## Best Management Practices

# TILLAGE EROSION

Tillage erosion is the net downslope movement of soil caused by working the soil. Due to gravity, more soil is moved downslope when tilling downhill than is moved upslope when tilling uphill.

The eroded cropland soil often includes the top few soil horizons or layers. This developed part of the soil is the most conducive to crop growth. Thus soil productivity and crop yields are reduced by tillage erosion.

Tillage erosion is a major form of soil degradation. Left unchecked, it can lead to other forms of soil health problems including accelerated rates of wind and water erosion, and reduced water- and nutrient-holding capacity.

This infosheet describes a set of diagnostic tools used to describe the type, nature and extent of tillage erosion on Ontario cropland soils. Proper diagnosis is essential to identify the most suitable best management practices (BMPs) for a given field.

**THE ROLE OF HEALTHY SOIL IN A CHANGING CLIMATE**

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

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

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# How soils are eroded by tillage

## TILLAGE EROSION PROCESS

Through tillage, soil is lost from knolls and upper-slope field positions (hilltops) and deposited, over many years, at the bottom of the slope or in depressional areas. Tillage erosion can also occur on gently rolling and nearly level sloping fields.

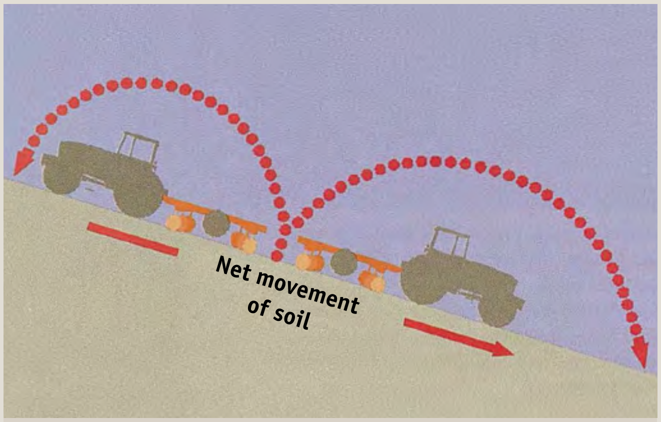
Characteristic patterns of soil loss by tillage erosion are very different to those produced by water erosion. Water erosion causes maximum soil loss in middle-slope and lower-slope areas of the field, and results in soil accumulating at the foot of slopes and in depressions.

The evidence for water erosion is readily recognizable – with rills and gullies forming after spring snowmelt and severe rain events. Tillage erosion, on the other hand, is not the result of any single event, but happens slowly over time.

This process is accelerated by the speed, intensity, and frequency of the tillage operation. Faster-moving equipment will shatter the soil more quickly, and send it faster and farther than slower equipment.

Deep or highly disruptive tillage equipment is going to affect and potentially move more of the soil. More passes over the field lead to increased soil structure breakdown and more movement of the soil downslope.

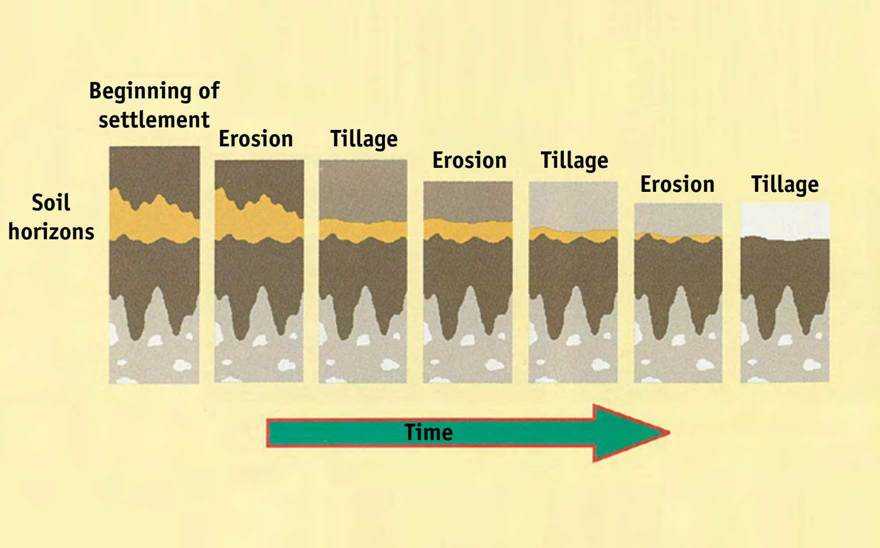
**The moldboard plow is not the only tillage implement that is erosive. Any tillage practice or field activity that disturbs the soil can cause tillage erosion.**




