



Best Management Practices

SOIL HEALTH IN ONTARIO

Soil is a vital natural resource and the foundation of agricultural production. The many benefits of a healthy soil are important – underpinning the long-term sustainability of the farm operation, our agri-food sector, and our environment.

What is a healthy agricultural soil? Essentially it refers to a soil's ability to support crop growth without becoming degraded or otherwise harming the environment.

While a soil can be degraded through particular practices, the good news is that many best management practices (BMPs) can build back and safeguard soil health. This publication provides a visual overview of these BMPs, along with soil basics and challenges to soil quality.

THE ROLE OF HEALTHY SOIL IN A CHANGING CLIMATE

Agriculture and climate are directly linked – anything that has a significant effect on our climate will influence farm production. Greenhouse gas (GHG) emissions and climate change are global concerns, and agriculture can be part of the solution.

BMPs that improve soil health can also help lower GHG emissions, reduce phosphorus loss from fields to surface water, and improve resilience to drought or excessively wet conditions. Healthy soil – an essential component of a healthy environment – is the foundation upon which a sustainable agriculture production system is built.

Get more from your soils – get your soils healthy!

Healthy soils:

- provide minimum resistance to root growth, improved crop development, and ultimately high yields and product quality
- provide better returns on crop inputs such as applied nutrients and pesticides
- allow for better infiltration, more water storage and less runoff
- are more resilient during low water conditions because their structure and organic matter content help retain plant-available moisture
- resist degradation, such as compaction, crusting, water and wind erosion, and ponding
- are better equipped to remove pollutants and protect groundwater quality
- reduce greenhouse gas emissions, i.e. carbon dioxide, methane, nitrous oxide. Implementing BMPs for soil health – especially those that add organic matter – will improve the soil's ability to serve as carbon and nitrogen sinks.

Healthy soils hold more moisture – making them more resistant to runoff and erosion.

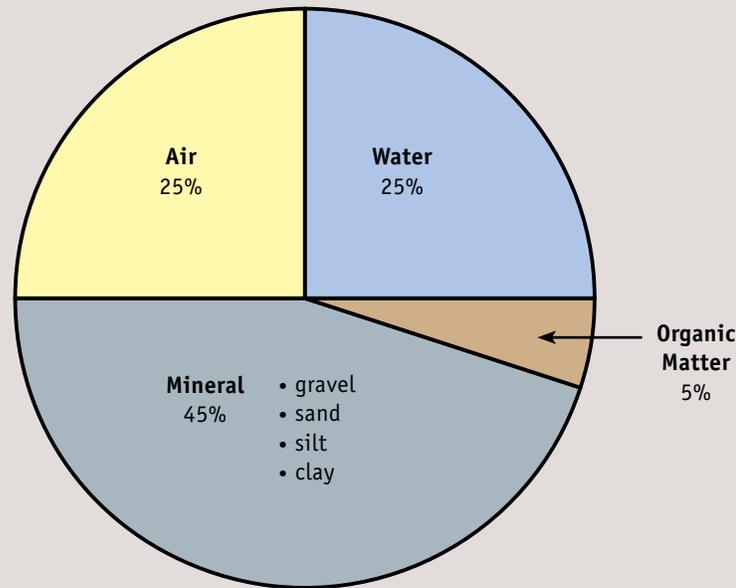


Healthy soils produce more, because crop roots are not struggling to find space, air, moisture and nutrients. There is more growth and better product quality.

The basics of soil

Soil has mineral and organic components. In ideal growth conditions, topsoil is half solids (mineral and organic fractions) and half space. The space or soil pores contain moisture and air for plant and soil organisms to breathe.

A healthy soil has a balance of soil organisms, efficient soil nutrient cycling, favourable conditions for root growth, good drainage, and adequate moisture for crop growth.



Soils are made up of four primary components: air, water, organic matter and mineral particles. The ideal soil will have a composition similar to what's shown in the pie chart. The amount of air and water within a soil will fluctuate throughout the year.

SOIL PROPERTIES

Soils have physical, chemical and biological properties. A soil's health or quality is often measured by these properties.

Physical properties include texture (coarseness or fineness of soil materials, e.g. sandy loam), structure (how soil particles are arranged), density, porosity and moisture characteristics.

Chemical properties include pH, mineral compounds and nutrient levels.

