BEST MANAGEMENT PRACTICES

Soil Management

Agriculture and Agri-Food Canada

Ontario
Ministry of Agriculture, Food and Rural Affairs

What is a Best Management Practice or "BMP"?

- a proven, practical and affordable approach to conserving soil, water and other natural resources in rural areas

Who decides what qualifies as a BMP?

- a team that represents many facets of agriculture and rural land ownership in Ontario, including farmers, researchers, natural resource managers, regulatory agency staff, extension staff and agribusiness professionals

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Table of Contents

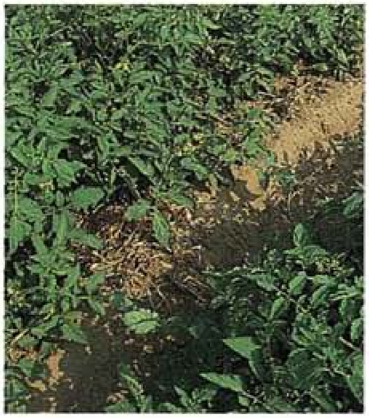
UNDERSTANDING THE BASICS

INTRODUCTION

Soil is the basis of most crop production. If you manage the soils on your farm with care, you'll be rewarded with:

- ► more consistent yields, even under adverse weather conditions
- ► lower input costs
- ► sustainable soils for years to come.

Well-managed soils can result in lower input costs and greater yields.



Well-managed soils also produce crops that have greater resistance to environmental stresses such as weather, and to many diseases such as root rot.

Soil is the basis of most crop production: manage it wisely.

The best management practices described in this booklet relate soil management to your entire crop production operation.

We'll look at how soil management benefits drainage, moisture storage, and crop yields. We'll also look at how good soil management helps reduce soil compaction, erosion, and runoff.

But first, it's back to the basics. This section provides an overview of the science that soil management is based on: what soil is, how it is developed, its physical, chemical, and biological properties, and how to find out more about the soils on your property.

A good understanding of the behaviour of soil and soil life will help you develop and use a soil management program that will serve you well in the long term.

Building on this knowledge base, the second half, "Putting It All Together", addresses in-field soil concerns and lays out best management practices for a variety of conditions.

Throughout the booklet, we'll be referring you to other booklets in the Best Management Practices Series. For the big picture, we urge you to read these too.

UNDERSTANDING THE BASICS

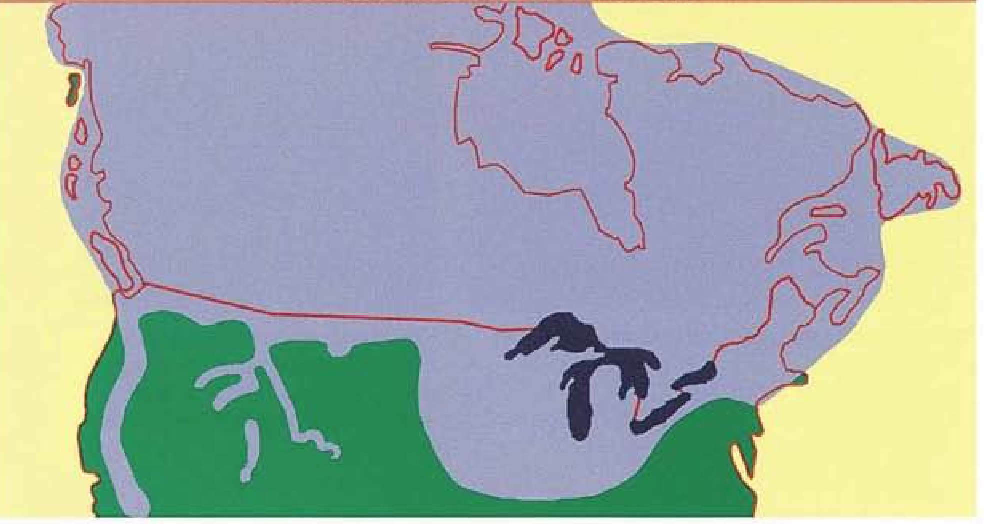
SOIL-FORMING FACTORS	
Climate	temperature, precipitation
Parent Material	source, size
Organisms	vegetation, animals, microorganisms
Topography	slope, position on slope
Time	start of soil formation, climatic change

The manner and speed in which a soil develops are determined by the interaction of five soil-forming factors.

SOIL FORMATION

The properties of today's soils are closely related to landforms. These landforms were created by glacial ice, meltwaters, glacial lakes, and wind. Advancing glaciers ground rocks into fine particles, and mixed and moved existing soil. Retreating glaciers dropped soil materials from within the ice itself. Meltwater deposited sands and gravel as mixed layers. Lakes that formed by ponding meltwaters deposited flat beds of sand, silt, and clay. Strong winds across bare, level landscapes further distributed the soils. Today's soils developed on these deposits.

EXTENT OF GLACIAL ACTIVITY IN ONTARIO



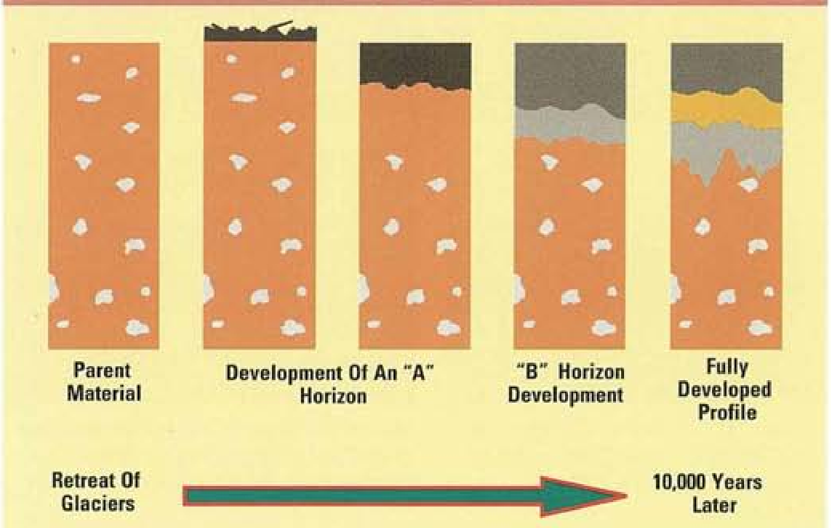
Today's soils are derived from the materials deposited by the retreating ice about 12,000 years ago. At that time, all of what we know as Ontario and most of Canada was covered with thick layers of ice called glaciers.

Thousands of years of coniferous forest have helped to form the distinct layers in this coarse-textured acid soil.

While soil formation has been an ongoing process for 12,000 years, the process can be easily disrupted by human activities. A host of physical, chemical, and biological processes combine to alter the original rock or rock debris.

UNDERSTANDING THE BASICS

SOIL DEVELOPMENT WITH TIME



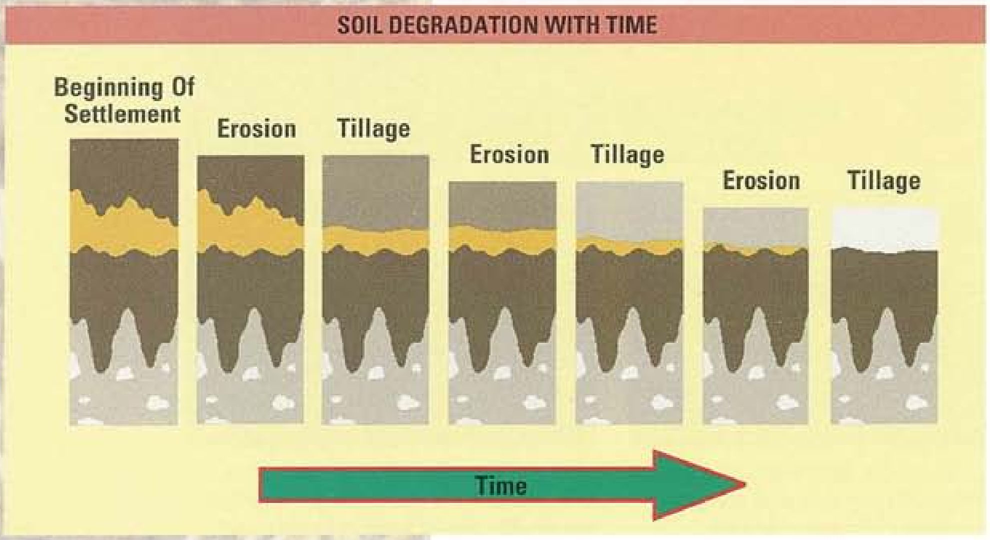
Soils develop over time. After glaciation, vegetation established itself on the unweathered parent materials. Gradually, roots and dead plant materials were added to the surface, and eventually incorporated into soil parent materials by soil organisms – forming topsoil. Acids released by roots and decaying organic matter helped lime and clay particles leach through the soil. This process created a leached layer below the topsoil and a clay-enriched layer below that. Today, the lime-rich parent materials are found at 60-120 centimetres (2-4 ft.) below the soil surface in uneroded fields.

COMMON SEQUENCE OF SOIL HORIZONS ON ONTARIO FARMS

Horizon	Description / Classification	
A	• an organically enriched layer at the surface. • a layer where minerals or clays have leached out.	Topsoil
B	• below, a layer where leached materials from above have accumulated. ▸ leached material is predominantly clay in Southern Ontario and iron in Northern Ontario.	Subsoil
C	• the parent material from which the soil has developed.	Parent Material

The next two pages illustrate Ontario's most common landforms and the soils that have developed in each. Environmental and production limitations are also described.

UNDERSTANDING THE BASICS



This illustration shows the impact of cropping and tillage on our soils. Note the loss of organic matter (lighter soil colour) due to erosion and dilution of the topsoil with less fertile subsoil. If erosion continues unchecked, less suitable subsoil materials form the seedbed.

Eroded knolls, also known as whitecaps, indicate that the parent material is at the surface. Almost a metre of soil has been lost from these areas.

"Ontario soils are young and relatively shallow, often with a thin layer of topsoil over dense subsoil. These soils are fragile; therefore soil management is critical to long-term sustainability."

Dr. G.J. Wall, Agriculture and Agri-Food Canada

Humans have had, and continue to have, the most influence on soil development in recent years, largely through farming practices such as tillage and crop production.

Tillage can lead to:

- a breakdown of organic matter that had accumulated in the soil, and dilution by mixing with lower horizons
  - loss of organic matter and increased specialization and mechanization of agriculture have created soil structural problems such as compaction and soil crusting
- erosion
  - tillage of eroded areas dilutes the topsoil, as less fertile subsoil is brought up by the plow.

Each soil is unique, with characteristics developed over time that hinder or help manage a crop. All soils respond to proper management. Understanding your soil's limitations will help you design an effective management program.

Soil characteristics – such as soil physical properties, chemical properties, and biological properties – are related to soil formation and also influence ongoing soil management.

Soil properties that influence choices in crop production and environmental sustainability are considered in the next section.

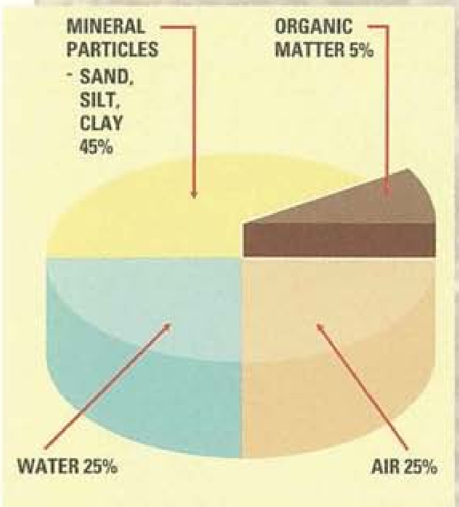
UNDERSTANDING THE BASICS

SOIL PHYSICAL PROPERTIES

The term **physical properties** includes:

- soil texture (sand, silt, clay)
- soil structure
  - structural form
  - structural stability and strength
  - porosity
  - bulk density
- organic matter
- water and air
- temperature.

A good understanding of what these components do and how they interact can help you better appreciate their considerable effect on crop production.



Shown here is an ideal loam topsoil, with the proper balance of air, water, organic matter, and mineral components. Note that the mineral fraction of the soil is almost 50%.

SOIL TEXTURE

Texture refers to:

- the mixture of different-sized mineral particles in a soil
  - soil particles range in size from gravel and stones to very fine clay particles
  - the percentage of sand, silt, and clay.

Sand has the largest particles; silt are smaller, and clay are the smallest. The texture of your soil influences all other soil physical properties, including drainage, water-holding capacity, soil temperature, aeration, and structure.

Soil texture can be considered an inherent soil property that you can't affect easily. However, you should know your soil texture and be aware of the limitations of that soil. (See the remainder of this book for more information on managing specific soil types.)

There are two ways to determine soil texture: a field method using your hands, and a laboratory method using a hydrometer.

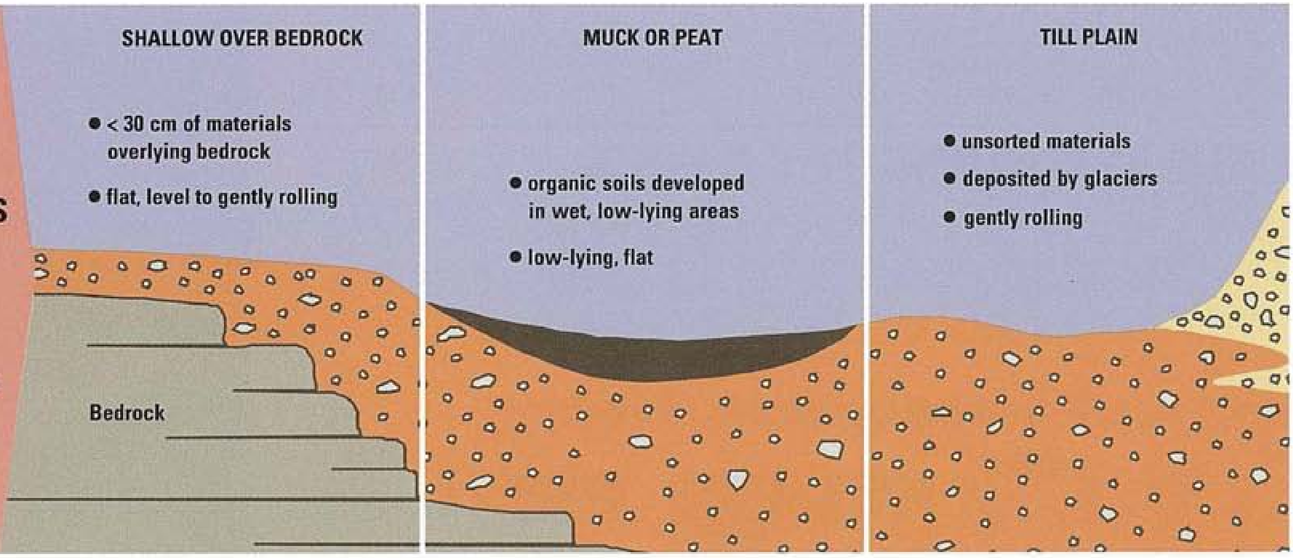
Hand texturing is used in the field to identify soil textures quickly. The first step is to determine the sand content. Rub a small amount of soil in the palm of your hand – is it under or over 50% sand?

If the sand content is less than 50%, add water to create a soil that is wet enough to roll.

Squeeze the soil roll between your thumb and forefinger to make the longest possible ribbon. A loam soil will form only a short ribbon.

Clay soils will form a much longer ribbon.

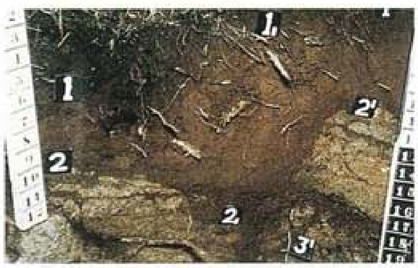
GLACIAL LANDFORMS AND THE COMMON SOIL TYPES OF ONTARIO



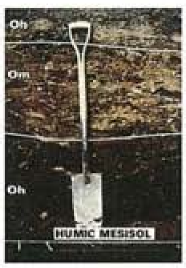
Shallow over bedrock lands are commonly used for extensive pasture and forest management in Eastern Ontario, and Bruce and Simcoe counties. *(Farmington landscape from West Carleton)*

Muck soils, also known as organic soils, are used for intensive production of high-value vegetables. *(Holland Marsh, Bradford area)*

Most of Southern Ontario's field cropland consists of gently rolling till plains. *(Guelph loam, Wellington County)*



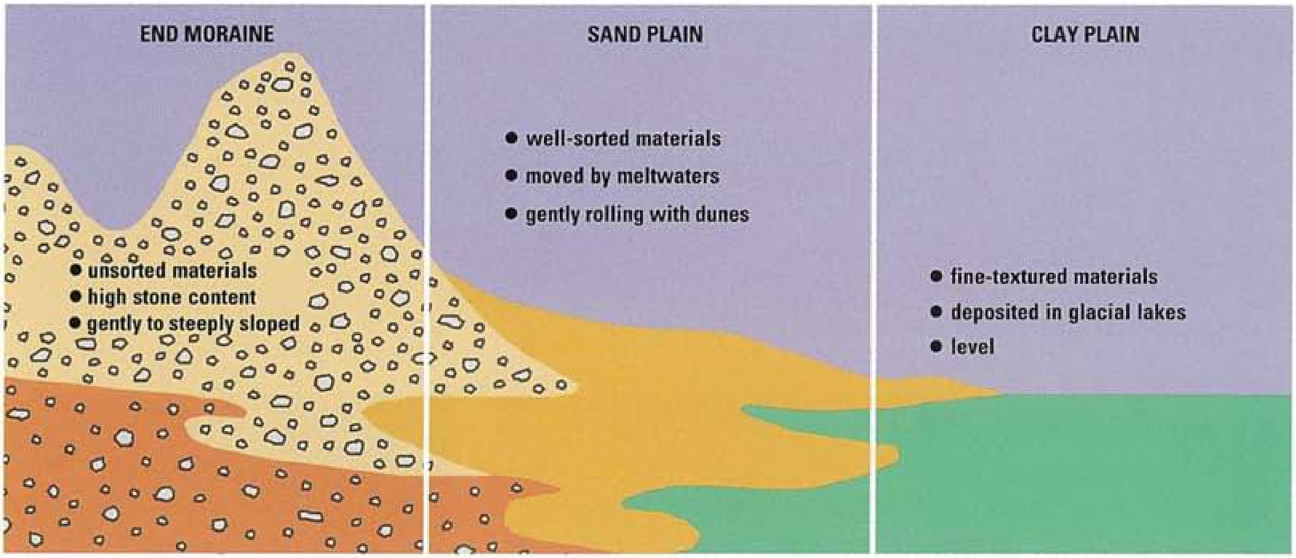
Most shallow over bedrock soils are too shallow for cultivation and for rooting of high-value crops. *(Farmington loam, Lanark County)*