**The action of tillage up and down slope moves soil from uphill-slope positions to downhill-slope positions due to gravity. When soil from hilltops and side slopes is disturbed and lifted from tillage, it does not fall back to the same location it was lifted from. Gravity and the forward movement of the equipment lift and carry the soil downhill.**

**D.A. Lobb's research has shown that tillage erosion can move downslope up to 100 t/ha/pass with moldboard or chisel plows on sandy potato cropland. This work has also shown that soil particles are on average moved 15–30 cm (6–12 in.) downslope per pass, but some can be moved 2–24 m (6.5–79 ft) depending on the direction of tillage and the implement used. The rate of tillage erosion is reduced with cross-slope cropping and tillage practices.**

**SOIL PROFILES IN A SLOPING FIELD SUBJECTED TO TILLAGE EROSION**




### LONG-TERM EFFECTS OF TILLAGE EROSION

**With the removal of soil horizons that are inherently more resilient to degradation, tillage erosion can accelerate the rate of structure loss, as well as water and wind erosion. Severe tillage erosion can lead to other forms of degradation including low moisture availability, increased bulk density, lower fertility and very poor crop productivity. It is not uncommon for large contiguous areas of soils degraded by tillage erosion to be retired to trees or other permanent cover.**

## RESIDUAL SOILS

Ontario soils have on average 60–70 cm (24.5–27.5 in.) of developed soil horizons (layers) over the original geological material – also known as parent material.

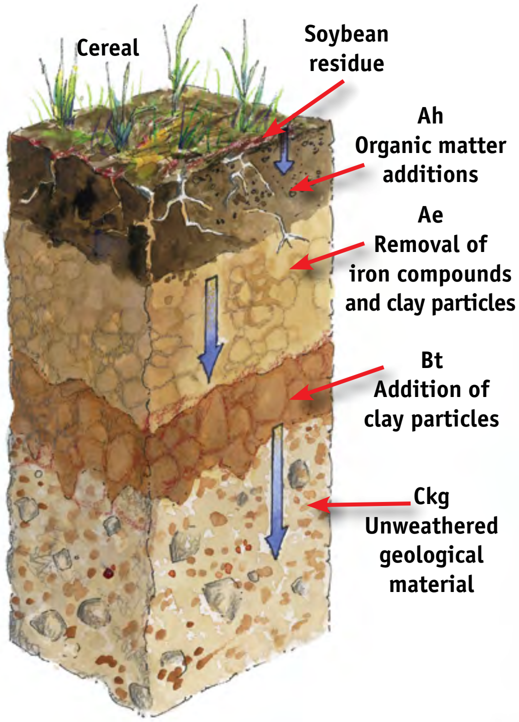
The upper layers – commonly referred to as the topsoil (A horizons) and the subsoil (various B and some A horizons) – have developed and weathered over the last 8,000–12,000 years to form soil conditions that are generally hospitable to crop growth. These conditions include high organic matter levels, well-formed structure, neutral pH levels, lower bulk densities, higher levels of plant-available nutrients, and greater water-holding capacities.

The parent material (various C horizons) is most often unhospitable for crop growth. Its features typically include basic or acidic pH levels, high levels of lime (in calcareous soils), high bulk densities, higher stone content, lower infiltration rates, lower percolation rates, and fewer plant-available nutrients.

Following decades of tillage erosion, residual soils on knoll and upper-slope positions are, in effect, not soil at all. They are often parent material or parent material with a thin layer of subsoil mixed in.