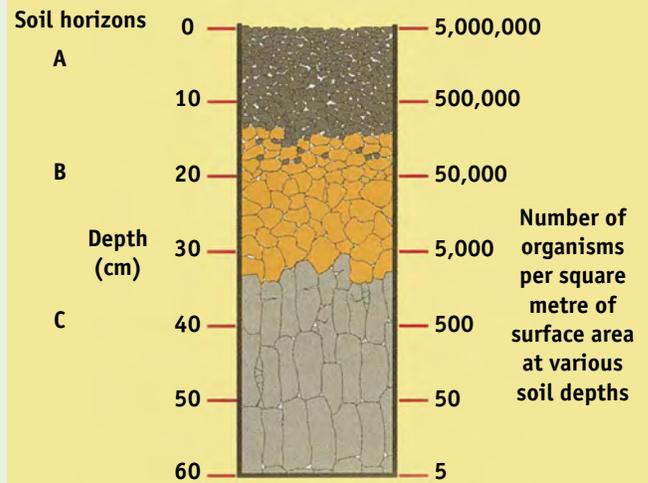
Biological properties include the habitat (the amount of soil organic matter) and the diversity and numbers of flora and fauna. Soil life includes not only plant roots and earthworms, but hundreds of thousands of different insects, wormlike creatures (nematodes) and micro-organisms as well.

Soil health cannot be measured by one property or feature alone. A healthy soil has desirable conditions for a combination of physical, chemical and biological properties.

COMPONENTS OF SOIL HEALTH



SOIL STRUCTURE – is the aggregation of soil particles. A healthy soil has well-defined structure. An unhealthy soil has weak structure – making the soil susceptible to surface crusting, compaction and erosion.



SOIL LIFE – refers to the numbers and diversity of visible and microscopic soil animals and plants. A healthy soil is biologically diverse.

SOIL FERTILITY – refers to the overall ability of a soil to supply nutrients to crops. It is directly related to the natural chemistry of the soil, soil pH, its ability to retain nutrients, and the crop nutrient management practices.



SOIL WATER – refers to the amount of water in the soil and the rates at which water moves into and through soil. Healthy soils are drought-resistant, maintain adequate levels of available moisture, and do not pond.

Challenges facing soil health in Ontario

On average, Ontario's agricultural soils are considered moderately healthy. However, the health of most cropland soils is on the decline. Soil health challenges are most often regional or localized.

Ontario soils have relatively shallow profiles of weathered soil (<70 cm), and cannot sustain substantial loss. Historically, mixed farming allowed for regular additions of organic matter from sod and manure. But by the 1950s, row crop practices were beginning to replace forage-based rotations on lands that now grow grains, oilseeds and specialty crops.

Increased tillage, traffic and fewer additions of organic amendments have led to declines in soils used exclusively for production of grain and oilseeds or field-grown vegetables.



Refer to the BMP book *Soil Management* for much more information on soil conditions and challenges, and BMPs to improve them.



An example of regional degradation is the seedbed deterioration found in the clay plains of the southwest.



An example of localized degradation is the evidence of erosion by water and tillage in fields with rolling topography and convergent slopes.

SOIL HEALTH CHALLENGE	DESCRIPTION OF CONDITION	SIGNIFICANCE
LOW FERTILITY	<ul style="list-style-type: none"> Soils that are naturally acidic or that have fertility levels below minimum requirements for crop production 	<ul style="list-style-type: none"> Lower yields and biomass production Poor cover for soil protection
EXCESSIVE FERTILITY	<ul style="list-style-type: none"> Fertilizer materials have been added to soil beyond levels recommended for crop production or regardless of soil test results 	<ul style="list-style-type: none"> Loss of nutrients to environment Excessive vegetative growth (e.g. lodging in cereals)
SALINITY	<ul style="list-style-type: none"> Soils that are too salty due to irrigation, fertility practices or fossil fuel extraction 	<ul style="list-style-type: none"> Most crop roots have low salt tolerances
CONTAMINATED SOILS	<ul style="list-style-type: none"> Soils used as brownfields, industrial sites, spill sites 	<ul style="list-style-type: none"> Soils contain intolerable levels of harmful chemicals such as heavy metals