Muck soils have a naturally high water table. Tile drainage is essential for economic agricultural production. *(Pelee Marsh, Leamington area)*

Till-plain soils are deep, loamy, and have good internal drainage. This makes them suitable for crop production, yet prone to erosion by water. *(Guelph loam, Wellington County)*

	SHALLOW OVER BEDROCK	MUCK SOILS	TILL PLAINS
SOIL MATERIALS	sands to clays – mostly loams	poorly decomposed (fibric); highy decomposed (humic)	sandy loams to clay loams; some stone content
RISK OF: water erosion	high	moderate	high
wind erosion	moderate	high	moderate
compaction	moderate	low	moderate
ground water contamination	very high	high	moderate
surface runoff	high	moderate	moderate to high



The hilly terrain and stoniness of end moraines make them suitable for pasture-forage-small grain rotations or forest management. ***(Pike Lake loam, Grey County)***

Fruits, vegetables, and other horticultural / specialty crops (e.g. tobacco) are grown on sand plains. ***(Granby sand from Haldimand-Norfolk)***

With tile drainage, Ontario's stone-free clay plains are used for forages and field crops. ***(Napanee clay from Lennox and Addington County)***

High stone content and shallow depths to unweathered, high-lime parent materials make end moraine soils too droughty and infertile for sustained crop production. ***(Dummer loam, Peterborough County)***

Some of the soils in sand plains, like this one, have clay-enriched layers at depths of 50 to 100 cm. These layers are crucial for improving the available water for high-value crops. ***(Fox sand, Brant County)***

The soils of clay plains have slow internal drainage and naturally high soil water tables – the grey colours and rust-coloured flecks are evidence of this. ***(Brookston clay, Kent County)***

END MORAINES	SAND PLAINS	CLAY PLAINS
sandy loams and loams; very stony and gravelly	sands, loamy sands; stone-free	clays, clay loams, silt loams; stone-free
high	low to moderate	low to moderate
moderate	high to very high	low
low to moderate	low	high
high	high to very high	low
moderate to high	low	low to moderate

UNDERSTANDING THE BASICS

The laboratory method relies on the fact that heavier particles such as sand drop out of suspension more quickly. Here are some sample figures from a Soil Analysis Report:

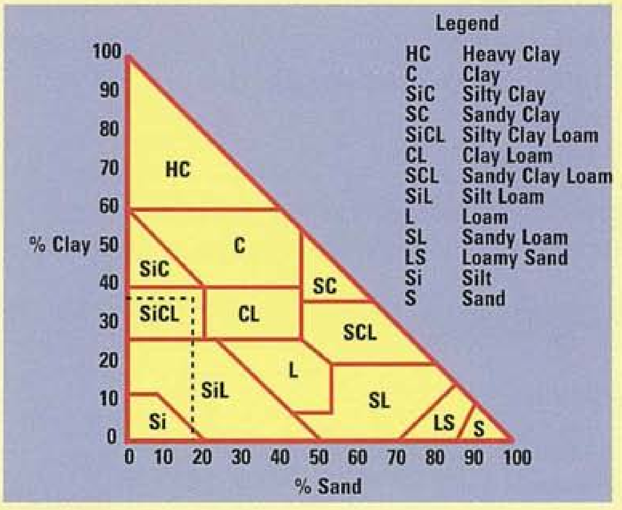
SAND 18.2% SILT 44.7% CLAY 38.0%

Results from the laboratory (i.e. percentage sand and clay) must be plotted on a textural triangle to determine soil class.

To use the triangle, start by finding one of the percent figures along that axis, then draw a line at right angles to the axis, e.g. clay 38.0%

Using the percent sand axis, find the percent figure e.g. sand 18.2%, again drawing a line at right angles to the axis.

The point where the lines cross is the soil textural class for that soil. Shown here is a silty clay loam.

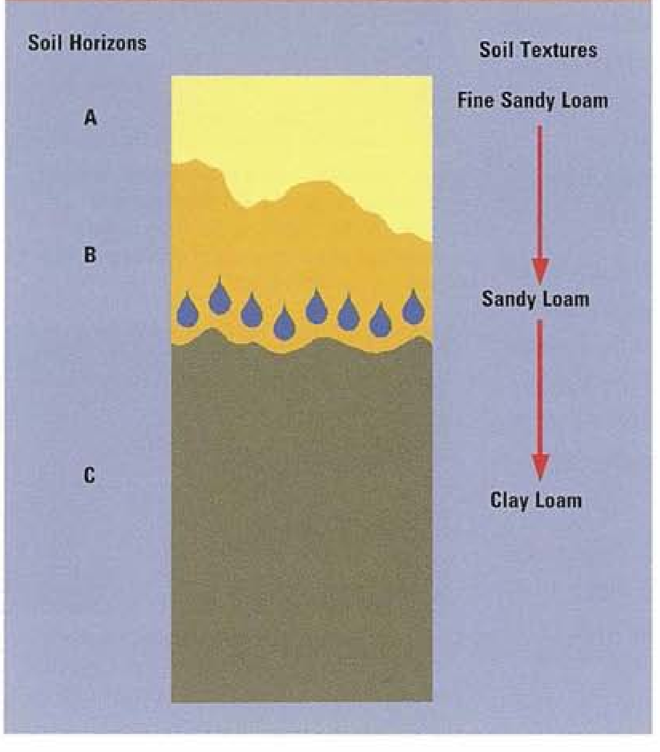


TEXTURAL LAYERS

Within some fields, the soil surface texture can be highly variable. This is also true of the subsoil. Because of the manner in which our soils were deposited and formed, layers of different textures are often present. This means that the subsoil can be an entirely different texture from the topsoil.

This can be seen easily during tile installation or along ditches. Refer to your county soil report.

INFLUENCE OF TEXTURAL LAYERS ON WATER MOVEMENT



Textural layers can play an important role in the drainage and water-holding abilities of a soil. Perched water tables are the result of textural layers – a layer of coarser-textured soil (e.g. sandy loam) over a finer one (clay loam in this example). Berrien sands and sand loams look somewhat like this.

UNDERSTANDING THE BASICS

SOIL STRUCTURE

Soil structure refers to how textural particles (sand, silt, and clay) are arranged into clumps or aggregates. The aggregates are bound together by clay and organic matter.

Soil structure can be considered in terms of form, stability, and strength.

The Brookston clay is one of the most common soil types (series) found in Southwestern Ontario. This particular sample is from a woodlot – note the fine, granular shape of the aggregates.

STRUCTURAL FORM

Structural form refers to:

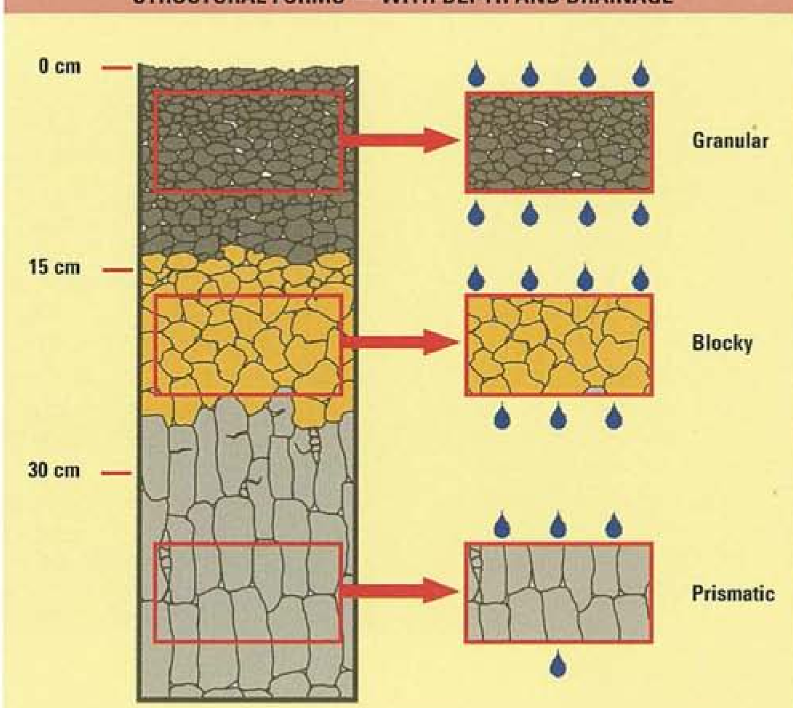
- the size and shape of the aggregates
- the network of pores or open spaces between and within the aggregates.

Many factors influence the size and shape of soil aggregates. These factors have the greatest influence in the topsoil layer, where there's usually a mixture of granular and blocky structures. The structure of the subsoil is more stable and the aggregates tend to be larger.

Structure affects:

- drainage
- infiltration
- aeration
- root growth
- germination.

STRUCTURAL FORMS — WITH DEPTH AND DRAINAGE



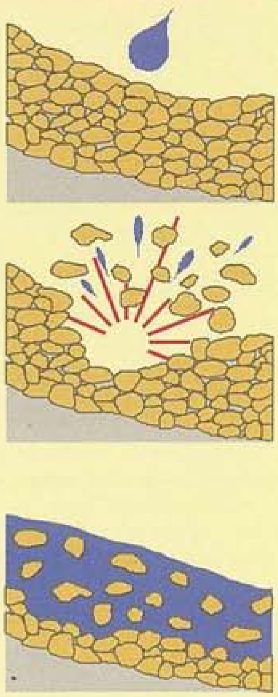
This diagram shows how structure can change with depth in a clay loam soil. The fine granular aggregates form a suitable seedbed and allow the free movement of air and water. Blocky aggregates are usually seen below the granular level and comprise the rest of the topsoil or A horizon.

Prismatic structures appear in the subsoil. This soil is usually more dense, hence water moves through this area more slowly.

In intensively managed soils, platy structures can also be seen (see disk pan, page 34). Platy structures slow the downward movement of water in soil.

UNDERSTANDING THE BASICS

RAINDROP IMPACT



Raindrops may feel gentle, but to a soil surface they can be like small bombs, breaking apart aggregates.

STRUCTURAL STABILITY AND STRENGTH

Structural stability refers to:

- the ability of the soil to maintain its structural form when subjected to stresses such as tillage, traffic, and climate.

CONTINUOUS CORN SOIL

WOODLOT SOIL

To illustrate soil stability, water was added to two petri dishes, with aggregates from a Brookston clay. One contained a soil sample from a woodlot (right); the other had soil from a field that had been continuously cropped to corn for 30 years. The continuous corn is unstable (i.e. it breaks apart), while the woodlot soil is strongly held together.

Here are the factors that affect soil aggregate formation and stability:

FACTOR	EFFECT
WETTING AND DRYING	• deep cracks that form during summer dry weather help to break down large clods and improve drainage and root penetration on heavy clay soils
FREEZING AND THAWING	• these encourage breakdown of large clods into smaller aggregates suitable for seedbed preparation
PLANT ROOT GROWTH	• roots penetrate weak areas in large aggregates and exert pressure to expand existing pores • roots and the substances they secrete help soil particles bind together
TILLAGE	• tillage reduces the size of soil aggregates
EARTHWORMS AND OTHER SOIL LIFE	• soil structural stability is improved when topsoil has passed through worm gut • fungae and other soil life help to stabilize soil aggregates

UNDERSTANDING THE BASICS

Soil scientists and farmers often talk about the **strength** of the soil. Soil strength refers to:

▶ the amount of energy that's required to break apart aggregrates or move implements through soil.

Soil strength is influenced by a number of factors:

FACTOR	EFFECT
SOIL WATER CONTENT	• as soils become drier, soil strength increases and more force is required to break down aggregrates
TEXTURE	• finer-textured, more dense soils (clays) stick together more than sands
STRUCTURE	• small, firm, granular aggregates are more easily tilled than large solid slabs.

You'll often find that a soil with poor structure is "tighter", which can interfere with root penetration and with tillage practices.

SOIL POROSITY

Soil porosity refers to the amount of pore space within the soil. **Soil pores** are the open spaces between and within aggregates, and are filled with air or water.

Soil pores play a vital role in the movement of air and water, as well as the growth of plant root systems.

Pores that are visible to the human eye permit water to pass and roots to move through, as long as the pores are continuous or connected.

There's also a network of smaller pores that can't be seen. They're important for the storage of plant-available water. Air and water move slowly through these micropores. For optimum plant growth, a mixture of large and small pores is necessary.

Note the roots and root hairs growing along the surface of this aggregate. Roots take the path of least resistance when soil strength is too great.

Penetrometers are used to estimate soil strength and to look at the different responses in experimental treatments. Penetrometers give a good estimate if used properly, although a flexible tile probe works just as well, particularly in farm fields. See "Detecting Compaction", page 36.

UNDERSTANDING THE BASICS

A plow layer in a no-till soil will usually have a bulk density that can be up to 20% higher than a moldboard plow layer.

The bulk density of the subsoil will be higher, depending on how it was deposited and the texture. For example, the subsoil density of a Guelph loam can be as high as 1.7 g/cm^3.

Ontario research suggests that the soil structural improvements generated by three years of a forage crop (e.g. hay) can be lost during one year of corn production with intensive tillage practices.

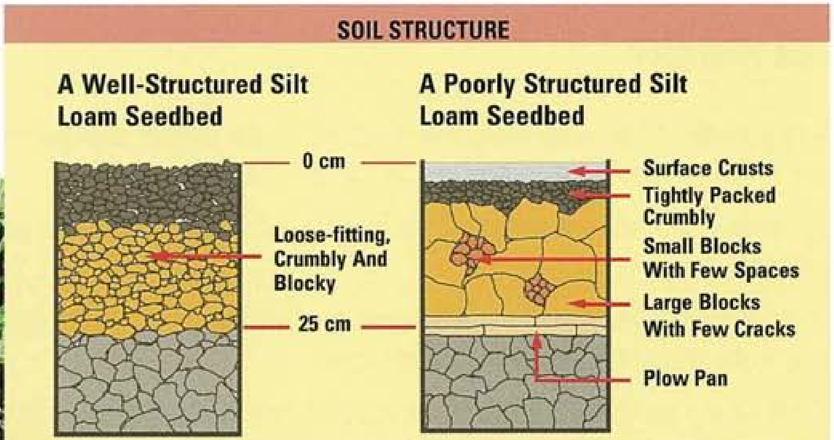
BULK DENSITY

An estimate of total porosity can be determined by measuring the bulk density of the soil. Bulk density is expressed as grams of soil per cubic centimetre.

A plow layer that has a density of 1.33 g/cm^3 will have a total porosity of 50%. This means that half the soil volume is available for occupation by water and air. As soils become more compacted, the bulk density will increase, meaning the porosity will decrease. The result is considerably less volume for water and air.

Soil is often tilled to loosen it or to create some structure in poorly structured soils. Tillage does "fluff" or increase the space between aggregates. However, excessive tillage also breaks down aggregates and increases the rate of organic matter loss.

Aggregates are altered by tillage. No-till and hay-pasture systems help to build stable aggregates, because they leave crop roots intact, increase biological activity, provide residue cover to protect the soil surface from weather, and leave undisturbed continuous pores such as worm holes and old root channels.



Poorly structured soils may have two common problems: compaction and crusting. Compare the "ideal" structure on the left with the crusted surface and compacted plow layer on the right. Note the changes in aggregate and pore sizes and arrangements.

Cropping and tillage practices affect soil structure. Note the granular structure of this sandy loam with grass hay (left), as opposed to the block structure of the same soil under edible beans (right).

UNDERSTANDING THE BASICS

SOIL ORGANIC MATTER

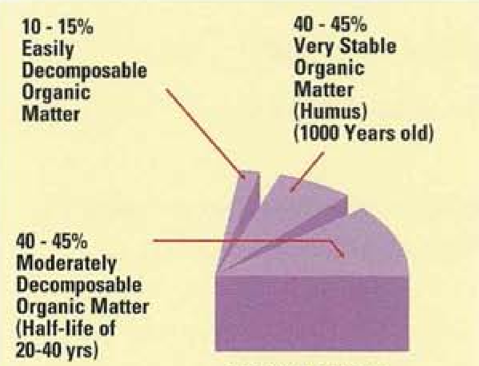
Of all the components that make up our soil, **organic matter** is the most important. Organic matter:

- ► plays a major role in moisture retention, helping crops withstand drought
- ► contributes to the chemical and biological properties of the soil
  - ▷ is a source of and exchange site for nutrients
  - ▷ affects the fate of applied pesticide
- ► contributes to the physical properties of the soil
  - ▷ organic matter provides glue-like substances that act to stick individual particles together to form stable aggregates and good soil structure.

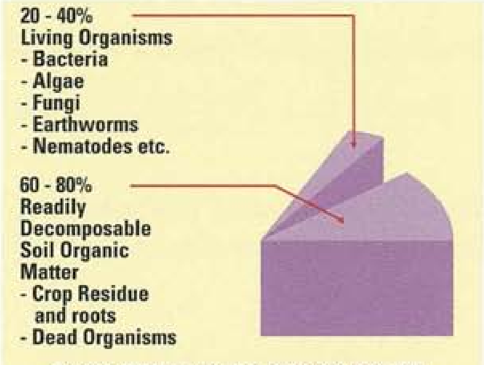
EFFECT OF SOIL ORGANIC MATTER ON SOIL TYPES AND STRUCTURAL PROBLEMS

SOIL TYPE	CRUSTING	INFILTRATION / DRAINAGE	COMPACTION	ERODIBILITY	WATER-HOLDING CAPACITY
SAND	■ (decreases)	■ (increases)	■■ (decreases)	■■ (decreases)	■■■ (increases)
MEDIUM (loam)	■■ (decreases)	■■ (increases)	■■ (decreases)	■■■ (decreases)	■■ (increases)
CLAY	■■■ (decreases)	■■■ (increases)	■■ (decreases)	■■ (decreases)	■ (increases)

■ decreases ■ increases



ORGANIC MATTER

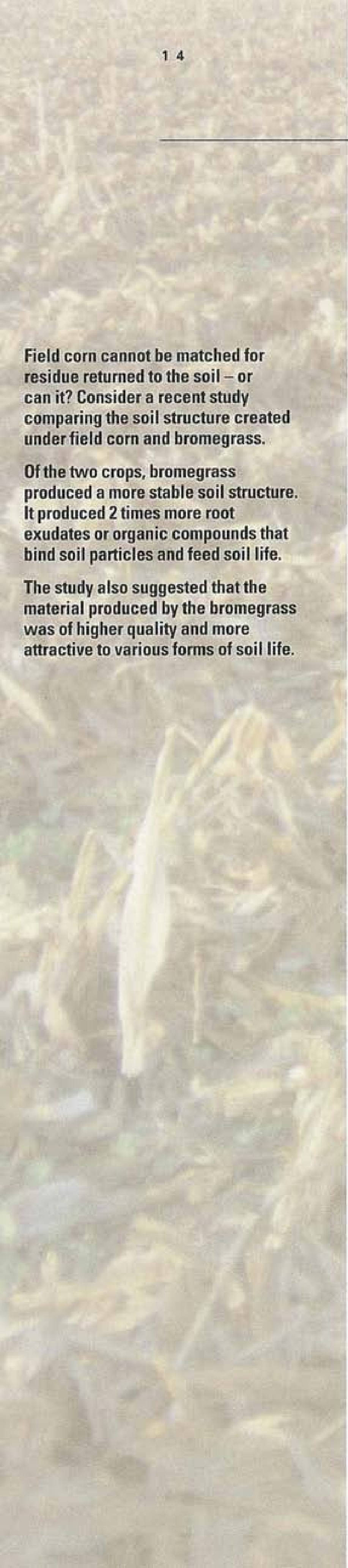


EASILY DECOMPOSABLE ORGANIC MATTER

An understanding of organic matter and its forms within soil is helpful when considering soil management techniques. There are three pools of organic matter in soil:

- ► **40 to 45% is very stable and with an age in the thousands of years (Humus)**
- ► **40 to 45% is moderately stable with a half-life in the range of 20 to 40 years**
  - ▷ **this portion is protected or held within soil clods and on clay particles**
- ► **the remaining 10 to 15% is easily decomposable material, and is composed of living and dead organisms.**

Dense, fibrous root systems encourage the development of stable, granular aggregates. These help form the type of seedbed that's resistant to crusting. Try to include grasses and forages in your rotation.



