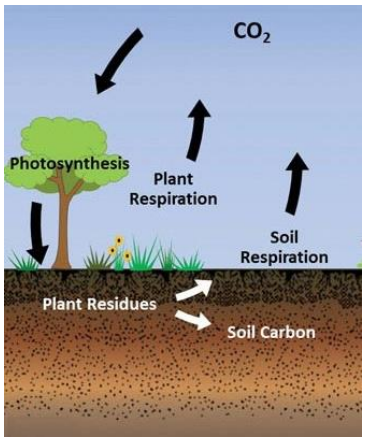
The carbon in soil organic matter originates from carbon dioxide (CO_2) from the atmosphere. The BMPs described in this paper help build soil organic matter and thus remove carbon from the atmosphere. This removal can help reduce CO_2, one of the greenhouse gases. The magnitude of the potential for soil organic matter to do this is the subject of debate among scientists. Some believe that soils could absorb a large portion of the world's greenhouse gas emissions (see Lal 2016 in Resources, page 34). Others believe the potential is more limited (see VandenBygaart 2016 in Resources). More importantly, the same BMPs can also reduce emissions of other greenhouse gases (N_2O, CH_4). The Ontario

Potential role of soil organic matter in climate change mitigation

government is assessing the potential for agricultural practices to increase soil organic matter, and the feasibility of providing viable offsets for greenhouse gas emissions within a cap and trade system. Regardless, increasing soil organic matter has many other important economic, environmental and social benefits.

Most of Ontario's agricultural soils (82 per cent) are currently estimated to be emitting CO_2 to the atmosphere rather than increasing soil carbon (Agriculture and Agri-food Canada). Reversal of those emissions is required first, before additional carbon can be actively removed from the atmosphere.

[1]Soil carbon is part of the carbon cycle, a complex biological process affected by many factors (see diagram). Extensive use of the practices already mentioned – such as crop rotation, cover crops, reduced tillage and organic amendments – offers significant potential to build soil organic matter. Widespread change in practices by a great many farmers would increase soil carbon and reduce emissions of all greenhouse gases at a scale needed to offset other greenhouse gas emission sources.



There are biological limits to the amount of carbon that can be incorporated and maintained in agricultural soils, because it eventually reaches equilibrium. The potential of increasing soil organic matter also varies with geography, climate, and type of ecosystem. For example, forests and perennial grasslands (such as pastures) generally have higher levels of soil organic matter than cropland. Ontario's humid climate increases the rate of decomposition of organic matter back into CO_2 compared to drier climates. By contrast, agricultural soils in the drier Prairie provinces are currently estimated to be gaining soil organic carbon.

Over the long term, much more can be done to stop and reverse the current trend of decreasing soil organic matter in Ontario's agricultural soils. Increasing organic matter in agricultural soils is one way of reducing Ontario's net greenhouse gas emissions while improving soil health.

Soil Information and Mapping

Soils information takes many forms. Farmers and their advisors collect soil samples to test for nutrients, organic matter and other soil parameters that are important for

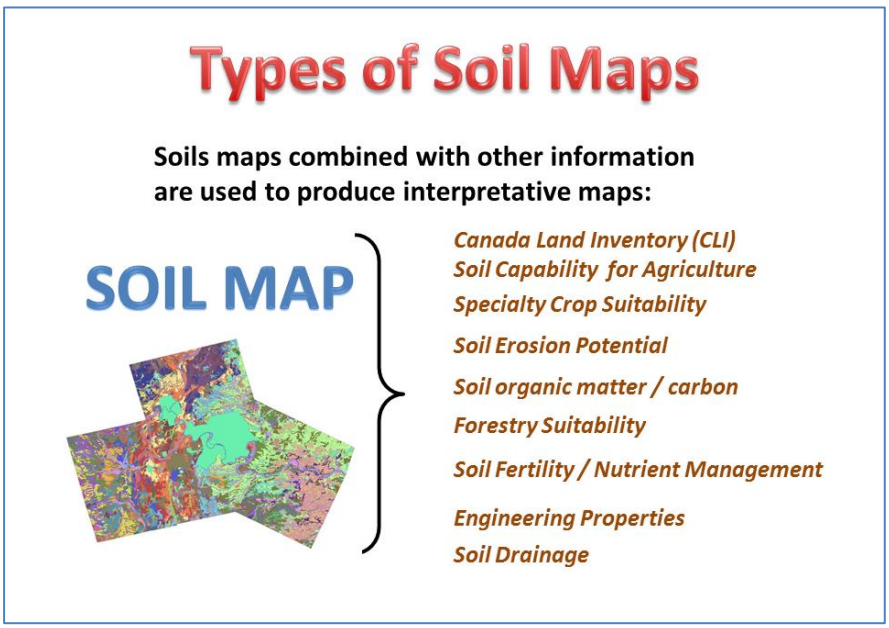
[1] Diagram modified from "Slowing Climate Change One Highway At A Time" by Doug Romig, Bill Dunn, Amy Estelle, and Greg Heitmann, in Public Roads 78 (4) 2015.