SOIL HEALTH CHALLENGE	DESCRIPTION OF CONDITION	SIGNIFICANCE
WIND EROSION	<ul style="list-style-type: none"> • Movement and deposition of soil material by wind • Soil material is mostly sand particles 	<ul style="list-style-type: none"> • Loss of topsoil and inputs • Possible sandblast of high-value crops
WATER EROSION	<ul style="list-style-type: none"> • Movement and deposition of soil material by water • Erosion can be concentrated or in thin layers 	<ul style="list-style-type: none"> • Loss of topsoil and inputs • Loss of productivity • Lower surface water quality due to runoff
TILLAGE EROSION	<ul style="list-style-type: none"> • Relocation of soil material downslope from tillage movement and gravity 	<ul style="list-style-type: none"> • Subsoil exposure on knolls • Extreme productivity loss on knolls



WIND EROSION – Open and unprotected croplands with sandy soils are most prone to wind erosion. If you can see soil material moving, it is estimated that up to 5 tons/acre are being lost.



TILLAGE EROSION – Tillage erosion is most likely to occur on complex sloped fields with a history of downslope tillage and cropping practices. The relocation of topsoil downslope results in the exposure of lighter-coloured subsoil on shoulder or knoll slope positions, indicating tillage erosion.



WATER EROSION – Steeply sloping fields with converging slopes and loamy soils are among the soil conditions at most risk to erosion by water. Look for finger-like and slightly larger channels on upper-slope positions as well as fan-shaped areas of soil deposition downslope as evidence of previous water erosion.

SOIL HEALTH CHALLENGE	DESCRIPTION OF CONDITION	SIGNIFICANCE
DROUGHTINESS	<ul style="list-style-type: none"> • Soils are more susceptible to irreversible crop damage during low water conditions 	<ul style="list-style-type: none"> • Lower crop yields and product quality
COLD AND WET	<ul style="list-style-type: none"> • Soils with naturally high water tables (poorly drained) and in areas with cooler local climates 	<ul style="list-style-type: none"> • Poor growth environment for crops • Reduced effective growing season
pH EXTREMES	<ul style="list-style-type: none"> • Soils are too acidic or too basic 	<ul style="list-style-type: none"> • Certain crop nutrients not available, lowering yields and quality

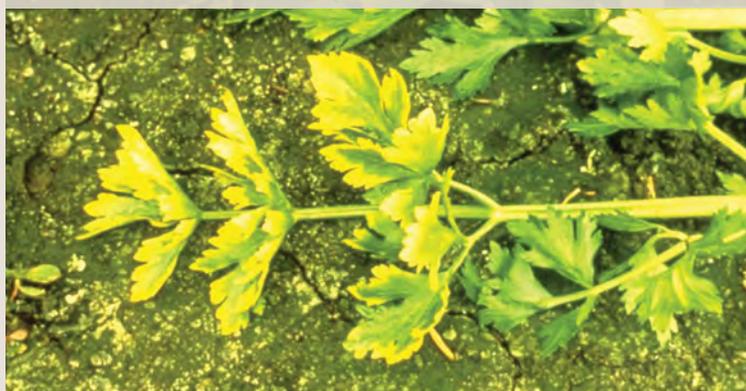


COLD AND WET SOILS – Soils with high water tables and poor internal drainage are prone to becoming saturated or ponded for prolonged periods in the spring or following storm events. Look for surface ponding, stunted or poorly emerged crops, and pale green crops (N-deficiency symptoms).

DROUGHTINESS – Crops grown on rapidly drained sandy soils that do not receive regular additions of organic matter are prone to moisture stress. Look for crop wilting and discoloration patterns on certain landscape positions (e.g. premature maturation on knolls).



pH EXTREMES – Low pH or acidic conditions can be found in all textures but are common on sandy and other coarse-textured soils found close to the Canadian Shield. Look for evidence of nutrient deficiencies such as calcium, magnesium (as shown in celery photo below), manganese and molybdenum.



SOIL HEALTH CHALLENGE	DESCRIPTION OF CONDITION	SIGNIFICANCE
SURFACE CRUSTING	<ul style="list-style-type: none"> Overworked fine seedbeds with low organic matter and weakened surface structure will form crusts after rain events 	<ul style="list-style-type: none"> Poor crop emergence and early growth Yield loss Reduced infiltration rates
SUBSURFACE COMPACTION	<ul style="list-style-type: none"> Soils below seedbed become dense due to on-field traffic, weight, moisture conditions and/or tillage depth 	<ul style="list-style-type: none"> Restriction of soil moisture movement and crop root growth, reduced water infiltration and increased runoff
SUBSIDENCE	<ul style="list-style-type: none"> Loss of organic soils due to aerobic decomposition 	<ul style="list-style-type: none"> Loss of productive capacity

SUBSURFACE COMPACTION – Most soils types are at risk of compaction if they are not in good condition. Examples of practices that increase compaction risk include frequent heavy field traffic when the soil is moist to wet (shown below with sawdust layers in soil to illustrate compaction in tire tracks), and tillage to the same depth during similar soil moisture conditions. Look for stunted plants along traffic lanes or dig to find soil layers with higher densities.