Field corn cannot be matched for residue returned to the soil – or can it? Consider a recent study comparing the soil structure created under field corn and bromegrass.

Of the two crops, bromegrass produced a more stable soil structure. It produced 2 times more root exudates or organic compounds that bind soil particles and feed soil life.

The study also suggested that the material produced by the bromegrass was of higher quality and more attractive to various forms of soil life.

UNDERSTANDING THE BASICS

Soil aggregate stability and porosity are directly affected by soil organic matter content. This is then observed as less crusting, better water infiltration and drainage, reduced compaction and erodibility, and an improved water-holding capacity.

Crops and other plants vary in their ability to influence aggregate formation and stability:

- ▸ long-term crops with dense fibrous root systems help to form water-stable aggregates, e.g. forage grasses and legumes
- ▸ row crops such as corn, soybeans, or vegetables have relatively sparse root systems.

BUILDING ORGANIC MATTER (A CALCULATION)

Soil organic matter is measured in the top 15 centimetres or to plow depth. This "hectare/furrow slice" weighs about 2,000,000 kilograms. Thus, 1% organic matter equates to 20,000 kilograms.

	Crop Residue kg/ha	Common Cover Crops*	Dry Matter kg/ha
Corn Stover	5,400-7,200	Oats	1,000-5,500
Wheat Straw	1,800-3,600	Rye	1,000-4,000
Plowdown Clover	2,700-4,500	Oilseed Radish	2,000-7,500
Soybean Residue	1,400-2,200		

* dry matter production depends on a number of factors related to plant growth.

In a best case scenario, only 20% of any residue returned to the soil will make it to the organic matter pool. The remaining 80% becomes part of living organisms, is released as gases during digestion, or has not become part of the organic matter flow.

It takes 5 kilograms of residue to make 1 kilogram of organic matter.

$$20{,}000 \text{ kg O.M.} \times \frac{5 \text{ kg residue}}{1 \text{ kg O.M.}} = 100{,}000 \text{ kg residue (1\% O.M. increase)}$$

Thus, it requires 100,000 kilograms of crop residue to raise the soil organic matter 1%. Assuming an average residue return of 5,000 kilograms from the above table:

$$\frac{100{,}000 \text{ kg residue}}{5{,}000 \text{ kg residue/y}} = 20 \text{ yrs}$$

UNDERSTANDING THE BASICS

It would take 20 years to build the organic matter by 1% (provided that the soil was never worked to speed up decomposition). But don't despair! It may be a slow process, but it's possible to improve over time. Cover crops and manure certainly help.

Work to either improve or at least maintain organic matter. If you do nothing and continue cropping, your organic matter levels will continue to drop.

Organic matter levels vary across fields in response to soil texture and slope position. For example:

	LOCATION	CULTIVATED ORGANIC MATTER	WOODED ORGANIC MATTER
Sand Middlesex Co.	Knoll	2.0%	7.0%
	Depression or low area	5.8%	20.0%

As you can see, erosion and tillage have taken their toll on organic matter. The depression (or deposition area) has retained much higher levels.

In contrast with the sand soil illustrated above, clay soils typically have higher organic matter levels, probably due to the greater aeration and organic matter loss in sand soils.

WOODLOT – 21% ORGANIC MATTER

CONTINUOUS CORN – 3.8% ORGANIC MATTER

PERMANENT SOD – 7.1% ORGANIC MATTER

Management and crop rotation directly influence soil organic matter levels. Crop rotations that involve a variety of crops, including forages and grasses, help to maintain and build organic matter levels.

A long-term experiment with clay soils illustrates this. Soil colour and structure indicate the soil organic matter level: woodlot, 21%; plowed, continuous corn, 3.8%; and permanent sod, 7.1%. (The apparent darker colour of the continuous corn soil is due to slightly higher soil moisture at time of photo.)

UNDERSTANDING THE BASICS

Earthworms are one of the first visible signs of soil improvement under no-till. Well-managed soils under conventional soils can also have large worm populations. However, under no-till systems the worm burrows are not disturbed. These continuous macropores help to improve water infiltration.

SOIL WATER AND AIR

Soil water and air play vital roles in plant growth, as we'll see in this section.

SOIL WATER

As soil moistens from rainfall or irrigation, the soil eventually reaches a point where it can't hold any more water, and any excess drains away freely. The soil moisture content after the excess water has drained is known as **field capacity.**

As more and more moisture is taken out of the soil by plant roots, eventually it becomes very difficult for the plant to remove any more water and the plant starts to wilt. The **permanent wilting point** is the soil mosture content at which plants will not recover from wilting.

The difference between field capacity and permanent wilting point is the **available water-holding capacity** or the moisture available for plant growth.

SOIL TYPE	mm OF WATER AVAILABILITY IN A METRE OF SOIL	
	AT FIELD CAPACITY	AVAILABLE TO PLANTS
SAND	100	75
SILT LOAM	267	167
LOAM	283	167
CLAY LOAM	317	167
CLAY	325	117

The available water in a soil varies, depending on texture, structure, and soil depth. These concepts are important in water management for irrigation and can help to explain some differences in field performance under identical conditions.

UNDERSTANDING THE BASICS

The **drainage** of water through the soil depends on the continuity of large pores and channels. Drainage can be influenced by structural layers as well as other layers of different permeability (texture, buried crop residues).

For more information on drainage, see the Best Management Practices booklet, *Water Management*. *Field Crop Production*, *Horticultural Crops* and *Irrigation Management* address crop and field management in greater detail.

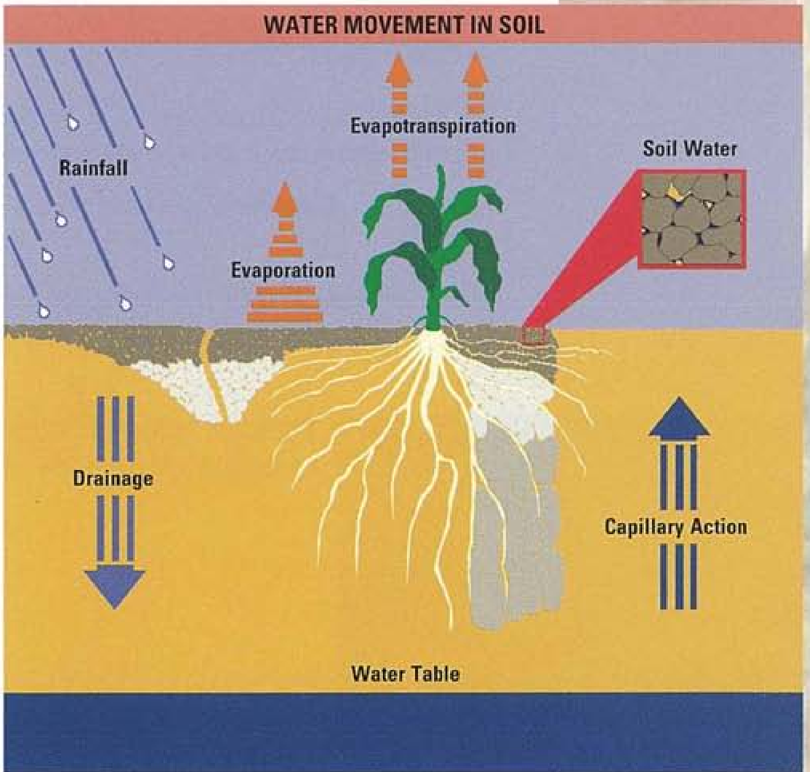
Once the water has drained, there's still some water movement called **capillary water movement**. This includes water drawn upward from the water table through very narrow cracks and pores. Capillary water can play an important role during dry weather in loams and clays.

Ontario has more **precipitation** during the cold months of late fall, winter, and early spring than there is moisture loss due to **evaporation** or **plant transpiration.** This net gain of moisture replaces the moisture used during the growing season, and replenishes ground water.

Sometimes there's a moisture deficit during the growing season, usually during the months of July and August. You can employ a number of cropping practices and soil management options to reduce the impact of the moisture deficit. See the "Droughty Soils" section on page 48 for more information.

Water can be lost from soil through evaporation from wet soil and from transpiration from plant leaves. Transpiration is the major source of water loss from soils.

There has been talk in recent years of using plants (particularly living cover crops) as a "bio-pump" to remove moisture from heavy soils for early planting. Transpiration is reduced in saturated soils, so it isn't effective when the soil is at its wettest. But it can dry a soil that is close to or at a workable moisture level. All the answers are not in: this is a recent innovation and requires further testing.



Water movement in soil occurs in a number of ways. Evaporation and evapotranspiration remove water, while rainfall replenishes soil water. Water drains through the soil; capillary water movement carries water upward.

UNDERSTANDING THE BASICS

Anaerobic conditions stop plant root growth and can kill plant roots and whole plants due to the toxic substances formed by anaerobic bacteria.

SOIL AIR

Soil air or **soil aeration** refers to:

▸ the amount and ease of air movement in the soil.

Roots and soil organisms need oxygen and also give off carbon dioxide as part of respiration. There needs to be a constant exchange of air and carbon dioxide in the soil, or else the oxygen will be depleted and the area will become anaerobic (no oxygen). Plant roots need air to be healthy.

Soil aeration decreases as the amount of water increases. As pores become filled with water, the air is forced out. Air moves primarily through the macropores.

Higher clay-content soils tend to have more pores that are smaller, and do not lend themselves to air movement.

SOIL TEMPERATURE

The temperature of the soil follows the temperature of the air, but with a time lag. As you go deeper in the soil, air temperature has less effect on soil temperature.

Although air temperature has a great influence on soil temperature, there are other factors at play.

Water content affects the rate of temperature change. More heat is needed to warm a wet soil than a dry one. Evaporation is occurring simultaneously, absorbing heat and keeping the soil cool.

Sunshine also affects soil temperature. Any shading, i.e. clouds, weeds, or residue, will reduce the transfer of energy to and from soil.

Dark soils absorb more heat; light-coloured residues tend to reflect heat, causing soils to warm more slowly.

UNDERSTANDING THE BASICS

Frost occurs when the temperature at the soil surface drops below the freezing point. Most spring frosts are associated with rapid cooling of the soil under very clear, still conditions. The temperature at the soil surface can be 4-5° C cooler than the air 1.5 metres above. The amount of cooling at the surface under these conditions depends on how warm the soil is to start with, and how quickly heat can move out of the soil.

We often see crop damage from frost in fields that have been freshly cultivated, because cultivation creates an insulating zone of fluffy, dry soil at the soil surface. This zone blocks the movement of heat out of the soil, allowing temperatures to drop low enough to cause crop damage, while adjacent areas that weren't cultivated are not damaged.

Heavy crop residue can also increase crop damage from frost by insulating the soil and preventing the release of stored heat. Sunshine and soil water content play major roles in determining the amount of heat stored.

Frost heaving occurs when water freezes in the soil. This can wreak havoc with deep-rooted crops like alfalfa. However, frost heaving can help to build soil structure, and can break up shallow, compacted layers in soil.

Wet or poorly drained soils are often called "cold-bottomed" because the soil takes longer to warm up in the spring. Soils that drain quickly such as sands will warm quickly. But they also give off the heat more quickly and so can be more frost-prone.

UNDERSTANDING THE BASICS

SOIL CHEMICAL PROPERTIES

To understand soil management, you need to know a little about the chemical aspects of the soil, such as soil pH, cation exchange capacity, and chemical properties of soil organic matter.

For a more detailed discussion of soil chemical properties, see the Best Management Practices booklet, *Nutrient Management*.

SOIL PH

Soil **pH** refers to the level of acidity in a soil. The pH is a measure of the number of hydrogen (H^+) ions that are in the soil.

The pH is recorded on a logarithmic scale that goes from 0 to 14. A pH of 7.0 is considered to be neutral. The higher the number, the less acidic or more alkaline the soil; the lower the number, the more acidic the soil. With a logarithmic scale, a pH of 6.0 is 10 times more acidic than a pH of 7.0, while a pH of 5.0 is 100 times more acidic than a pH of 7.0.

Poor crop growth is common in soils with a low pH.

Soil pH influences how efficiently a crop grows in a soil by affecting:

- ▶ nutrient availability (and potential toxicity)
- ▶ microorganism activity
- ▶ disease organism activity
- ▶ potential crop damage by some herbicides.

Most crops in Ontario grow best in soils that have a pH ranging from 6.0 to 8.0. Agricultural practices tend to lower the pH of soils over time, making them more acidic. This is the result of a number of activities:

- ▶ crops and plants removing nutrients
- ▶ leaching or water flow through the soil, removing nutrients
- ▶ decomposition of organic materials
- ▶ fertilizer application, particularly banded ammonium fertilizers
- ▶ acid rain.

Eventually, the drop in pH will become great enough to affect crop growth and yield, and you'll have to take steps to raise the pH. Soil pH can be raised using agricultural lime. Ontario Ministry of Agriculture, Food and Rural Affairs *Publication 296, Field Crop Recommendations for Ontario* gives the current liming recommendations with some discussion of lime quality.

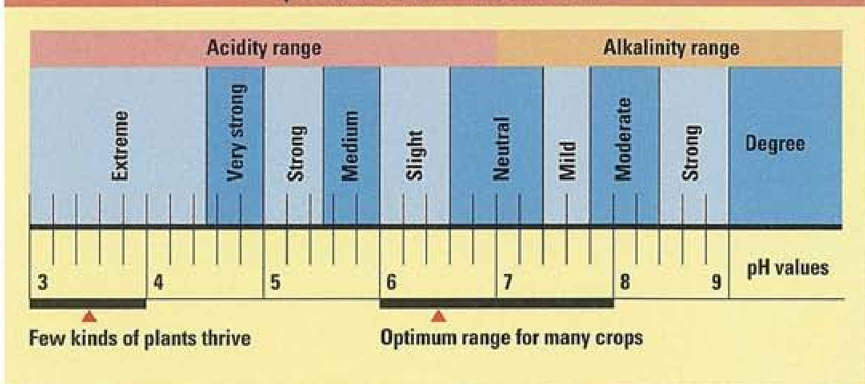
Not all soils become acidic. In areas with alkaline (calcareous) subsoils, tillage practices tend to raise the pH. This is due to dilution with subsoil as a result of tilling too deep, tillage erosion, and wind and water erosion.

UNDERSTANDING THE BASICS

Soil pH should be tested regularly, as part of your normal soil testing program. Regularly soil test fields to which large amounts of nitrogen are being applied to monitor changes in soil pH.

Some plants need highly acidic conditions to grow, such as blueberries, rhododendrons, and chestnuts. In some instances it may be necessary to lower the soil pH. For example, to grow blueberries effectively, a pH of 5.0 or less is required. You can lower soil pH through the application of elemental sulphur. However, if the soil pH is high (above 6.5), this can be extremely expensive.

pH SCALE AND PLANT GROWTH



CATION EXCHANGE CAPACITY

The **cation exchange capacity** is a measure of the capacity of the soil to hold some nutrients. It plays a role in soil fertility.

As soil minerals weather, **cations** are released into the soil water or solution. Cations are positively charged elements such as calcium, magnesium, hydrogen, and potassium (among others). These cations are attracted to the negatively charged surfaces of clay and organic matter particles. There's a constant exchange of cations between these surfaces and the soil water, called **cation exchange**. Cations aren't held tightly to these surfaces. Water can't remove them; however, they can be removed by changing places with cations discharged from plant roots.

The cations held on the organic matter and clay surfaces act as a reserve of nutrients, continually resupplying the soil solution with nutrients required by plants.

The size of the cation exchange capacity depends on the kind and amount of suitable surfaces for the cations to attach to. Organic matter supplies a much greater number of exchange sites for the cations than clay particles.

A high cation exchange capacity is desirable, because it indicates a fertile and resilient soil. However, the cation exchange capacity of a soil doesn't tell the whole fertility story – only the cation portion. That's why the Ontario system of fertility recommendation isn't based on cation exchange capacity.

High cation exchange capacities are associated with high clay contents and high organic matter levels. **For sandy and loamy soils, it's not easy to change clay content. However, organic matter levels can be maintained and improved to enhance cation exchange capacity. Follow the best management practices for soil structure and organic matter.**

UNDERSTANDING THE BASICS

Here are some examples of soil texture and cation exchange capacity:

SOIL TEXTURE	ORGANIC MATTER %	CLAY %	CATION EXCHANGE CAPACITY cmole (+) kg
SAND	1.7	7	6.3
SANDY LOAM	3.2	13.2	13.7
LOAM	4.9	16.8	20.2
SILT LOAM	5.4	18.4	24.0
CLAY LOAM	5.5	31.2	27.2
ORGANIC MATTER	100	—	100 - 300

NB: The cation exchange capacity of a soil is expressed in terms of centimoles of (+) charge per kilogram of soil. What's important here are the relative numbers as the clay and organic matter content increases.

SOIL ORGANIC MATTER

Soil organic matter acts like a bank for many essential plant nutrients, by:

- ▶ providing exchange sites for cations such as potassium and magnesium
- ▶ releasing nitrogen during breakdown
- ▶ providing virtually all of the manganese and boron that crops require throughout the growing season.

If you've ever taken out an old fencerow to make a larger field, you'll know that the fencerow produces tremendous crops during the first few years in production. This is attributable to organic matter, both in nutrient release and soil structure.

The benefits of organic matter to soil structure, coupled with increased nutrient release, explain the dramatic yields. Tillage promotes greater aeration of the soil, which increases the breakdown of organic matter and releases a large quantity of nutrients to support the following crop. In fact, this bank of nutrients is what many farmers relied upon to sustain crop production before the advent of commercial fertilizers.