crop production. Site-specific farming methods combine GPS and supportive technology along with modern farm machinery to collect very detailed information on crops harvested, moisture and precise geographic location. This data can produce a very detailed yield map. This can be used to accurately spread nutrients based on soil characteristics and expected yield of the next crop.

The amount of data collected is growing very quickly as technological innovation makes soil data immediately available through on-board computers, smart phones and tablets. There is competitive pressure on farmers to adopt these technologies in order to become more efficient. These new technologies can also be used for environmental benefits such as more efficient and effective use of fertilizers and pesticides.

Soil samples have been taken by farmers and scientists for many decades and analyzed by laboratories for nutrients (e.g. phosphorus, potassium, magnesium, zinc, manganese), organic matter, soil acidity (pH) and sometimes other parameters. Farmers generally test their fields every few years. Scientists and consultants may collect samples on an ongoing basis or just for a specific study.

Tens of thousands of soil sample test results exist across Ontario, some in digital format and some only on paper. This wealth of data is not available for analysis by farm organizations, universities or governments. There may be privacy issues regarding privately sponsored samples. But even the thousands of publicly funded soil samples are not centrally compiled and available for analysis. Analysis of these data would facilitate monitoring of soil health and soil organic matter.



Another key form of soil data are soil inventories, classification and maps. Soil scientists classify soils into categories based on the types of soil horizons found, related soil profile features and key landscape

attributes. These categories are defined by soil origins, mineral and organic content, texture (sand, silt, clay), drainage class, depth and position in the landscape (hills, valleys, etc.).

Scientists have described, sampled, classified and mapped soils across southern and parts of northern Ontario. Soil inventories and mapping started in Ontario over 100 years ago and continued as a collaborative effort by federal and provincial governments and the University of Guelph. Some maps have been updated several times, others only occasionally.

Soils information can be interpreted for various uses; answering the question `what is this soil good for?' This can be done for a wide range of uses including overall agricultural capability, forms of degradation (e.g. erosion), engineering/ soil mechanics as well as for land drainage, forestry and septic systems (see diagram above).

The Canada Land Inventory (CLI) classification is one of the most commonly used forms of interpretation for agricultural capability. Soils are ranked into land capability maps showing Classes 1-7 farmland. Class 1-3 farmlands are Prime Agricultural Lands and receive greater protection in Ontario's land use policies (e.g. the Provincial Policy Statement under the Planning Act). These soil inventories and maps guide Ontario land use planning to ensure farmland is protected for the long term. They are also used to assess the locations of water protection and green energy facilities.

Satellite and radar technology is also transforming how soil maps and inventories are created. Other jurisdictions like the United States, Europe and Australia are updating and modernizing their soil inventories with these new technologies. In addition, the environmental impacts of soil erosion can be reduced through the use of these technologies.

At OMAFRA, 'legacy' (older) soil resource inventory maps have mostly been digitized, but significant gaps and deficiencies remain. While there is considerable data about soil attributes across Ontario, only a small fraction of it is in digital format. Currently, Ontario has limited Geographic Information System (GIS) coverage of agricultural land use patterns and crop types. While there is digital elevation data (topographic information derived from radar), it is for only limited areas. OMAFRA's Ag Maps web portal [see Resources, page 34] supplies maps to clients and allows clients to create the maps they need. AgMaps' functionality and the amount of data it can access are continually expanding and improving.

Ontario is already changing to keep up with the times and be more strategic, effective and accurate in soil information and mapping. On April 23, 2016, Ontario and Canada announced $5.1 million in funding for provincial soil mapping activities using a range of new technologies including Light Detection and Ranging or LiDAR, remote sensing, Geographic Information System tools and specialized computer software (see Resources, page 34).