SURFACE CRUSTING – Surface crusting is most likely on fields where medium- to fine-textured soil seedbeds are worked too finely on a regular basis. Look for light soil colours, extra-fine aggregates in the seedbed following tillage, and puddles on the surface after rain events.



SUBSIDENCE – Shallow peat deposits over mineral soils are at risk of losing organic soil material and exposing mineral subsoil due to subsidence (rapid aerobic decomposition). Look for exposed patches of white or marly subsoil after tillage and harvest practices.

How do we assess soil health?

In Ontario, soil health is assessed with a range of ready-reference and easy-to-apply diagnostic tools. While a soil's physical and chemical properties can be directly measured, the assessment of biological conditions is more difficult.

Soil assessment involves this diagnostic approach:

- **Soil type and conditions** – texture, colour, structure, horizons, drainage class
- **Field conditions** – erosion, crusting, cracking, ponding, etc.
- **Past management** – tillage, traffic, drainage, nutrient management, erosion control
- **Crop conditions** – discoloration, emergence, changes in yield and crop quality, rooting pattern



Soil test results are an essential component of assessing soil health, by telling you the status of available crop nutrients. However, they cannot provide the complete picture. A full soil health assessment includes examining the condition of key soil physical, chemical and biological properties.



A healthy soil provides the habitat requirements for diverse soil life. Desirable conditions for a soil's physical and chemical properties (e.g. well-aerated, humus-rich topsoil) usually translate into a suitable habitat for soil life.

Key BMPs for soil health

Best Management Practices are Ontario's working definition for environmentally sustainable agricultural practices. To qualify as a BMP, a practice, technology or structure has to be practical, proven to protect the environment, and compatible with Ontario farming systems and conditions.



COVER CROPS – Cover crops provide many benefits to soils and crops. One key soil health benefit is to provide cover when other living crops or crop residue cannot. A solid stand of a drilled or broadcast cover crop will protect soil from wind and water erosion.



CROP ROTATIONS – Changing the crop grown from year to year in a particular field will provide a variety of root systems and different types of crop residues. This can help to maintain or improve soil organic matter levels and improve soil structure.



PERENNIAL SYSTEMS – Over the long term, pastures and other perennial cropping systems dramatically improve soil health components such as soil structure and organic matter levels. One of the key benefits of perennial systems is the lack of disturbance, which allows for measurable improvements in soil biodiversity.

LAND RETIREMENT – Some upland portions of fields are not suitable for remediation because the amount of soil eroded is too great to economically return to the upper slope. Retirement to trees, shrubs or natural grassland species will improve habitat conditions, provide long-term cropping options, and rehabilitate the soil health for future generations.



MULCH TILLAGE – Conservation tillage systems disturb soils less than conventional systems. The remaining residue cover will provide protection from wind and water erosion.



SOIL REMEDIATION – Soil health can be restored. Sediments deposited in depressions from severely eroded knolls can be excavated and returned to knoll slope positions. Remediating soils will improve water-holding capacity, resistance to erosion, and crop productivity.



BUFFER STRIPS – Buffer strips are a land retirement option for riparian (streamside) areas prone to flooding and erosion. Buffer strips provide double-duty benefits of remediation and protection for the floodplain soils and for the watercourse.



RESIDUE MANAGEMENT – Soil cover can be achieved with effective residue management. Effective cover begins at harvest: a uniform cover of crop residue will provide a more complete mulch effect and will be easier to manage when planting the next crop.



NO-TILL – In no-till cropping systems, crops are established with no or minimal soil disturbance. This provides cover from erosive forces and enables soils to develop more stable seedbed conditions.

CONTOURING – Growing crops across a slope will prevent preferential pathways for rill formation (water erosion). Contour strip-cropping combined with no-till or cover crops can reduce the risk of soil erosion by as much as 85% compared to bare soil conditions.