Unfortunately, tillage also reduces the level of organic matter over time to the point that it may become difficult to maintain good soil structure, and increased additions of fertilizer are required.

UNDERSTANDING THE BASICS

SOIL BIOLOGICAL PROPERTIES

Soil structure is greatly affected by the animals and microbes in the soil. For example, the chemical and physical nature of the soil is changed as it passes through the intestines of worms. Soil animals and microbes can directly impact the availability of certain nutrients.

There are more organisms in a teaspoon of topsoil than there are people on Earth. Soil organisms are an intimate part of the organic fraction of soil, and contribute significantly to soil fertility and soil structure.

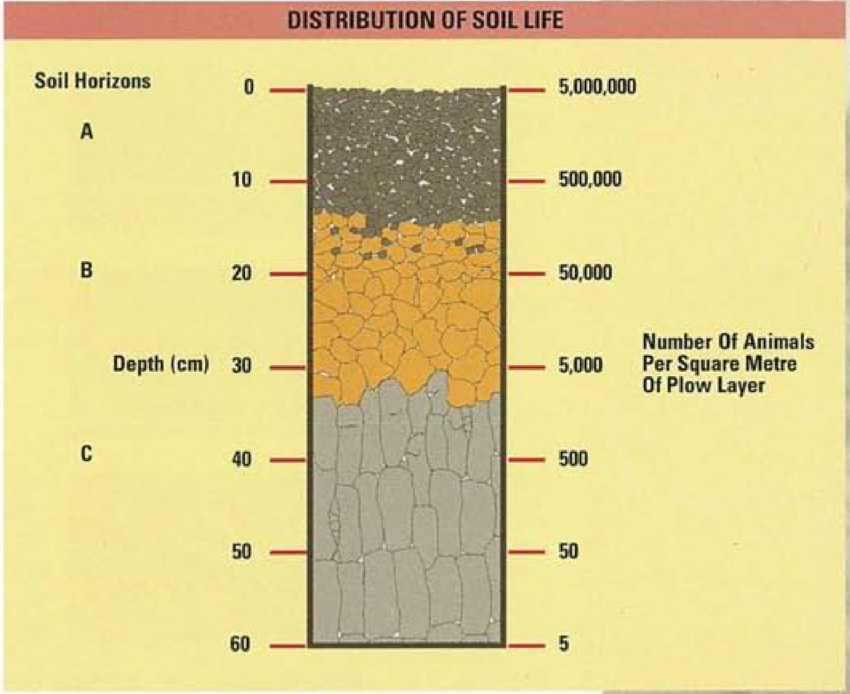
Plant residues have little value in the form we return them to the soil. The soil organisms, whether large (macro) or small (micro), feed on this residue and break it down in a continuous process.

Virtually all topsoil has passed through the gut of soil animals. Although we might think of burrowing animals such as groundhogs, moles, and shrews as having a large impact on soil because they are relatively visible, they are far less important to soil processes than the much more numerous, tiny animals and microbes.

The living organisms of soils can be divided into two broad categories:

- ▶ microorganisms
  - ▷ includes fungi, bacteria, actinomycetes and algae
- ▶ macroorganisms
  - ▷ includes protozoa, nematodes, earthworms, arthropods (insects, spiders, etc.), and rodents.

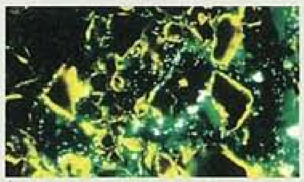
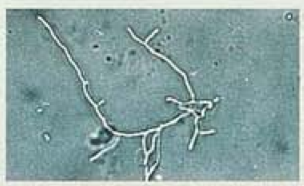
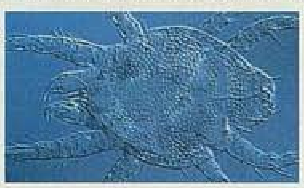
There may be billions of protozoans (one-celled animals) and bacteria, tens of millions of nematodes, and hundreds of thousands of mites in a square metre of plow layer.



The animals and microbes are not evenly distributed throughout the soil. Their numbers shrink very rapidly as we move below a few centimetres deep in the topsoil, and most of them seem to gather around plant roots and earthworm burrows.

UNDERSTANDING THE BASICS

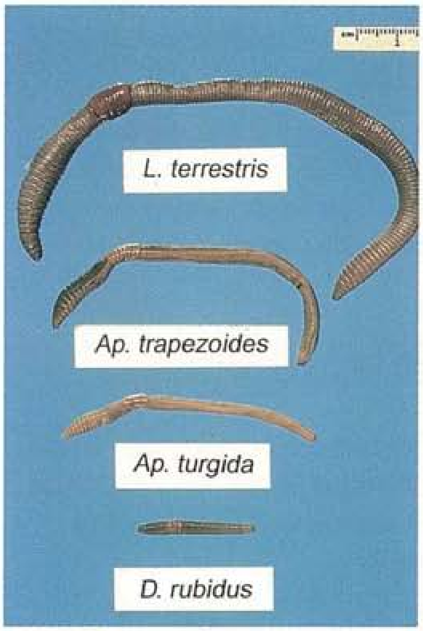
SOIL ORGANISMS

TYPE			IMPORTANCE
MICROORGANISMS	FUNGI		• after plant roots, they make up the largest amount of living material in the soil • help make soil nutrients available to plants • intolerant of intensive tillage • greatly involved in decomposition of organic matter
	BACTERIA		• important for good soil quality and fertility • N-fixing bacteria are particularly important and are associated with N-fixing plants such as soybeans, peas, clover, and alfalfa
	ACTINO-MYCETES		• decompose organic matter • abundant in low pH, droughty soils
	ALGAE		• decompose organic matter • commonly found in poorly drained soils
MACROORGANISMS	ARTHROPODS e.g. mite, spider, beetle		• graze on bacteria and fungi or decomposing plant materials • help to accelerate microbial decomposition
	EARTHWORMS		• burrow extensively, creating macropores and mixing soil • reduce bulk density • improve air and water infiltration • improve soil structure • increase nutrient pool
	RODENTS e.g. mice, groundhogs, muskrats, chipmunks		• pass organic materials through their gut when they burrow and feed in the soil • deposit fecal pellets rich in nutrients such as N, P, and K

Bacteria photo courtesy of H-J Altemuller FAL Braunschweig

UNDERSTANDING THE BASICS

EARTHWORMS AND ONTARIO SOILS



Smaller earthworms play an important role in organic matter cycling. They live within the top 4-8 centimetres, while the much larger dew worm can burrow 1-2 metres deep.

Earthworms are common in fine- and medium-textured soils (clays and loams), but rare in coarse-textured soils (sands). You can see this in a soil landscape where worms are rare on the sandy ridges, but abundant in depressional areas where fine soils, organic matter, and water accumulate.

One species, the **dew worm** or **Canadian Nightcrawler** (Lumbricus terrestris), is very abundant and widely recognized by most people. It's the species that's harvested from golfcourses, parks, and pastures. Hundreds of millions are annually exported to the USA for fishing bait.

Earthworm populations will dramatically increase in number:

- ► over two or three years when fields are converted to no-till or forages
- ► from regular manure applications
  - ▷ especially if conservation or no-till techniques are used.

WORMS AND GULLS

Studies have shown that gulls account for the death of only about 5% of the earthworms, while plowing can kill as many as 25% of the population. Many of the worms that gulls take are damaged by plowing and would die anyway. Gulls may also be feeding on soil insects.

EARTHWORMS

What are earthworms worth to you? Beyond the obvious soil benefits, earthworms are big business. Per thousand earthworms, pickers get \$15-\$20, wholesalers get \$40-\$50, and bait shops get \$1.70 to \$2 per dozen.

A field rich in earthworms can yield 100,000-150,000 worms/acre annually. Be aware of your worm population if negotiating with worm pickers. Don't be shortchanged!

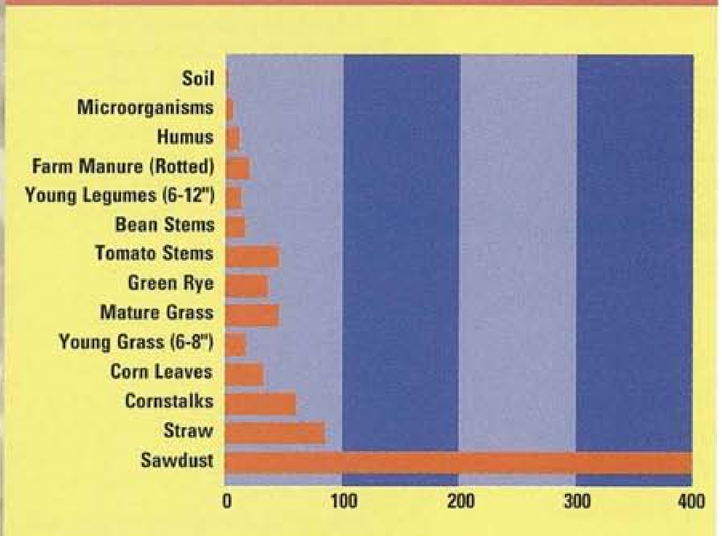
THE CARBON AND NITROGEN CYCLES AND C:N RATIOS

Most soil organisms are involved in breaking down plant material (and other soil organisms) in different stages of decay to more readily available plant nutrients or more stable forms of organic matter.

We call this the **carbon cycle**. It's the single most important element cycle in soil. It converts some of the annual growth of plants (crop residues) into soil organic matter that can be recycled for more plant growth.

UNDERSTANDING THE BASICS

CARBON TO NITROGEN RATIOS OF COMMON MATERIALS



When materials with high C:N ratios are added to the soil, microorganisms will tie up nitrogen. This creates a risk that nitrogen may not be available when a crop needs it.

A measure of the interaction of carbon and nitrogen is the **C:N ratio**. This number gives an indication of the difficulty of breakdown or **decomposition.** Usually decomposition, like plant growth, is nitrogen-limited due to too much organic matter or not enough nitrogen.

When the C:N ratio is very high (as is possible with added crop residues), nitrogen is used up by microorganisms, and the crop could become nitrogen-deficient. However, as the microorganisms die, nitrogen becomes available to either microorganisms or the crop.

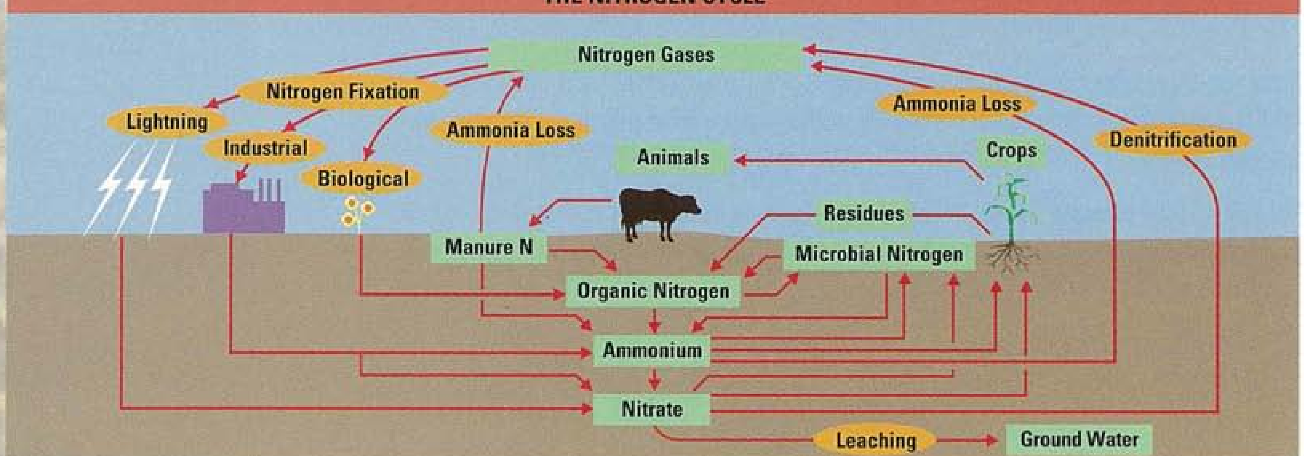
SOIL ORGANISMS AND SOIL STRUCTURE

The effect of soil animals on soil structure is considerable. Topsoil is basically composed of animal feces of varying ages. Soil animals ingest organic matter and mineral components of soil, and mix them together before depositing the combined material as fecal pellets or casts.

Reduce tillage and add organic matter: this will increase soil organism populations and improve soil structure.

Highly specialized microbes, mostly bacteria, are involved in the transformation of nitrogen through the N cycle. Nitrogen is essential for plant growth and microbial activity. The rate of the decomposition is governed by the relative availability of a few key nutrients: carbon (C) and nitrogen (N). (The processes of this nutrient cycling are discussed more fully in the Best Management Practices booklet, *Nutrient Management.*)

THE NITROGEN CYCLE

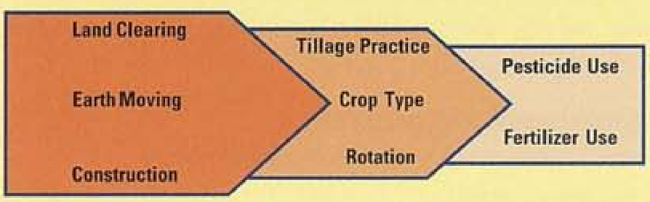


Nutrients are constantly cycling through soil, plants, and animals. The nitrogen cycle is an example of the nutrient cycling process.

UNDERSTANDING THE BASICS

IMPACT OF HUMAN ACTIVITIES ON SOIL ORGANISMS

HOW SOIL LIFE IS AFFECTED BY OUR ACTIVITIES

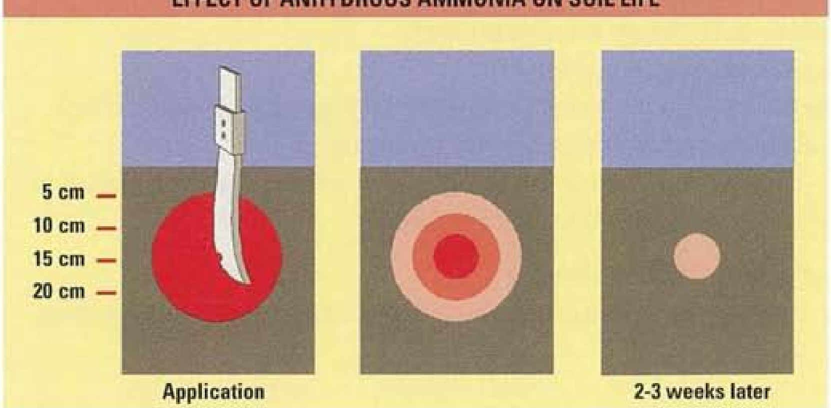


Tillage and earth moving have a much greater effect on the population of soil microorganisms and their diversity than pesticide use. Rotate crops and add organic materials such as manure when possible to increase biological activity and improve soil quality.

Pesticides have measurable but highly variable effects on soil organisms.

PESTICIDE TYPE	IMPACT
HERBICIDES	• can cause large reductions (usually temporary) of many soil organisms • less toxic than insecticides to soil animals
INSECTICIDES	• earthworms and other organisms can be very susceptible to rootworm insecticides, but the effect is limited to the zone of insecticide application
FUNGICIDES	• short-term reduction (2-3 weeks) in soil fungi populations. Benomyl fungicides are extremely toxic to earthworms and somewhat toxic to soil mites.

EFFECT OF ANHYDROUS AMMONIA ON SOIL LIFE



Anhydrous ammonia kills soil life in a small area around the applicator tooth. Soil animals move back into this zone over a period of several weeks.

FUNGAL MATS AND VAM FUNGI

The symbiotic relationship of bacteria and legume plants is well known. Researchers are just beginning to understand the role that fungi (VAM or vesicular arbusclar mycorhizzae) play.

VAM assist plant roots in obtaining nutrients from the soil by increasing the area exploited by the roots (up to 10 times the area). VAM play a significant role in low-fertility soils.

VAM in corn magnified 400 times.

Many microorganisms actually feed on pesticides: this is the primary means of pesticide breakdown.

UNDERSTANDING THE BASICS

Soil properties such as texture (surface and subsurface), organic matter, pH, etc. are intensely variable across a field. This variability is due to the original soil formation, erosion, and past and present management. Site-specific or precision management techniques are designed to measure and manage the differences across a field.

SOIL INFORMATION AND INTERPRETATIONS

Soil maps are available for most counties in Ontario. Soils are mapped based on their surface and subsoil texture, natural drainage (before tiling), stoniness, and other criteria. The amount of detail that can be included is limited, and your own experience of your farm's soils is important. Consider soil type and variability when making field management decisions about tillage, fertility, drainage, etc.

What is meant by "soil information and interpretations"?

- **soil information** refers to local (county or district) soil maps and reports
- soil maps show the extent of soil types (series)
- **soil interpretations** are suitability or risk ratings of soil types for various uses, e.g. agricultural capability and limitations for soil management, suitability for specialty crops, erosion risk, etc.

How can this information be useful for a soil management program?

- **soil maps** can help with farm planning by showing your soil types, their properties (materials, slopes, natural drainage class, stoniness), and the extent of these soils on your farm or area of concern
- **soil reports and interpretations** can help you learn more about the properties of your soils, the unseen areas of your soil (subsoil and geology), the implications for soil management, and potential environmental risks.

What are the limitations of this information?

- **scale** – most soil maps are mapped at a level of detail that is too general for intensive farm planning and development of a soil management program. Interpretations are based on experience and observation.

Soil properties within your farm can be quite variable. Often, only years of cropping a given parcel of land will reveal the extent of variability. Fortunately, soil maps give an excellent overview of the soils in your area, and are a good starting point for planning a soil management system.

How do you use the information on soil maps?

- **locate property** – use township, lots, concessions, and noticeable features like streams, woodlots, and buildings to locate property
- **list** – soil map unit symbols on property
- **soil map legend** – use legend to look up soil type and properties of interest (slope, texture, subsoil features, natural drainage), e.g. Brookston clay
- **soil report** – if you need further information about soil properties and interpretations of your soil type, look them up in the Soil Survey Report

How can you obtain soil information?

- **contact** your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs.

PUTTING IT ALL TOGETHER

Soils are complex – their health is affected by many factors, and symptoms of problems can be misleading. You must consider all aspects of what's going on in your fields before concluding what the problem is.

Is your soil healthy?

Ask yourself these questions. Do your soils:

- ▶ drain and warm quickly in spring?
- ▶ stay open and friable after planting, i.e. aren't prone to crusting?
- ▶ have little runoff, even after heavy rains?
- ▶ store moisture well for crop use during dry periods?
- ▶ resist erosion and compaction?
- ▶ have a varied crop rotation?
- ▶ produce high yielding, high quality, consistent crops (without excessive nutrient or pesticide applications)?