Soil Monitoring and Modelling

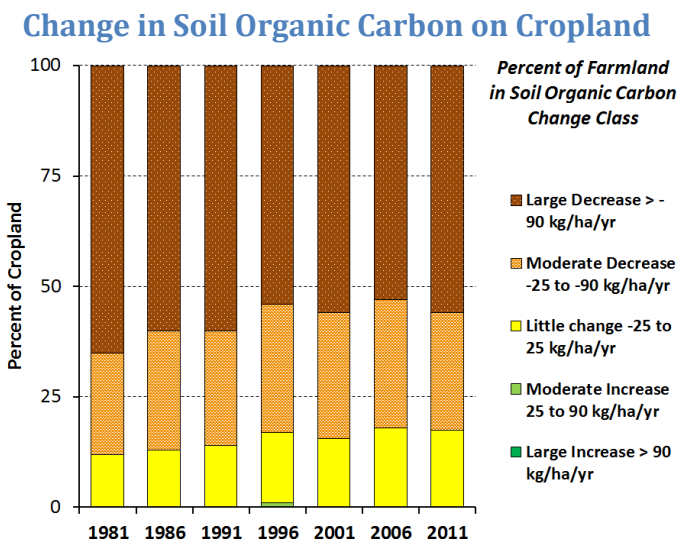
How can we tell if soil health is improving or not? How can we know whether more or less soil erosion is occurring? Is soil organic matter declining or increasing? These are questions that farmers, conservationists and governments around the world have asked for years.

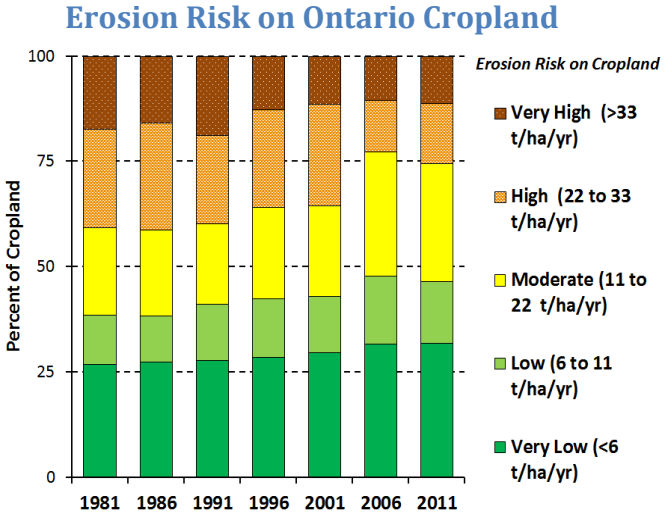
Farmers want to know if soil health, fertility and erosion are getting better or worse, for each of their fields. Farm organizations, conservation authorities and governments want to know whether there are positive or negative changes in soils occurring across the landscape, watershed or province. Measuring soil health and erosion for an individual farm field versus an entire province are different tasks that require different approaches. Finally, everyone wants to know what management practices will result in improved soil health.

Agriculture and Agri-food Canada (AAFC) has developed agri-environmental indicators to assess changes in soil carbon, soil erosion risk and other factors (see box below). Overall these indicators suggest that soil health and erosion risk are not improving in Ontario.

Trends in Soil Organic Carbon and Erosion Risk in Ontario Agricultural Soils

Soil organic carbon is known to be an important factor in soil health. Using sources like the agricultural census conducted every five years, the AAFC agri-environmental indicator estimates the change in soil organic carbon based on the change in crops and farm practices over time. Ontario's cropland is increasingly dominated by annual crops with varying degrees of tillage, crop rotation and other practices that affect soil carbon, as noted earlier. So soil organic carbon in many parts of Ontario (82% of cropland) is estimated to be decreasing (see above graph).





Erosion risk is also estimated by AAFC scientists (see graph at left). They use information on crops grown, farm practices, soil characteristics and erosion potential. Ontario's many sandy and loam soils generally have a higher risk of erosion. These and other factors have led to the estimate that 54 percent of Ontario's cropland has a risk of erosion above the annual rate of soil regeneration. Some improvements 1981-2006 are shown in lower proportions of cropland in higher-risk categories. But the improvement trend did not continue into 2011 (all data from Agriculture and Agri-food Canada).

Different tests and approaches are available to farmers to assess soil health, fertility and erosion on their land. Regular soil tests look at fertility and organic matter. Some new tests are being developed to examine a broader range of soil health indicators in Ontario (e.g. Soil Health Assessment and the Cornell Soil Health Test adapted for Ontario – see box). There are tools to assess erosion at a field level (e.g. Revised Universal Soil Loss Equation).