**One of the key diagnostics of tillage erosion is the presence of “white caps” on knoll and upper-slope positions. The white colour indicates the presence of soil parent material at the soil surface, which suggests a net loss of 60 cm (24.5 in.) of topsoil and subsoil.**

## SOIL HORIZONS




**Ah –** horizon showing how plant growth adds organic matter to the soil

**Ae –** horizon showing how iron and clay have been removed

**Bt –** horizon showing how soil clay materials have been translocated

**Ckg –** horizon showing how iron minerals can change to grey or rust spot (mottle) colours

For more information about how Canadian soils are classified, see www.soilsofcanada.ca/orders/

**The soil horizons labelled A or B indicate the weathered or "root-friendly" part of the soil. Following years of soil loss by tillage erosion, it is the C horizon that remains.**

**Residual soils on eroded knoll positions exhibit the properties of parent material, such as higher bulk densities, higher stone content and, in southwestern and south-central Ontario, higher pH levels – resulting in accelerated rates of degradation (compaction, water erosion) and poor crop performance (average yield loss of 30–50%).**

## DEPOSITIONAL SOILS

Along with soil loss is the loss of organic matter and fertility on hilltops. The soil that moves from the top of the slope to the bottom of the slope is added to the topsoil in the soil profile below.

In some cases, the topsoil thickness downslope is 2–3 times more than the field average.

As such, these areas can be considerably more productive than the previously eroded knoll-site positions. However, with time the subsoil on the hilltops will continue to erode to the bottom of the slopes, which would bury the topsoil under calcareous subsoil (inverted soil profile).

**Soils in downslope depositional areas will most often have thick layers of topsoil. This is evidence that soil moved from upper-slope positions has been deposited to lower-slope positions. Decades of ongoing tillage erosion will lead to buried topsoil conditions, where eroded subsoil and parent material cover the original topsoil layer.**

## CONDITIONS WHERE TILLAGE EROSION IS LIKELY

### Soil + Topography

- Soil texture – all soil textures
- Rolling or complex to gently sloping topography
- Multiple knoll-slope positions in the field
- Naturally shallow topsoil depth on knoll-site positions

### Tillage

- Type of tillage equipment – the higher the drag, the greater the amount of soil moved
- Depth and speed of tillage – rates of tillage erosion increase when speed and depth of tillage increase
- Number of passes – the greater the number, the higher the rate of tillage erosion
    - tertiary (third) tillage can do the most damage (D.A. Lobb, 2005)
- Tillage direction and pattern – downslope tillage moves the most soil

### Past Management

- Proportion of past crop years in tillage
- Crops grown that require intense soil management (e.g., finely worked seedbed)
- No forages or cover crops in the rotation
- No manure or other organic amendments added

**The rate and severity of tillage erosion increases with increased slope, slope curvature, tractor speed, tilling up and down slope, and depth of tillage.**

# Diagnostics for tillage erosion

## FIELD OBSERVATIONS

- Buildup of soil in depressions and lower-slope positions
- Soil on knolls is lighter in colour, and stones may be visible on the hilltop
- Reduced water infiltration and increased severity of water and wind erosion on hilltops and possible ponding in depressions

## CROP OBSERVATIONS

- Uneven stand establishment on knolls
- Slower and stunted crop development on knolls
- Nutrient deficiency symptoms on knolls
- 30–50% yield reduction on knolls
- In drought conditions, crops on knolls stressed before rest of field
- Variable crop growth and development

**Look for shorter and yellowed corn plants on knoll positions.**

**Readily recognizable light soil colours and higher stone content on knolls are evidence of tillage erosion.**

**Soybeans on eroded knolls will look stunted, have fewer pods per plant, and mature weeks ahead of the crop stand on other slope positions.**