Did you answer yes each time? Give yourself a pat on the back. A few no's? Read on for information on common soil management problems that can have an impact on soil health. We'll look at several challenges in soil management:

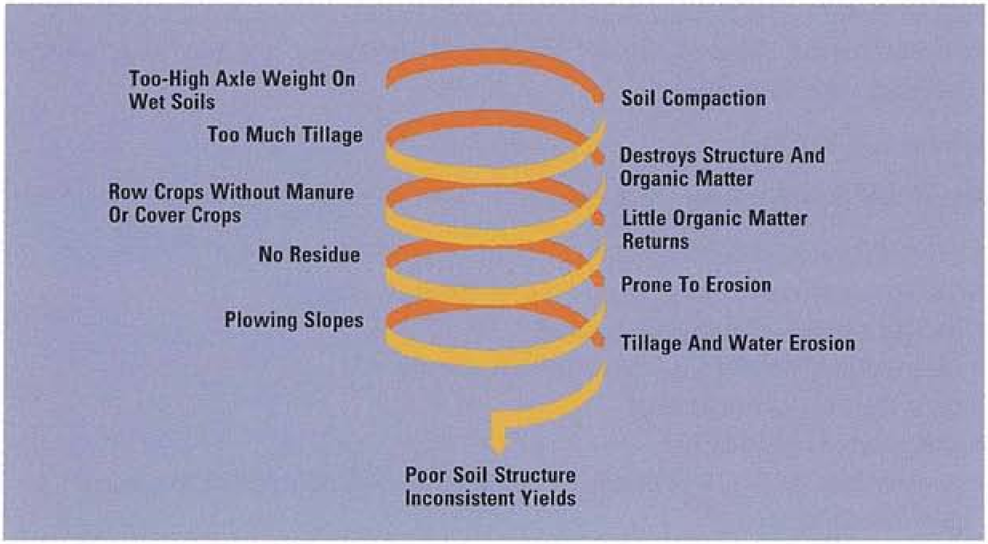
- ▶ soil structure
- ▶ erosion
- ▶ droughty soils
- ▶ subsidence
- ▶ wet fields.

Tree fruits are long-term crops that may not show the effects of soil-related problems for several years. Before establishing a new orchard, take a close look at your soil.

Before you start to no-till, ensure that fertility and pH levels are adequate. With time, the root systems and surface residues will help to improve soil structure.

It all comes down to productivity and sustainability; if you take good care of the soil, it will take care of you.

PUTTING IT ALL TOGETHER



Poor soil management is a vicious cycle. With increased tillage, fewer organic materials are returned to the soil, and soil structure and productivity suffer. Over time, the soil organic matter levels drop. When combined with erosion or compaction, yields drop and fewer organic materials are returned to the soil. The cycle continues in a downward spiral.

SOIL STRUCTURE

If your soil has structural problems, chances are it is weather-sensitive or stress-prone due to difficulties in root development and soil exploitation. Well-managed soils are productive, even under difficult growing conditions.

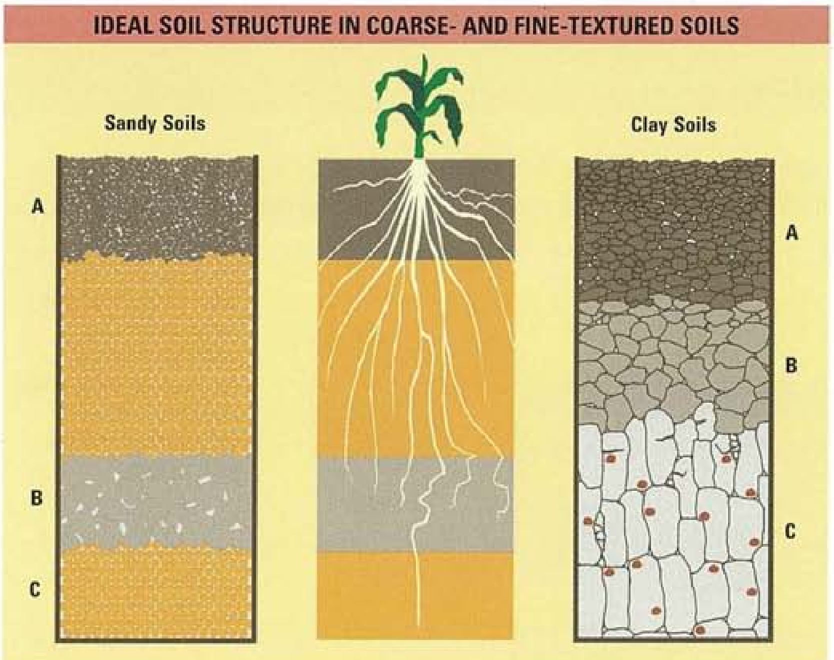
To maintain yields, short-term solutions are often used (such as extra fertilizer, better hybrids, and irrigation), even though poor soil structure is the main problem.

There are four main types of soil structure problems that occur across a range of soil types in Ontario:

- ▸ crusting
- ▸ compaction
- ▸ under-consolidation
- ▸ setting-up.

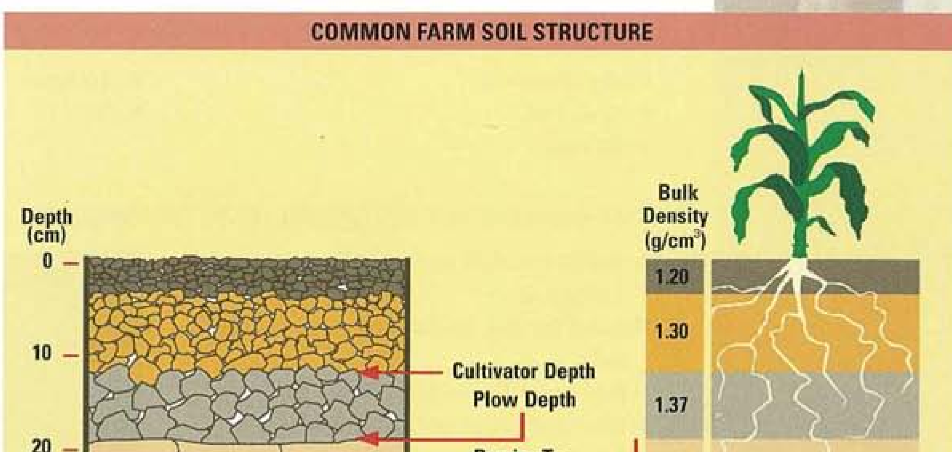
We'll be considering the first two in greater detail. They are more common and more complicated than the others.

PUTTING IT ALL TOGETHER



Soils with good structure have little or no impediment to plant growth. Plant roots follow the path of least resistance.

No-till cannot solve all soil structure woes. This field in early no-till desperately needs the benefit of zone tillage. Note the zone of rooting: very few roots extend beyond the area that the coulters have disturbed.



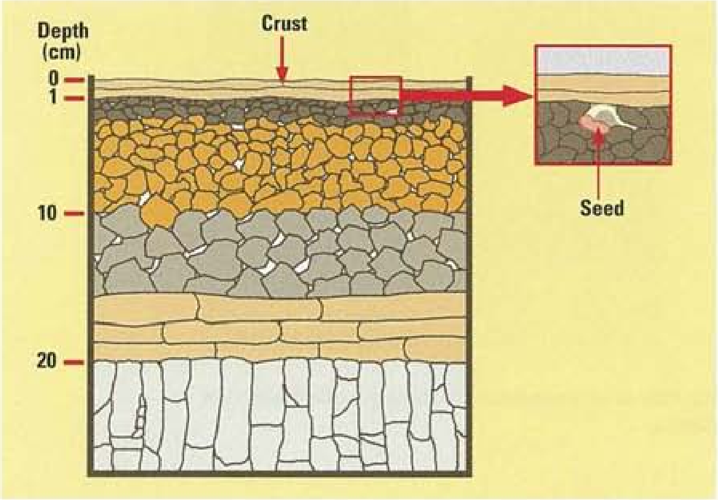
Soils farmed with modern agriculture rarely appear like the ideal soil. The processes of tillage, crop seeding, and harvesting tend to destroy aggregates and create a platy or compacted layer. Note how the bulk density increases in the compacted areas, and the impact on crop rooting.

PUTTING IT ALL TOGETHER

ADDRESSING SOIL STRUCTURAL PROBLEMS

SOIL CRUSTING

Following the rapid wetting and drying of an overworked seedbed, a solid sheet forms (0.2 to 5 centimetres thick) that is tight enough to prevent crop emergence. This is known as soil crusting.



After a heavy rainfall, some of the fine aggregates in the seedbed have formed a solid sheet of soil, preventing seedling emergence.

SOIL TYPES MOST AFFECTED

- very fine sands
- sandy loam
- silt loam
- clay loam
- clay.

PAST MANAGEMENT THAT CONTRIBUTES TO THE PROBLEM

- seedbed worked very fine with more than 3 tillage passes
- use of the disk (tends to pulverize and pack soil)
- field was rolled or packed after planting
- no crop rotation used, or limited use of legumes or grasses
- cover crops not used, soil is left bare
- crops that return very little crop residue to the soil are grown regularly (e.g. soybeans, edible beans, tomatoes, peas)
- no residue left on the soil surface after planting.

Excess tillage contributes to the problem of crusting. Repeated passes of tillage implements pulverize and pack the soil, destroying the stability of soil aggregates.

PUTTING IT ALL TOGETHER

FIELD SYMPTOMS

- following an intensive rain, the soil in top 1 to 2 centimetres flows together to form one solid sheet
- water ponds on the surface
- soil structure below crust still intact.

CROP SYMPTOMS

- crop emergence is sporadic and delayed
- growth is slow and stunted
- crops leaf out under the soil surface.

In crusted soil, corn will often leaf out under the crust.

Beans are particularly vulnerable to crusting, due to the cotyledons emerging. In soils prone to crusting, drill or plant beans in rows to get more concentrated upward movement.

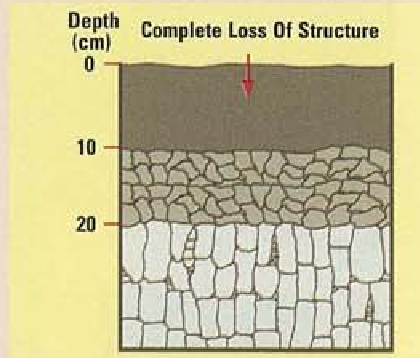
WHAT'S HAPPENING IN THE SOIL

- soil aggregates too small and not stable
- lack of organic matter.

BEST MANAGEMENT PRACTICES

- reduce secondary tillage; don't overwork the soil
- use reduced tillage, no-till, or ridge tillage systems to leave crop residue on the soil surface
- use a good crop rotation – include grasses and legumes where possible
- use cover crops
- use manure management to build soil organic matter
- use timely tillage
  - work ground at suitable moisture level to prevent bringing up clods – more clods require more tillage
- if a crust has formed before the crop emerges, rotary hoe to break up the crust – this will help the crop emerge, although this perpetuates soil structural problems
- check plant populations
  - replant as a last resort
- a light rain will help soften the crust.

OTHER SIMILAR PROBLEMS



SETTING UP

- a more severe form of crusting, usually seen on poorly structured soils after heavy spring rains.

Soil Types
- silt loam
- clay loam
- clay.

UNDERCONSOLIDATION

- tillage of wet soil has produced soil clods that are too large to create a good seedbed; further tillage fails to break the clods. The seedbed is loose, dries out quickly, and provides poor soil-to-seed contact.

Soil Types
- all soil types, including muck.

Best Management Practices
- a packer may improve the situation by breaking the clods
- timely tillage – delay first tillage pass until soil condition is suitable.

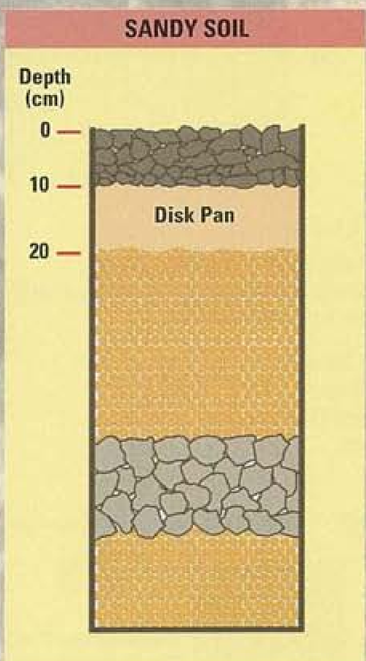
PUTTING IT ALL TOGETHER

Soil compaction makes a soil stress-prone. Weather extremes (too wet, too dry) will have the greatest impact on yield.

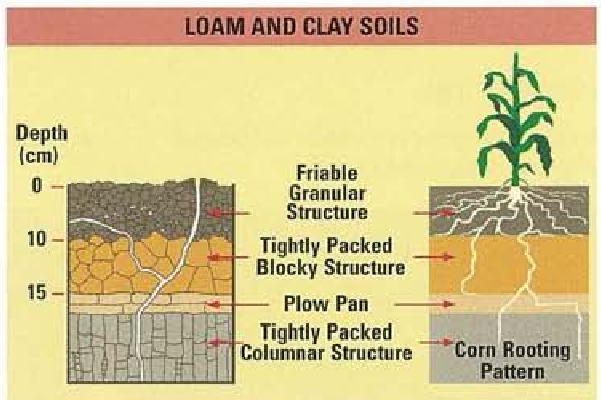
ADDRESSING SOIL STRUCTURAL PROBLEMS

SOIL COMPACTION

Compaction is the process of increasing soil density by packing soil particles closer together. It can occur anywhere in the soil profile, but tends to be seen near the surface or at plow depth. Good management can lessen the impact of compaction on soil structure.



Compaction can develop in any soil type. Sandy soils will exhibit an area of tightly packed soil particles. Finer-textured soils often have a gradually increasing density and resistance. The depth of the compaction depends on the type of compacting equipment. Disk pans develop at the bottom of the disked area. Plow pans tend to develop slightly deeper at plowing depth.



SOIL TYPES MOST AFFECTED

- sands
- sandy loams
- silt loams, loams
- clay loam.

PAST MANAGEMENT THAT CONTRIBUTES TO THE PROBLEM

- you're the first person in your area on the land each season
- the depth of primary tillage hasn't changed in years
- tillage occurs when soil is wet at or below tillage depth
- rotations are short with few forages/cereals
- specialty crops are grown with short windows for planting and harvest
- frost doesn't regularly penetrate to 15 centimetres or more.

Processing crops such as tomatoes, peas, and sweet corn must be harvested on time – regardless of soil conditions – to ensure quality. If harvest conditions are not good, considerable soil damage can occur.

FIELD SYMPTOMS

- water is ponding on soil surface
- pond sizes are getting larger
- erosion is occurring.

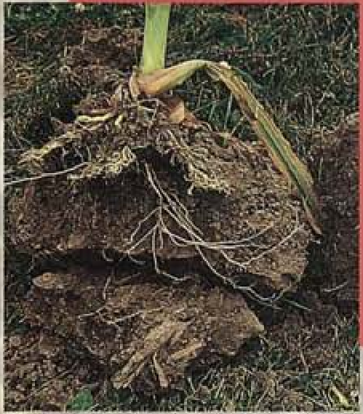
CROP SYMPTOMS

- crop growth can be slow, stunted, and variable, particularly under stressful weather conditions
- crop may exhibit various nutrient deficiencies
- roots tend to grow sideways or down large-sized holes/cracks
- roots below compacted layer grow normally
- root tips are flattened and/or swollen
- root growth is concentrated along face of soil clods
- roots aren't penetrating evenly into the soil.

PUTTING IT ALL TOGETHER

WHAT'S HAPPENING IN THE SOIL

- lack of organic matter
- poor soil structure
- unstable soil aggregates
- limited water infiltration – loss of pore size and continuity will reduce drainage and water will saturate topsoil first before infiltrating subsoil
- aggregates packed into dense layers
- soil pore size reduced
- decreased aeration – as pore size decreases, more of the pore space is filled with water. Soil becomes anaerobic, damaging plant roots.
- increased soil strength – roots will only grow into pores with a larger diameter than the root tip. Reduced root growth affects the water- and nutrient-gathering ability of a plant, especially under poor growing conditions.



Use a shovel to take a look at crop roots. This fine-textured soil poses a management problem under most conditions. Note the restricted root system and the large, solid area with few roots in the area between the cultivator and plow depth. Continuous corn production has contributed to the problem.

BEST MANAGEMENT PRACTICES

- timely tillage and field operations – stay off wet fields; soil should be at proper moisture conditions at tillage depth
- good drainage – tile drainage should be installed in fields with variable drainage
- longer crop rotations that include forages/cereals
- forage crops – leave in for longer than 1 year
- tillage equipment – ensure it lifts and shatters soil (coulter chisel, cultivator) as opposed to pulverizing and grinding (disk)
- alternate tillage depth so that tillage pans aren't created
- limit the amount of traffic, including tillage, across a field
- restrict compaction – create a long, narrow "footprint" with tire arrangement, e.g. radials, large tires, tracks
- limit axle loads to less than 5 tonnes/axle.

VARIATIONS – WHEEL TRACK COMPACTION

SOIL TYPES
- silt loam
- clay loam
- clay.

SYMPTOMS
- ruts and wheel tracks left during harvest, tillage, or planting in field and on field borders
  - crop growth pattern matches wheel spacing
  - tall, short plants
  - slow, stunted growth
  - uneven maturity.

BMP TIP
- till wheel tracks or avoid planting into them. See also Best Management Practices elsewhere on this page.

PUTTING IT ALL TOGETHER

A 170-180-lb person can exert up to 300 psi of pressure using a probe. A plant can exert 100-250 psi of pressure at the root tip.

Compacted areas will have plant roots that are flattened and stubby. The roots and root hairs will be concentrated in cracks, along the sides of aggregates.

When considering subsoiling, it's critical to follow the Detecting Compaction steps to determine the extent and depth of the problem. Subsoiling is a prescription tool and must be approached with care to avoid creating a greater problem.