On-farm Soil Health Test being adapted for Ontario

An on-farm method to assess soil health field-by-field is needed. OMAFRA soil specialists Adam Hayes and Anne Verhallen worked with researchers (Laura Van Eerd, David Hooker, Bill Deen at University of Guelph) and AAFC researchers Ed Gregorich, Craig Drury and Ron Beyaert to adapt and refine a soil health test to Ontario conditions. Currently, indicators to assess aggregate stability, potentially mineralizable nitrogen and soil organic matter look promising.

It is often said that "you can't manage what you can't measure." This maxim underscores the need for monitoring what is happening to Ontario's agricultural soils and using existing data for computer modelling to provide evidence-based predictions about how certain agricultural practices will affect soils in the future. Soil health measurement and soil erosion modeling are two critical monitoring and modeling needs – they inform OMAFRA's soil management recommendations to producers.

Ontario's soil monitoring has several gaps and challenges:

- New modeling tools can be adapted from neighbouring US states but better data are needed to use those models.
- Existing Ontario land resource data are being used to their limits; they are insufficient for both governments' and clients' needs.
- The questions about Ontario's soils being asked today cannot be answered using older data.
- Data on field scale soil management practices by farmers is limited.
- A growing need is evident for a validated Ontario on-farm soil health test which also feeds into an Ontario soil health database for monitoring.
- In tandem, a need for on-farm soil health planning tools which would also feed into the soil health database.

Soil Knowledge and Innovation

Soil knowledge, including research, is crucial to successful management of soil health and erosion at both the farm level and across Ontario. Over the last couple of decades, the number of specialists involved in soil science and soil management advisory services has decreased in the public sector. Other important priorities have driven government and organization staffing decisions and work planning. This has begun to change in response to recognition of the ongoing need to provide services

to assist with maintaining soil health.

There has been decreasing emphasis on soil science at universities worldwide. A number of Ontario universities and colleges provide some basic training in soil science and the University of Guelph has more extensive courses offered. There is limited capacity in Ontario universities and colleges for some types of technical soil science training, while universities in western Canada continue to provide key soils training.

Surveys of students show a significant decline in the number of undergraduate and graduate students in soil science in the U.S. and Canada. Some argue that this is because the names of institutions and programs have become more generalized as environmental or earth sciences or similar names, rather than soil science specifically. The soil science capacity within agri-business and the consulting sector is less well-documented, but anecdotal accounts suggest the decline in capacity also exists here.

Education and technology transfer programs encourage farmers to adopt a range of soil management and soil erosion reduction practices. Knowledge gets spread through many mediums such as workshops and the series of Best Management Practice booklets developed by OMAFRA and its partners (see Resources, page 34). OMAFRA and its partners also develop a variety of information products to assist farmers in soil management and continually update them to reflect changes in the industry and in technology.

Services and knowledge about soils available to farmers have changed over the last couple of decades. Government is providing less extension and educational services via direct personal contact. More information is available digitally through websites and social media and through workshops and other mediums.

More of the government extension effort is now targeted at providing training for agri-business personnel and in turn agri-business is providing more direct advice to farmers. Farm organizations also play a key role in providing information and working in partnership with government to provide information to farmers. For example, the Ontario Soil and Crop Improvement Association and Farm and Food Care work with OMAFRA and conservation authorities to run workshops for farmers on soil health.

OMAFRA collaborates with agricultural researchers to enhance knowledge and

particularly close working relationship between OMAFRA, Agriculture and Agri-Food Canada and the University of Guelph, with each contributing funds to advance soil health and conservation research. Farm organizations also participate in research including Grain Farmers of Ontario, Ontario Soil and Crop Improvement Association and others.

The future health and conservation of Ontario's agricultural soils depends on ongoing, timely dissemination of soil knowledge and technology transfer to end-users. Yet in Ontario over the past 25 years, a gradual diminishing has occurred in our soils education and training capacity as well as public sector expertise in soil science.

Reminder: Comments and Input

OMAFRA and the working group look forward to everyone's comments on the draft vision, goals and objectives (Pages 10-13) and responses to the discussion questions (Page 15).

Please provide comments via the OMAFRA web site, the Environmental Registry, or the email address soilhealth@ontario.ca .

Resources

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