SUBSURFACE DRAINAGE – Cropland drainage will remove excess moisture from cropland soils with high water tables or poorly draining soil materials. Drained soils are healthier and less prone to compaction. They are better aerated, provide for greater rooting depths, retain more soil moisture during storm events, and are less erodible.



ADDING ORGANIC AMENDMENTS – Returning organic material to the soil will increase soil organic matter levels. Higher soil organic matter levels are essential to improving soil health: organic matter improves soil resilience, water-holding capacity, and aeration.



EROSION CONTROL STRUCTURES –

Rill erosion can be controlled with the construction of a water and sediment control basin (WASCoB) across an erosion-sensitive draw. WASCoBs and other erosion control structures are most effective when complemented with other soil conservation BMPs such as residue management, crop rotation, and cover crops.



FIELD WINDBREAKS – Treed windbreaks provide protection from wind erosion and erosion by water. Protected soils are healthier, retaining topsoil and soil moisture. Yield increases of over 30% for corn and beans have been measured downwind of windbreaks on cropland in the southwest.



WIND STRIPS – Wind strips are rows of cereals between sensitive, high-value crops. As with treed field windbreaks, wind strips protect soil health by reducing the erosive force of wind and protecting high-value crops from sandblasting.



SOIL TEST – A healthy soil is a fertile soil. Don't guess; soil test! Sample your soil regularly for fertility analyses. Keep records and adjust your nutrient management program according to the results and follow OMAFRA crop recommendations.



Best Management Practices ADDING ORGANIC AMENDMENTS

The amount of organic matter strongly influences the health, productivity, and resilience of cropland soils. Building and maintaining the level of organic matter in your soil offers many benefits.

Higher soil organic matter improves a soil's physical properties, such as water retention, permeability, water infiltration, drainage, aeration and structure. Ultimately it provides a better growing environment for crop roots.

One of the most effective ways to build and maintain levels of your soil's organic matter is by adding suitable organic amendments.

This factsheet describes the nature and function of soil organic matter, sources of organic amendments, and best management practices (BMPs) for adding organic amendments to soil.

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Ontario
Canada

Factsheets regarding Soil Health BMPs are available to help you safeguard soil quality.

For more information

ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

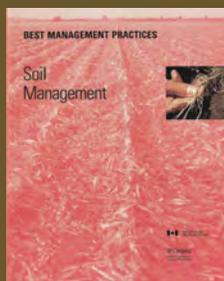
Many sources of supplementary information are available.

Below are some suggestions to get you started. Most can be found online at ontario.ca/omafra or ordered through ServiceOntario.

- Publication 811, *Agronomy Guide for Field Crops*
- Publication 611, *Soil Fertility Handbook*

Best Management Practices Series

- *Application of Municipal Sewage Biosolids to Cropland*
- *Buffer Strips*
- *Controlling Soil Erosion on the Farm*
- *Cropland Drainage*
- *Establishing Tree Cover*
- *Field Crop Production*
- *Managing Crop Nutrients*
- *Nutrient Management Planning*
- *Soil Management*



Environmental Farm Plan (4th ed.) and EFP Infosheets

- #15, *Soil Management*
- #16, *Managing Nutrients in Growing Crops*
- #17, *Use and Management of Manure*

- #18, *Horticultural Production*
- #19, *Field Crop Production*

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BMPs for Soil Health Factsheet Series:

- Adding Organic Amendments
- Buffer Strips
- Contour Farming and Strip Cropping
- Cover Crops and Manure
- Crop Rotation for Vegetable Crops
- Cropland Retirement
- Erosion Control Structures
- Field Windbreaks
- Inter-Seeding Cover Crops
- Mulch Tillage
- No-Till for Soil Health
- Perennial Systems
- Pre-plant Cover Crops
- Residue Management
- Rotation of Agronomic Crops
- Soil Remediation
- Subsurface Drainage
- Wind Strips
- Winter Cover Crops

BMPs for Soil Health Diagnostic Infosheet Series:

- Cold and Wet Soils
- Contaminated Soils
- Droughtiness
- Excessive Fertility
- Low Fertility
- pH Extremes
- Salinity
- Soil Erosion by Water
- Subsidence
- Subsurface Compaction
- Surface Crusting
- Tillage Erosion
- Wind Erosion