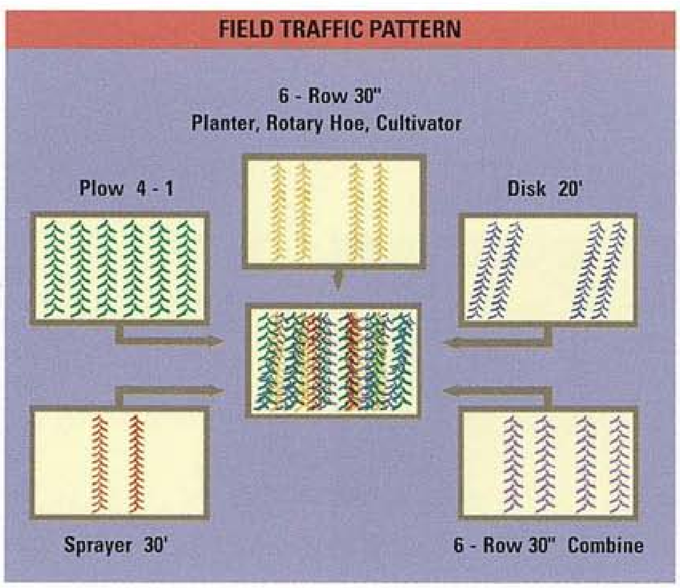
DETECTING COMPACTION

You can detect compaction easily with inexpensive tools. Here's how:

- ▸ flag the areas with symptoms that indicate a potential compaction problem
- ▸ using a tile probe or flexible rod, probe the affected area to a depth of 50 centimetres, and compare to a fencerow or an unaffected area
- ▸ the tile probe should be slowly inserted into the ground at a steady speed
  - ▹ your arms should be slightly bent, acting as the pressure gauge measuring the force required to push the tip of the probe through the soil
  - ▹ record the depths at which the tip of the probe requires more force to get it through the ground. These areas may be spots that roots can't penetrate.
- ▸ use a shovel to dig up the plants in the affected area and examine the roots. Compare the roots to healthy plants from an unaffected area. The compacted area will have plants with malformed/restricted roots. Roots may be concentrated in the top few inches of the soil.

Note: When using a probe to compare compaction of fields, the areas measured must have similar moisture content for the results to be comparable.

TILLAGE CONSIDERATIONS



How much of a field is covered with tire tracks in a year? The answer is often 90% for conventionally tilled fields. Here is the pattern of tractor wheel tracks during traditional seedbed preparation. This represents an ideal situation, where the equipment is matched to the tractor, and the number of field passes is kept reasonably low.

PUTTING IT ALL TOGETHER

SEEDBED PREPARATION

Cultivations play an important role in modifying topsoil structure, as large aggregates are broken into smaller ones, suitable for seedbeds.

Aggregates next to the seed must be small enough to provide favourable moisture conditions for germination. This is also known as the **soil-to-seed contact** .

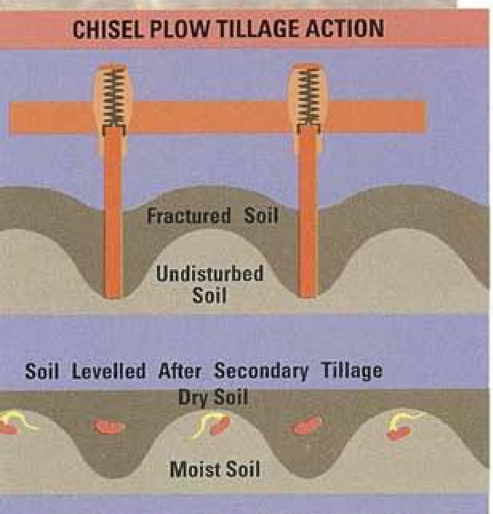
SEEDBED PREPARATION

	LOOSE SEEDBEDS	TIGHTLY PACKED SEEDBEDS
CAUSE	• seedbeds worked too fine • seedbeds left too cloddy	• excessive tillage • post-secondary tillage packing • farm implement traffic during growing season
IMPACT ON SEEDBED	• overpulverized seedbeds revert to block structure • crust formation after heavy rain • less permeable • more erosion and runoff	• density of soils increases below plow layer • the volume of large pores decreases • internal drainage and air movement are impeded; surface crusting can develop
IMPACT ON CROP	• delayed emergence due to poor soil-to-seed contact • crops can dry out	• root growth is impeded • slow and uneven emergence • temporary wilting

A rough seedbed can often be linked to poor emergence. Too many large aggregates make for very loose soil arrangement and poor seed-to-soil contact.

Ontario research has suggested seedbeds should have 50% of aggregates 2 mm in diameter or less.

PUTTING IT ALL TOGETHER



THE CHISEL PLOW

Chisel plows and coulter/disk chisels are often blamed for a variety of cropping problems, such as poor weed control and crop establishment. The problems can be traced back to the action the tillage implement has on the soil.

The straight or twisted shovel cuts through the soil, fracturing soil aggregates. If conditions are wet, the tooth will not fracture the soil completely, leaving strips of poorly loosened soil between valleys of loose soil. The surface of the field may look like the soil is all loosened, but below the surface the soil will appear more like the illustration on this page.

Seedbed preparations will smooth the soil surface, pushing dry soil off the ridges into the furrows. It is this uneven soil moisture profile and soil loosening that can cause poor weed control and crop germination.

BEST MANAGEMENT PRACTICES

- ► use a levelling bar (buster bar) at the back of the implement to level the tilled area and encourage even drying
- ► use sweeps or a combination of sweeps and twisted shovels to loosen all the soil. Be careful: sweep teeth can smear the soil at working depth under wet conditions.

Caution: soil moisture at working depth (the lowest level at which the equipment is operating) has the most effect on the success of a tillage system. Avoid wet soils: check soil moisture at working depth (see page 66).

Twisted shovels will create ridges of undisturbed soil. Levelling operations at seeding can help to create an uneven soil moisture profile.

Sweeps loosen all the soil, encouraging even soil drying. Take care to check soil moisture at working depth. Sweeps will smear under wet conditions.

PUTTING IT ALL TOGETHER

NO-TILL – WHAT'S REALLY HAPPENING IN THE SOIL

Experience, research, and observation have shown that no-till yields of winter wheat and soybeans are as good or better than yields under conventional systems on all soil types. Corn continues to present a challenge – but why?

It's thought that corn is affected by a combination of factors, including higher soil density (making corn root development and exploration more difficult), and cooler, wetter soils in early spring. The impact of these factors varies with soil type and previous management. For example, a sandy soil that has been properly managed will produce corn well under a no-till system.

Much is known about the hardware and machinery for no-till. Soil management and the interactions of a no-till soil structure and plants need much more research and development. In the meantime, **if you are in a no-till system, use a shovel to monitor your soil structure!**

Physical, chemical, and biological changes occur in no-till soils. Some of these changes are short-term as the system establishes itself; others are longer lasting.

PHYSICAL

SHORT-TERM	• density increases by 10-20% • loss of macropores (actually become smaller pores) • lower water infiltration
LONG-TERM	• more pore continuity • cooler, wetter soils due to residue cover • more stable aggregates • less erosion potential.

More stable aggregates and residue cover combine to reduce erosion potential. Surface runoff may be higher in no-till due to reduced water infiltration, but the residue cover slows the water movement. This causes the soil particles to be dropped. In the end, the water that runs off is cleaner.

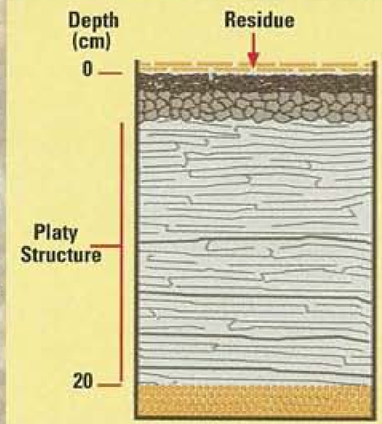
CHEMICAL

▸ organic matter is concentrated near the soil surface
▸ higher concentration of phosphorous and potassium near the soil surface.

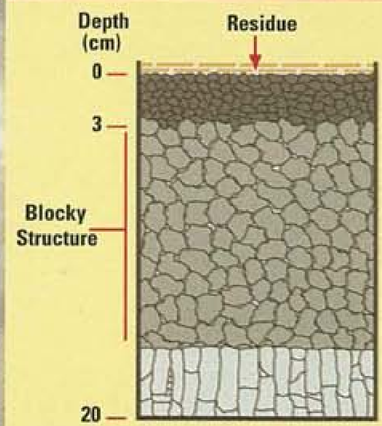
BIOLOGICAL

▸ significant increases in earthworm and biological populations (particularly fungi)
▸ total carbon content (organic matter) may increase slightly.

NO-TILL STRUCTURE ON SANDS AND LOAMS



NO-TILL STRUCTURE ON CLAYS



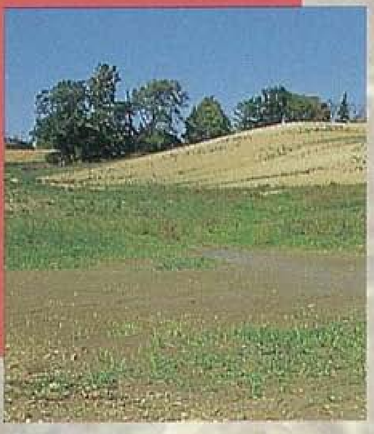
The top layer is very active biologically and produces relatively stable aggregates. However, these break down easily with coulter action to create a fine seedbed. Take a look under the residue cover and compare the soil surface to exposed soil.

Below the surface, soils with a coarse to medium texture will take on a platy appearance, while clay soils will have a thin granular layer over small- to medium-sized blocky aggregates. Over time, the clay will develop a definite structure and the aggregates will be easy to break apart with your fingers.

The structure illustrated here takes time to develop and may be subtle.

PUTTING IT ALL TOGETHER

EROSION



Water erosion moves and deposits soil particles. This Brant County field illustrates some of the problems: note the eroded hillsides and the deposited material in low areas.

Almost every farm in Ontario is affected by some type of erosion. It is a naturally occurring process. Farming practices have accelerated the rates of erosion, to the point that we are losing topsoil faster than we are creating it. Loss of topsoil on the farm:

- ► decreases crop yields
- ► increases cost of production
- ► degrades topsoil
- ► increases runoff and reduces water storage.

Off the farm, sediment or eroded soil can:

- ► increase the cost of maintaining drains and shipping channels
- ► destroy fish habitat and spoil recreational waters
- ► contaminate surface water, through runoff carrying pesticide residues and soil nutrients.

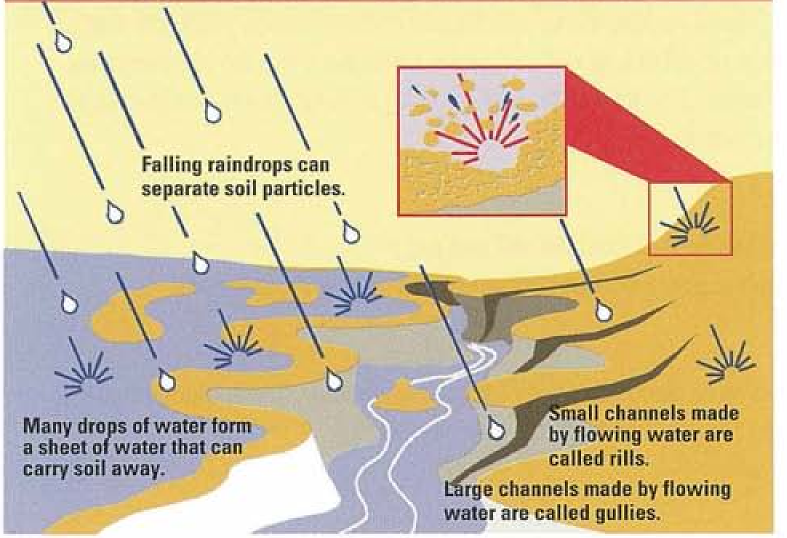
There are three main types of erosion: **water**, **wind**, and to a lesser extent, **tillage**.

Water can move soil particles from their original location by three processes: **detachment** (usually by raindrops), **movement** (usually by water), and **deposition** (where eroded soil accumulates).

Water removes more than just the topsoil. It also takes away or redistributes organic matter, fertilizer, and herbicides. In the long run, this can be very costly to you!

As soil continues to erode, the depth of topsoil decreases. Soon, you'll notice subsoil being mixed with topsoil. When the less productive subsoil is added to topsoil, the fertility and organic matter levels are diluted, and yields may decrease.

SOIL AND SOIL QUALITY LOSSES THROUGH EROSION



PUTTING IT ALL TOGETHER

As the smaller aggregates and single grains are eroded, the soil structure changes. The larger, blocky structures that are exposed require more tillage and management to create a suitable seedbed. Eventually, erosion can remove all the topsoil, leaving only subsoil. When this happens you'll notice a number of problems in your crop. You may not be able to get a crop to grow in these areas.

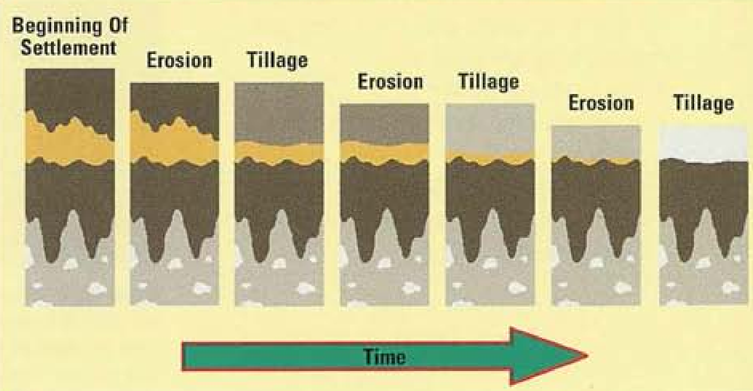
Wind erosion can also harm crop growth. Soil particles can move in three ways, depending on soil particle size and wind strength:

- **suspension** – occurs when very fine soil particles are carried high into the air (accounts for a small part of the total amount of soil lost by wind, but is the most visible)
- **saltation** – occurs with fine- to medium-sized particles that are lifted only a short distance into the air, then fall back to dislodge more soil
  - spinning action and downward movement of soil particles help to break off more particles and destroy stable surface aggregates
  - this is the most destructive form of wind erosion and can account for 50 to 80% of the total soil movement by air
- **surface creep** – occurs when larger-sized soil particles are loosened by the bouncing motion of other soil particles
  - these particles are too large to be lifted off the ground by most winds and must roll along the soil surface
  - accounts for up to 25% of the soil movement by wind.

Wind erosion not only moves soil around, but is very destructive to plants. Plants can be "sandblasted" by the soil particles that are carried in the air.

Wind erosion also removes the topsoil, organic matter, and crop inputs from cropland – which can be very costly. When the soil is deposited after a wind storm, seeds or plants can be physically buried.

SOIL AND SOIL QUALITY LOSSES THROUGH EROSION



Erosion reduces the fertility and productivity of a soil. It's a vicious cycle. More erosion means less crop production, which means fewer residues returned to the soil, which results in less soil surface protection.

Water erosion costs Ontario farmers approximately $68 million annually in lost fertilizer and herbicides.

Muck or organic soils are very prone to wind erosion. Wind speeds as low as 20 km/hr can cause muck soils to start to move.

WATER AND WIND EROSION: HOW MUCH TOPSOIL ARE WE LOSING?

Some areas in Southwestern Ontario are losing up to 150 tonnes per hectare of topsoil a year. An acceptable amount of erosion would be 3 tonnes per hectare.

Remember, it takes thousands of years to develop topsoil, but we can lose it through erosion in only a couple of decades.

PUTTING IT ALL TOGETHER

ADDRESSING EROSION PROBLEMS

WATER EROSION

Water erosion is the movement of soil by water to a new location. When the soil is saturated with water, or when rain is coming down faster than the soil can absorb it, water (such as rainfall) will run off the surface.

Rill erosion can often be seen following natural watercourses and in man-made planes of weakness in the soil. Two examples of the latter are the anhydrous applicator mark and, as seen here, a dead furrow.

Gully erosion refers to a rill that is too large to be crossed with equipment and cannot be filled in by tillage.

SOIL TYPES

- ▸ all soil types
- ▸ major problem with silt loams, very fine sandy loams, and loams
- ▸ acute problem on steep and irregular slopes.

PAST MANAGEMENT

- ▸ fall primary tillage performed every year
- ▸ tillage is up and down slope
- ▸ row crops are grown
- ▸ no or little crop residue is left on the soil surface
- ▸ cover crops are not planted
- ▸ a fine seedbed is prepared that may have been packed or rolled.

Many horticultural field crops, like these grapes, are grown in rows. Spring is the most dangerous time for erosion in row crops, as the inter-row soil is bare – unprotected by crop foliage.

PUTTING IT ALL TOGETHER

FIELD SYMPTOMS

- ► rills or cuts are formed on the soil surface after a rain or snowmelt
- ► soil has accumulated at the bottom of slopes or in depressional areas
- ► in the spring, fall-tilled soil seems to flow together
- ► ditchbank grass cover is buried with soil
- ► gullies formed in the field and tillage equipment can't fill them in
- ► soil on knolls is lighter in colour, and stones may be visible on the hilltop and sides
- ► crops buried with soil.

CROP SYMPTOMS

- ► varied crop development and yields across a field, with knolls having lower populations and shorter plants
- ► in drought conditions, crops on knolls stressed before rest of field
- ► seed exposed in seed trench following an intense rain.

Heavy rainfall and the resulting runoff and soil erosion have reduced the plant population in this cucumber field. The remaining plants have been stressed in areas of the field due to the moving of water and soil.

Water erosion removes soil from some areas and deposits it in others. Here, it is burying soybeans.

WHAT'S HAPPENING IN THE SOIL

- ► loss of organic matter
- ► soil has physically moved (aggregrates have been broken and detached)
- ► loss of topsoil
- ► rills or gullies formed in fields
- ► poor infiltration rates and reduced water-holding capacity
- ► soil crusting and increased runoff
- ► reduced fertility in eroded areas
- ► enhanced fertility and organic matter levels in depositional areas (which may not be within the field).

BEST MANAGEMENT PRACTICES

- ► use reduced tillage systems – no-till, minimum tillage, or ridge tillage
- ► use residue management – aim to leave at least 30% crop residue on the soil surface after planting
- ► use crop rotations that alternate row crops with solid-seeded crops
- ► drain wet fields
- ► construct erosion control structures where needed
- ► use strip cropping and buffer strips
- ► till and plant crops across the slope where possible or use a system of contour cropping.

Reduced tillage systems leave residue on the soil surface. The residue prevents erosion in several ways: it intercepts raindrops and creates a series of "mini-dams" to slow the flow of water across fields.

PUTTING IT ALL TOGETHER

ADDRESSING EROSION PROBLEMS

WIND EROSION

Wind erosion can be highly destructive to crops such as this tomato transplant. The leaves appear burnt and the plant has abrasions from the soil particles. Severe sand-blasting can reduce yields on tomatoes by 50%.

Wind erosion is the process of moving soil by air currents or wind.

SOIL TYPE

- all soils
- sands, sandy loams, and muck soils are the most prone.

PAST MANAGEMENT

- little or no crop residue left on soil surface
- fall tillage
- short rotations are used, mostly row crops or short-season crops, e.g. vegetables
- no cover crops grown – or are planted too late
- soil tilled to a very fine seedbed
  - may have been rolled and packed (creates a flat surface)
- fencerows have been removed.

FIELD SYMPTOMS

- soil surface appears smooth or rippled like beach sand
- knolls are lighter in colour
- during winter, the snow has a brown colour
- soil has accumulated on the leeward side of any barriers, e.g. buildings, equipment, trees, ditches, roads.

Wind erosion can occur at any time that the soil surface is bare. The soil surface may appear smooth or rippled like a beach or, as seen here, the soil may accumulate in the lee of a barrier (in this case, a fence).

CROP SYMPTOMS

- seeds or seedlings have been exposed, moved, or buried by soil
- plant may appear wilted or burnt
- stems and leaves have small pits or abrasions
- stems may be stripped of leaves
- crop growth slow, stunted, uneven
- plant population may be uneven.

These newly planted onion sets have been exposed by the action of the wind.

PUTTING IT ALL TOGETHER

WHAT'S HAPPENING IN THE SOIL

- detachment and movement of soil particles
- breakdown of any surface structure
- loss of organic matter
- loss of fertility.

BEST MANAGEMENT PRACTICES

- use crop rotations
  - alternate row crops with solid-seeded crops
- maintain and build organic matter levels
  - include forages and cereals in the rotation
  - apply manure (manure management) or other organic materials
- plant green manure crops after short-season crops
- keep the soil covered with cover crops
  - plant as early as possible
- keep the soil surface rough
  - use reduced tillage systems that leave residue and a rough surface
  - aim for 30% surface residue after planting
- plant windbreaks and use other wind abatement systems such as winter rye strips
- use strip cropping to break the sweep of wind.

Soil that is loose, dry, and exposed is prone to wind erosion. The keys to prevention are illustrated here:

- **keep it covered – rye cover crop**
- **keep the soil surface rough – chisel plowed**
- **reduce field size / break the wind flow – tree windbreaks.**

EMERGENCY TREATMENTS

- irrigate – but must wet surface before wind peaks (short-term)
- spread material to cover and roughen the soil surface – straw, cobs, etc.
  - may cause a harvest problem if machine-harvested, e.g. tomatoes
- create wind barriers
  - snow fence, wagons, straw bales, etc. to drop wind velocity. Beware of gaps – can cause jetting or channelling of wind.

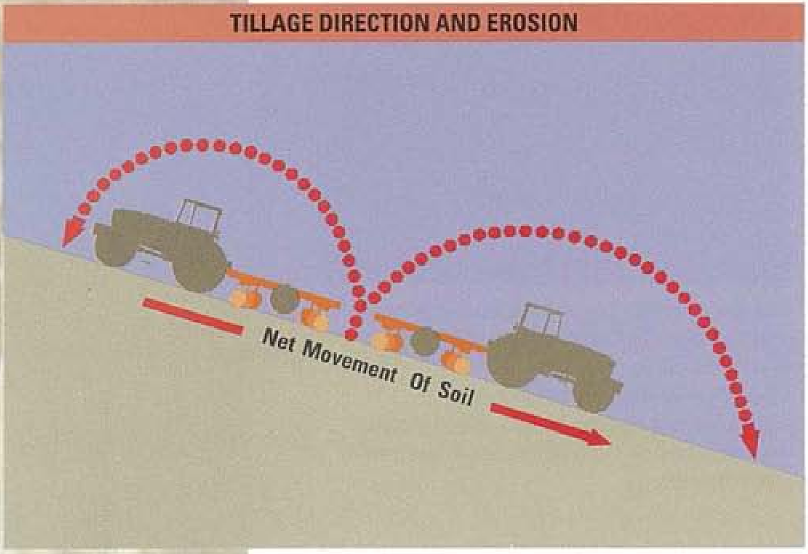
A variety of materials such as corn cobs can be used to control wind erosion in an emergency. When selecting the material, be aware of potential harvesting problems, and make plans to avoid the problem in the next year.

Timely irrigation can help to reduce wind erosion. This is a preventive measure only. It doesn't work well after the wind has started to move soil.

PUTTING IT ALL TOGETHER

ADDRESSING EROSION PROBLEMS

TILLAGE EROSION



If you plow up and down the slope, the plow throws soil uphill but gravity pulls it down. When you plow downhill, the plow and gravity work together and they move the soil downhill. Over time, there's a gradual movement of soil down-slope. Therefore, there's a net loss of soil on the hills or knolls.

"The tandem disc may be the most erosive tillage implement."

David A. Lobb,
Soil Conservation Specialist

SOIL TYPE

- all soil types
- most common on rolling topography.

PAST MANAGEMENT

- moldboard plow is the primary tillage tool or chisel plow with twisted shovels (any tillage system that tends to throw soil)
- field is sloping or hilly
- tillage direction is usually up and down slope.

Tillage erosion and the diluting effect of excess tillage depth have exposed white subsoil in this field.

PUTTING IT ALL TOGETHER

Soil loss of as much as 2 metres thick has been observed on upper slope positions.

FIELD SYMPTOMS

- soil on knolls/hillsides is lighter in colour and bare
- water erosion is worse than expected on hilltops eroded by tillage
- large amount of soil accumulated on lower slopes
- calcareous subsoil may overlay organic rich soil on lower slope positions.

When you plow or work soil up and down the slope, gravity helps to move more soil downhill than uphill.

CROP SYMPTOMS

- crop growth may be stunted
- crops may not grow on knolls
- crop growth and development are highly variable across the field
- yield losses on eroded areas of 30-50%.

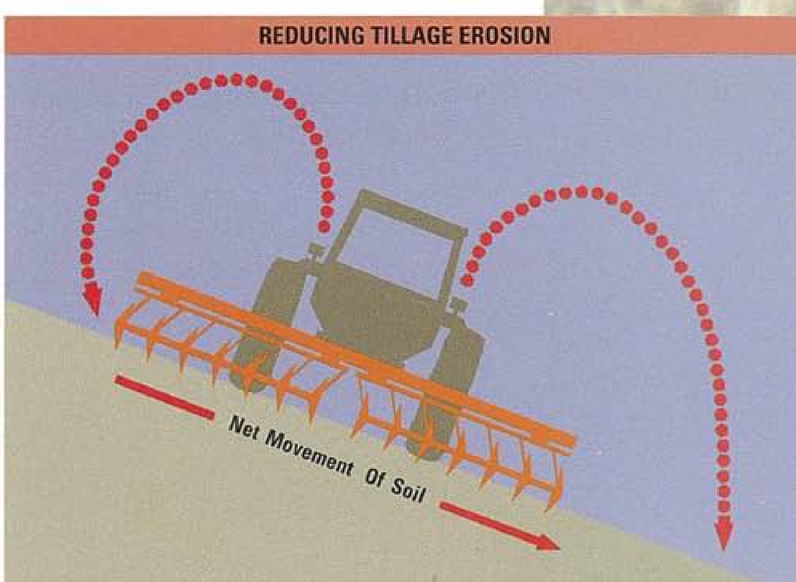
What impact does the exposed subsoil have on crop production? Here is a photograph of the same field during the growing season.

WHAT'S HAPPENING IN THE SOIL

- loss of organic matter on slopes
- gradual movement of soil downslope
- subsoil being tilled on knolls
- poor soil structure
- loss of organic matter on hilltops.

BEST MANAGEMENT PRACTICES

- where possible, till across slopes, not up and down slopes
- use reduced tillage systems such as minimum or no-till on hilly land
- keep eroded knolls and hilltops covered in vegetation as long as possible to reduce water erosion
- reduce the speed and depth of tillage operations (see owner's manual for recommendations)
- grow cover crops and/or add other organic matter sources such as manure to rehabilitate eroded soils
- if hillsides and knolls are severely eroded or extremely steep, consider retiring the land or planting the area to permanent forages.



By tilling across slopes, you'll reduce the gradual movement of soil downslope.

PUTTING IT ALL TOGETHER

OTHER SOIL MANAGEMENT PROBLEMS

While compaction and erosion are the two most common areas of difficulty in soil management, there are others.

DROUGHTY SOILS

Droughty soils have a low water-holding capacity due to the large number of large pores. As discussed on page 11, large pores drain quickly, while smaller pores hold plant-available water. The large pores are filled with air, which increases oxidation or loss of organic matter, further reducing the potential to store water.

Through irrigation, soils prone to droughtiness can be very productive. High-value vegetable crops grow well on many of these soils. However, the low return of plant material from vegetable production doesn't improve the water-holding capacity of these soils.

When checking the site for droughtiness, ensure that the moisture stress symptoms are not due to other factors, such as a restricted root system.

SOIL TYPE

- sands
- sandy loam.

PAST MANAGEMENT

- rotations with alfalfa, cereals not used
- crop residues not left on soil surface.

FIELD SYMPTOMS

- the soil is usually dry, and after a rain, water filters through quickly.

PUTTING IT ALL TOGETHER

CROP SYMPTOMS

- crops are stressed and wilted, leaves are curled or cupped
- plants are yellow, looks like a nitrogen deficiency
- crops are stunted.

Drought symptoms are very apparent on corn – wilted, pale green in colour with leaves that roll up. Dry soil conditions can also interfere with the movement and uptake of mobile nutrients such as nitrogen, which depends on water to move to the plant.

WHAT'S HAPPENING IN THE SOIL

- low water-holding capacity
- lack of organic matter.

BEST MANAGEMENT PRACTICES

- use reduced tillage systems and residue management to create a layer of residue to conserve and retain moisture
- use cover crops
- include forages in the crop rotation
- apply manure (manure management) or other organic materials to build soil organic matter levels and improve water-holding ability
- irrigate high-value crops using an irrigation scheduling system to conserve water
- use good irrigation practices such as irrigating in late afternoon or at night to reduce evaporation.

Droughty soils tend to have low organic matter levels, low nutrient-holding capacity, and a high potential for nutrient leaching. Manure application can help build organic matter levels and supply nutrients. A word of caution: apply manure at reasonable rates, just before planting, to reduce the potential for leaching.

PUTTING IT ALL TOGETHER

OTHER SOIL MANAGEMENT PROBLEMS

SUBSIDENCE

Subsidence is a gradual lowering of the surface elevation of an organic muck soil, or a reduction in the thickness of organic matter.

Over hundreds of years, organic soils have developed from the layers of plants laid down in low, wet areas. The high water table creates anaerobic conditions that slow the breakdown of organic materials. However, drainage is essential to make production of high-value vegetable crops practical.

Once the original muck soil is drained and tilled, the process of subsidence begins. The organic matter is lost or broken down in a number of ways:

- wind erosion
- water erosion
- biological oxidation
  - drainage and tillage add air to the soil, speeding the degradation of organic materials by aerobic bacteria.

Biological oxidation is the most significant.

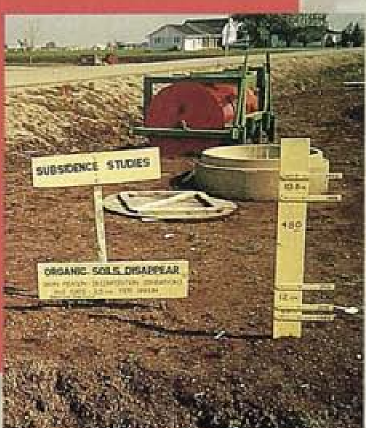
Unless properly managed, subsidence can quickly reduce the thickness of organic material and expose the mineral subsoil. In time, the remaining organic material becomes diluted through the incorporation of the organic layer into the mineral subsoil. This reduces the productivity of the soil.

SOIL TYPE

- organic or muck soils.

Muck soils are easily overworked. This speeds the breakdown of organic matter.

Muck soils are highly productive. But the productive lifespan can be greatly reduced by the loss of soil depth, through a process known as subsidence.



Subsidence can account for large losses of soil. For example, at the Bradford Muck Research Station the following losses have been measured:

1945-1957	1.08 cm/yr
1957-1967	4.8 cm/yr
1967-1975	1.08 cm/yr
1975-1983	0.47 cm/yr

for a total of 73.4 cm over 38 years.

PUTTING IT ALL TOGETHER

PAST MANAGEMENT

- soil drained
- tillage occurs regularly.

FIELD SYMPTOMS

- topsoil depth decreasing
- subsoil often exposed by plow
- foundations or previously buried objects may be exposed.

CROP SYMPTOMS

- nutrient deficiencies may occur
- pesticide interactions may occur due to changes in pH and soil organic matter
- crop may be less consistent in quality and yield.

BEST MANAGEMENT PRACTICES

- manage water table levels to reduce aeration, thereby minimizing the oxidation rate of organic matter
  - ▷ in non-crop situations, keep the water table as close to the soil surface as possible
  - ▷ during the cropping season, maintain the water table at the optimum level for the crop grown
- apply copper to soil to slow the rate of decomposition or loss of organic matter
  - ▷ copper inactivates certain soil enzymes that degrade organic matter
- plant cover crops to keep the soil covered and to return organic matter to the soil
- reduce wind and water erosion to stop soil loss (see pages 42-45).

Use water control systems to reduce soil exposure to air.

Early-season cover crops such as oats or barley help to reduce soil loss due to erosion and add organic matter. Fall and winter cover crops also provide valuable soil cover and organic matter.

PUTTING IT ALL TOGETHER

OTHER SOIL MANAGEMENT PROBLEMS

WET FIELDS (OR NATURALLY POORLY DRAINED)

Wet areas are often symptoms of other problems – compaction, for example. However, there are some soil types which, because of their position in the landscape or their texture and subsoil, are naturally poorly drained.

Without proper attention and management, these poorly drained soils can develop other problems:

- wet soils are more prone to soil structural damage from tillage, planting, and harvest operations
- wet soils are colder, and the slow warming of these soils can result in reduced yields.

SOIL TYPES

- silt loam
- clay loam
- clay
- high organic matter.

PAST MANAGEMENT

- low-lying fields cropped without drainage
- row crops always grown with no forages/cereals in rotation
- number of tillage passes exceeds 3, and a fine seedbed is prepared.

FIELD SYMPTOMS

- water is lying on the fields
- field is soggy in spring after fall plowing (there may be a thick layer of residue that was buried by plowing)
- sidehill seepage is evident
- field is rutted after harvest
- field is slow to dry in spring.

Wet soils require careful management and timing.

Wet soils are often in a vicious cycle. The wet soil conditions lead to compaction during tillage and harvest. This in turn reduces water movement. The poor soil structure leads to wet soil conditions, and so on.

PUTTING IT ALL TOGETHER

CROP SYMPTOMS

- crops are yellow or dead in areas of a field
- plants are stressed and more insect and disease damage is evident
- deep-rooted crops that overwinter are heaved
- root growth is concentrated at a shallow depth.

Late-planted crops are easier to establish on wet soils, but winter survival can pose a problem.

Wet soils require timely field operations. Note the sidewall compaction/smearing that occurred at planting. This restricted seedling roots.

WHAT'S HAPPENING IN THE SOIL

- soil is always wet
- cool soil temperature
- high water table
- poor soil structure
- very few air-filled spaces
- denitrification.

BEST MANAGEMENT PRACTICES

- install drainage tile and/or surface drains
- grow crops suited to wetter soil conditions or crops that are planted later in the growing season, i.e. soybeans, winter wheat (winter survival may be variable)
- use seed treatment
- use disease-resistant/tolerant crop varieties
- use a reduced tillage system such as ridge tillage, which will create a zone of drier soil for plant growth
- use tillage carefully to expose soil to the air for evaporation and soil warming
- use crop rotations
  - include deep-rooted crops such as alfalfa, clover, etc.
- encourage earthworm populations for macropore development, by leaving residue on the soil surface
- use timely tillage and field operations
  - minimize tillage passes to reduce compaction
- consider planting the area to pasture or trees.

PUTTING IT ALL TOGETHER

BEST MANAGEMENT PRACTICES FOR SOIL

Often for any soil management problem, there are several best management practices to choose from or to use in combination.

In this section, best management practices are presented in more detail, in alphabetical order by subject, with a list of sources where you can find more information.

BUFFER STRIPS

Buffer strips are permanent grass borders on field boundaries or along watercourses that help reduce soil input into streams.

Buffer strips can:

- act as filters to slow water and catch soil particles
  - should be a minimum of 3 to 6 metres to provide proper filtering action
  - reduce the sediment that reaches ditches and streams
- help maintain soil structure in heavy traffic areas
  - grow crops with a good root system if traffic is frequent.

For more information on design, grass species, and management, consult Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Buffer Strips*, to be available in the near future. See also Best Management Practices booklets, *Farm Forestry and Habitat Management* and *Field Crop Production*.

Buffer strips have a place beside every watercourse or ditch, to stabilize the bank and reduce erosion. A 3-6 metre strip doesn't take much land out of production on the average farm.

PUTTING IT ALL TOGETHER

COVER CROPS

Cover crops are crops grown to protect the soil when a crop isn't normally growing. Cover crops:

- help maintain soil structure
- add organic matter
- tie up excess nutrients
- control pests.

Many plant species are used as cover crops. When selecting a cover crop, keep in mind:

- what you need it for
- how you're going to control it
- if it will supply or use nutrients from the soil
- cost – seed, control, planting
- potential for carryover as a weed
- how it fits with your cropping system
- pest implications, e.g. nematodes.

See Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Cover Crops in Conservation Farming*, Agdex 537. See also Best Management Practices booklets, *Horticultural Crops* and *Field Crop Production*.

Oats can make a good cover crop if planted early. However, beware of late planting dates or planting on very coarse soils – the crop could be sandblasted off during winter.

Legumes such as clover are valuable as cover crops, due to the nitrogen they produce and the different root structure. However, you must consider the control measures you'll need for these.

PUTTING IT ALL TOGETHER

CROP ROTATION

Crop rotation involves alternating forage or cereal crops with row crops. The forage or cereal crops are solid-seeded, while the row crops leave the soil exposed for much of the year and return little residue to the soil.

The forage and cereal crops have root systems that improve soil structure and return organic matter to the soil. Some of these crops also overwinter, providing valuable cover during the late winter and spring when erosion potential is greatest.

ADVANTAGES

- there's usually a yield benefit from rotation of 5 to 15%
- costs are reduced
  - legume crops can provide some nitrogen to succeeding crops
  - rotating crops allows you to use a variety of chemicals, usually leading to better control for less cost and less potential for the development of herbicide resistance in weeds
  - insect and disease cycles are broken, e.g. first-year corn doesn't need rootworm insecticide
  - workload is spread over a larger portion of the growing season, and also spreads the risk to crops by weather
  - tillage needs and timing are also rotated.

For more information, see Best Management Practices booklets, *Field Crop Production* and *Horticultural Crops*, and Ontario Ministry of Agriculture, Food and Rural Affairs *Publication 296, Field Crop Recommendations*.

Including grains and forages in a cash crop rotation will improve soil structure. Rotation is just as important in no-till fields.

PUTTING IT ALL TOGETHER

DRAINAGE

Some soils in Ontario are naturally low lying or have high water tables and need drainage. Drainage benefits your crops and adds value to agricultural land.

Land can be drained in many ways. Talk to an experienced, licensed drainage contractor for cost-effective drainage options for your fields.

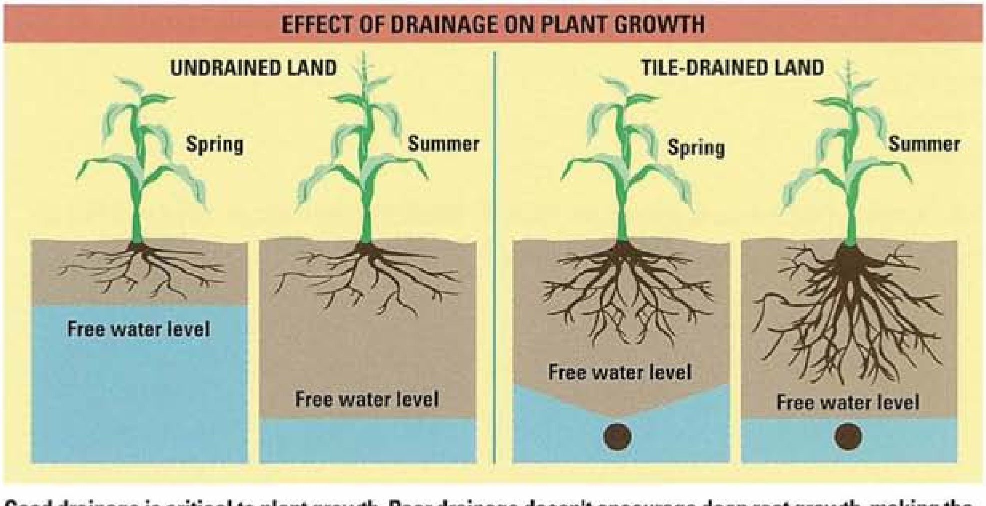
Subsurface drains remove excess water from the soil profile.

SURFACE DRAINS

These remove surface water in shallow open ditches, but have limited effect on the water table. They are usually used in fine-textured soils (i.e. clay, clay loam) where tile drainage isn't satisfactory. Improper use can create problems. When surface drains are used, they should be designed to channel water to a rock chute.

SUBSURFACE DRAINS

These remove excess water from the soil profile. Water moves down to the tile drains by gravity.



Good drainage is critical to plant growth. Poor drainage doesn't encourage deep root growth, making the plants more prone to drought stress and nutrient deficiencies.

PUTTING IT ALL TOGETHER

Subsurface tile drainage systems require maintenance to work efficiently.

ADVANTAGES

- reduces surface runoff of contaminated water
- reduces soil compaction
- increases crop yields
- enhances timing of field operations
- can extend growing season
- can provide more options for rotation
- may be used for drainage and possibly subirrigation.

DISADVANTAGES

- can increase risk of nutrient flow through tile to watercourses
- might increase springtime flooding downstream
- can damage wetlands or destroy small wetlands
- disrupts the flow of ground water to watercourses
- high capital costs
- some maintenance requirements.

MUCK SOILS

Muck soils behave differently than mineral soils. Draining them requires careful planning to prevent overdraining. Among the many considerations:

- subsidence
- settlement of drain
- water table control
- seepage
- springs
- drain sealing
- pumping.

For more information on drainage, see Ontario Ministry of Agriculture, Food and Rural Affairs *Publication 72, Handbook of Drainage Principles*.

PUTTING IT ALL TOGETHER

EROSION CONTROL STRUCTURES

Erosion control structures are measures taken to help control surface runoff to reduce soil erosion. These include:

- water and sediment control basins (WASCoBs or berms with drop inlets)
- terraces
- grassed waterways
- stabilization of streambanks
- livestock and machinery crossings.

These structures are usually used in combination with cultural techniques and conservation tillage systems to reduce water erosion.

Some of these structures require engineering. Consult your local Conservation Authority (see the white pages of your telephone directory) or Ontario Ministry of Agriculture, Food and Rural Affairs office (see the blue pages).

Refer to the Best Management Practices booklet, *Field Crop Production*, "Non-tillage Options". See also three Ontario Ministry of Agriculture, Food and Rural Affairs factsheets:

- *Grassed Waterways*, Agdex 573
- *Gulley Erosion Control*, Agdex 573
- *Water and Sediment Control Basins,* Agdex 751.

Drop chutes safely drop water from a surface drain into the ditch. Proper construction is important. Ensure that filter cloth is correctly applied beneath the quarry stone. Do not use fieldstone: the rounded edges will allow the rocks to roll and be moved by water.

The rock placed around the culvert helps to stabilize the ditchbank and prevent the swirling action of water from eroding the field edge.

PUTTING IT ALL TOGETHER

GREEN MANURE CROPS

Green manure crops are short-term cover crops used to cover and protect the soil between crops, particularly after short-season crops such as peas.

Green manure crops are grown for the plant material produced, which can then be returned to the soil to maintain soil organic matter levels – an excellent source of foodstuff for soil life.

See Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Cover Crops in Conservation Farming,* Agdex 537. See also Best Management Practices booklets, *Horticultural Crops* and *Field Crop Production*.

The success of green manure crops is highly dependent on weather.

PUTTING IT ALL TOGETHER

IRRIGATION

Irrigation is the practice of adding water to moisture-deficient soils to improve production.

Adequate moisture reduces crop stress and prevents disease. Overirrigation can lead to nutrient leaching and increased disease. You need to strike the right balance when planning an irrigation program.

Irrigation must be applied properly to be cost-effective and prevent harm to the environment:

- know the soil type and water-holding capacity
- irrigate when critical to the crop, and know your plant rooting depth
- watch the weather forecast
- use a scheduling method (i.e. tensiometer or evapotranspiration model)
- always monitor the system when in operation – breakdowns are costly
- apply water on cloudy days and when wind speed is low – avoid the heat of the day when evaporation is high
- get a permit from the Ontario Ministry of Environment and Energy if removing more than 50,000 litres (10,000 gal) a day from a water source.

There are many types of irrigation systems. The main ones are sprinkler, trickle, surface, or subirrigation. The most common ones used in Ontario are trickle (drip) or sprinkler (overhead). The type you choose will depend on the method of application, land slope, and crop to irrigate.

For more information, see Ontario Ministry of Agriculture, Food and Rural Affairs factsheets:

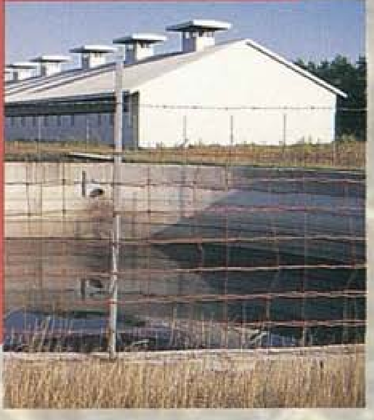
- *Irrigation Scheduling for Fruit Crops,* Agdex 210-560
- *Tobacco Irrigation with Stationary and Travelling Gun Sprinklers*, Agdex 181/565
- *Irrigation Scheduling for Tomatoes – Water Budget Approach,* Agdex 257/560.

Irrigation Management, a Best Management Practices booklet, provides a full review of systems, scheduling information, and handy tips.

Irrigation is often necessary on coarse-textured sandy soils with low water-holding capacities. Irrigating is only economic on high-value crops such as tobacco, vegetable, and fruit crops.

New irrigation technology (e.g. trickle) is more efficient, placing the moisture close to roots and reducing evaporation losses.

PUTTING IT ALL TOGETHER



Handling livestock manure with care will prevent pollution and help you reap maximum economic rewards.

MANURE MANAGEMENT

The proper application of livestock manure can benefit soil by:

- returning nutrients removed by crops
- supplying organic matter to feed the soil life, which in turn will help to improve soil structure.

However, livestock manure must be handled properly to prevent pollution and loss and to ensure the greatest economic benefit.

For more information, see Best Management Practices booklets, *Livestock and Poultry Waste Management* and *Nutrient Management*. See also Ontario Ministry of Agriculture, Food and Rural Affairs factsheets:

- *Manure Characteristics,* Agdex 538
- *Sizing Manure Storages*, Agdex 400/721 and related factsheets.

OTHER ORGANIC MATERIALS

Materials such as compost, cannery waste, sewage sludge, and other organic wastes can help to build and maintain soil structure.

A word of caution though – if you plan to use materials from off-farm sources you'll need an organic soil conditioning permit from the Ontario Ministry of Environment and Energy.

It's also wise to ensure that you know what is actually in the material. Some materials may contain contaminants that are harmful to plant or soil life.

See the Best Management Practices booklet, *Nutrient Management*. Also contact your local office of Ontario Ministry of Environment and Energy (see the blue pages of your telephone directory).

Cannery waste such as apple pomace can help to improve soil structure by adding organic matter and a food source for soil life.

Ensure that you know the content or origin of the material composted.

PUTTING IT ALL TOGETHER

REDUCED TILLAGE SYSTEMS

Reduced tillage covers a wide range in tillage systems, including no-till, ridge-till, and reduced tillage forms like chisel plowing or "soil saving". These systems leave residue cover on the soil surface and help to:

- reduce soil erosion, by both water and wind
- reduce tillage erosion
- improve soil structure (over time with good management).

Many management changes are required to make these systems work. For more information, see the Best Management Practices booklet, *Field Crop Production*.

Reducing the number of tillage passes across a field will also help to conserve moisture.

NO-TILL SYSTEMS

In general, no-till is the practice of planting crops with no primary or secondary tillage separate from the planter operations. The term encompasses a wide variety of farming practices, from slot planting to zone or strip tillage to inter-row cultivation after no-till planting.

No-till planting systems can help to improve or maintain soil structure.

Changing to a no-till system takes time, planning, and commitment. Modifying planting equipment is just the beginning – no-till will require changes to most aspects of crop production.

For more information on no-till, see the SWEEP Publication, *No-Till – The Basics*, the Best Management Practices booklet, *Field Crop Production*, and Ontario Ministry of Agriculture, Food and Rural Affairs factsheets:

- *Coulters and Presswheels,* Agdex 570/740
- *Suitability of Conservation Tillage Systems to Ontario Soil Types*, Agdex 512
- *Planter Modifications for No-Till*, Agdex 100/742.

There are also videotapes on no-till systems available through your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs.

No-till planters take a variety of forms, from three or more coulters with trash whippers to none. Most systems do move residue and perform some tillage.

PUTTING IT ALL TOGETHER

RIDGE TILLAGE

Ridges create a warmer, drier seedbed area in early spring, compared to conventional systems.

Ridge-till is an alternative to no-till. The system requires more initial effort and capital outlay. A cultivator forms a ridge in early summer. The following year, the next crop is planted directly onto the ridge. Once established, the ridges are not removed. This is a controlled traffic system: the ridges are never tracked.

The relatively undisturbed soil on the ridge is very similar to no-till in the changes that occur structurally. Residue is removed from the top of the ridge to cover and protect the ridge slopes and furrow areas. Similar to adopting no-till, making the change to a ridge-till system requires planning and thought.

For more information, see the Best Management Practices booklet, *Field Crop Production*, and the Ontario Ministry of Agriculture, Food and Rural Affairs factsheets:

- ▸ *Ridge Tillage Planters*, Agdex 516/742
- ▸ *Suitability of Conservation Tillage Systems to Ontario Soil Types*, Agdex 512.

There are also a number of videotapes available at your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs.

CONTROLLED TRAFFIC

Controlled traffic means limiting the area travelled by equipment to prevent widespread compaction. For example, tram lines in cereal crops are used for machinery traffic such as sprayers and fertilizer applications.

Ridge tillage systems are a good example of controlled traffic. All machinery runs in the valleys between the ridges, and doesn't track the ridge itself. This means the crop grows in soil that hasn't been packed by machinery traffic.

Bedding systems used in some horticultural crops such as tomatoes are also a form of controlled traffic.

For more information, see the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Soil Compaction*, Agdex 510.

Controlled traffic can take a variety of forms: from simple tram lines in soybeans or cereals to permanent traffic areas.

PUTTING IT ALL TOGETHER

RESIDUE MANAGEMENT

Increasing the levels of crop residues left on the soil surface will:

- protect the soil from erosion
- improve soil structure
- add organic matter.

Residue protects the soil in two ways:

- intercepts the raindrops and wind impact, preventing detachment of soil particles
- creates thousands of tiny dams and windbreaks on the soil surface, slowing the movement of water, wind, and soil across the field.

Residue cover moderates soil temperature and encourages higher earthworm populations, which benefit the soil structure.

For more information on residue management, see the Best Management Practices booklet, *Field Crop Production.*

Residue slows the movement of water, wind, and soil across fields.

STRIP CROPPING

Strip cropping is the practice of alternating strip widths of row crops with forages or cereal crops. There are four kinds of strip cropping:

- contour
- field
- contour buffer
- wind.

The method you choose depends on the:

- crops that can be grown
- kind of erosion you are eliminating
- topography of the field and soil type.

See the Best Management Practices booklet, *Field Crop Production*; also the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Strip Cropping for Water Erosion Control*, Agdex 573.

Strip cropping is a highly effective way to reduce or prevent erosion. The alternating strips of forage or cereal crops cover the soil and slow water movement across the field.

PUTTING IT ALL TOGETHER

TIMELY TILLAGE

Soils shouldn't be worked in the spring until the soil moisture conditions drop below the "lower plastic limit". This is the minimum moisture point at which soils begin to puddle and the maximum point at which soils are friable. Take the time to check soil moisture levels to the depth of tillage.

Besides the method described in the caption below, there is the "golf ball" test, where the soil is formed into a ball and tossed from hand to hand (a better method for medium- to coarse-textured soils). If the ball remains intact, the soil is considered unfit for tillage.

Working wet soil damages the soil. Smearing and compaction often result. Large lumps of soil that form during the first pass are often difficult to break down with subsequent tillage. A large number of tillage passes may be required to prepare the seedbed, which may still not provide enough seed-to-soil contact.

For **silt loams and loams**, a shallow tillage pass early in spring will encourage soil surface layers to dry out more quickly. This must be done with care to prevent compaction.

Finer-textured soils, such as **clays and clay loams**, should be allowed to dry out on their own before beginning spring tillage.

Coarse-textured soils are prone to wind erosion and excessive moisture loss: timely tillage will reduce the impact of this.

Waiting until proper soil moisture conditions occur can prevent long-lasting damage. If the soil is too wet, one tillage pass can significantly damage the soil structure.

It takes years to build good soil structure. Remember, be patient – it pays.

See the Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Tillage for Crop Production on Ontario Soils – Principles*, Agdex 100/516.

One way to determine soil moisture is to roll some soil between the hands:

- ► if a continuous roll or "worm" is formed, then the soil is too wet to till
- ► if the soil produces friable crumbs when rolled in this fashion, then the ground is ready to work.

What do you think: are these two fields ready to be worked?

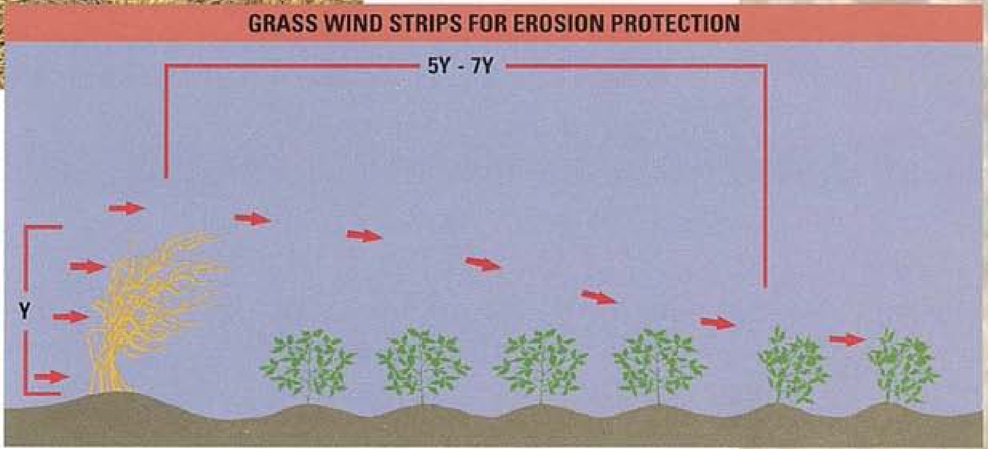
PUTTING IT ALL TOGETHER

WIND ABATEMENT SYSTEMS

Wind abatement systems are used with horticultural crops to protect tender plants. The practice includes using strips of cereal crops between beds or rows of crop. These strips slow wind and soil movement. Cereal strips can also reduce pest damage, and improve soil and air temperatures in the early spring.

There are various systems in use. For more information, see the Best Management Practices booklet, *Horticultural Crops*.

Grass wind strips are flexible and can be adapted to most cropping systems. Grass strips are particularly useful in areas where high land values discourage the use of tree windbreaks.



There are several wind control options. Grass wind barriers provide similar protection to tree windbreaks. However, grass can be pushed down by high winds, reducing the protected area.

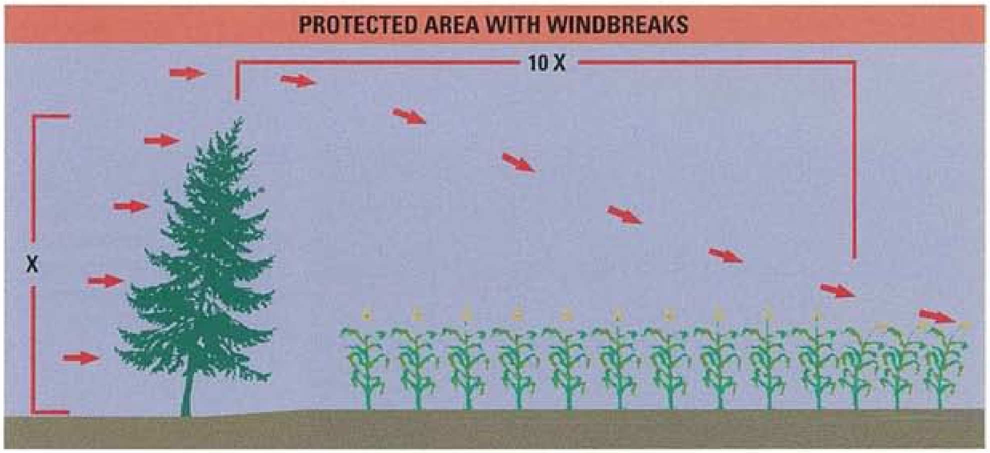
PUTTING IT ALL TOGETHER

Tree windbreaks can reduce wind damage and improve the production of crops and livestock. During early growth, holes in the windbreak should be replanted to prevent problems.

WINDBREAKS

Planting trees in strategic areas on the farm will benefit crop production, because trees act as barriers to the wind, thereby:

- ▶ reducing wind erosion
- ▶ providing protection to the crops
- ▶ preserving moisture in the soil, which is beneficial to drought-prone soils.



Crop yields can increase 10-20% if the field is protected by a tree windbreak.

For more information, see the Best Management Practices booklet, *Farm Forestry and Habitat Management*, and Ontario Ministry of Agriculture, Food and Rural Affairs factsheet, *Planting and Maintaining Field Windbreaks,* Agdex 572.

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Relevant publications are listed in the "Putting It All Together", "Best Management Practices" subsection in this booklet. You can also contact your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs. See the blue pages of your telephone directory for the office nearest you.

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