## SOIL OBSERVATIONS

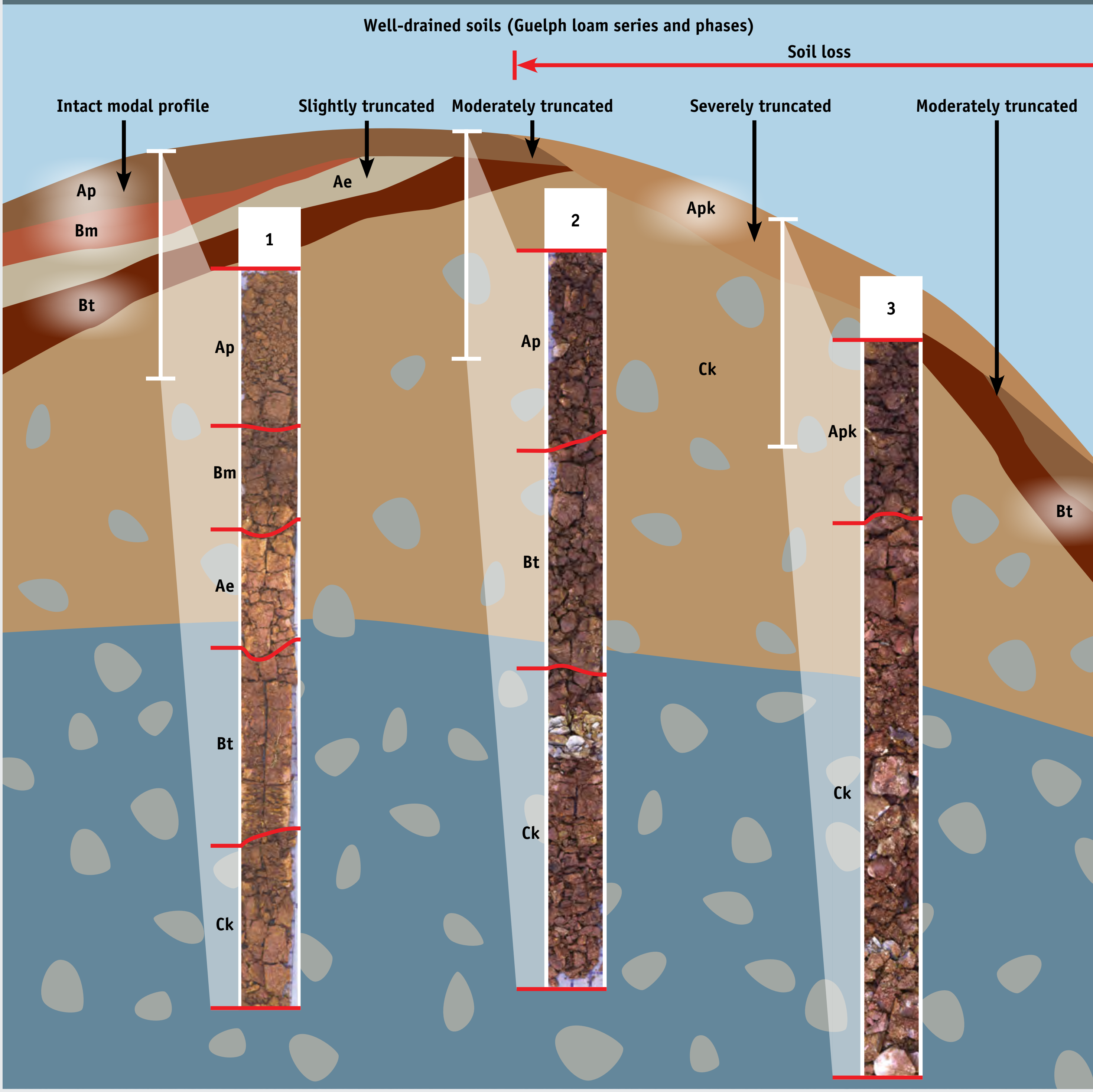
- Loss of organic matter, topsoil and subsoil from hilltops, and accumulation in depressions
- Depth to carbonates, indicating either depth to calcareous parent material or subsoil/topsoil mixed with parent material by tillage passes
- Lighter-coloured soil on knolls
- Soil particles have physically moved (aggregates have been broken and detached)
- Subsoil exposure on knolls (stones etc.)
- Inverted soil profiles in depressions – subsoil on top of topsoil
- Poor infiltration rates and reduced water-holding capacity on hilltops

**Beige, reddish-brown or lighter brown soil colours at the surface of soils in knoll positions indicate a slight-to-moderate rate of tillage erosion.**

**Stony, light-coloured and in some cases compacted soil at the surface of knoll positions indicate a site subjected to severe tillage erosion.**

**When 10% hydrochloric acid (HCl) is applied to soil and bubbles and foam appear, this indicates that calcareous (high lime) parent materials or a mixture of topsoil, subsoil and parent materials are present at the soil surface.**

## SOIL PROFILES IN A SLOPING FIELD SUBJECTED TO TILLAGE EROSION

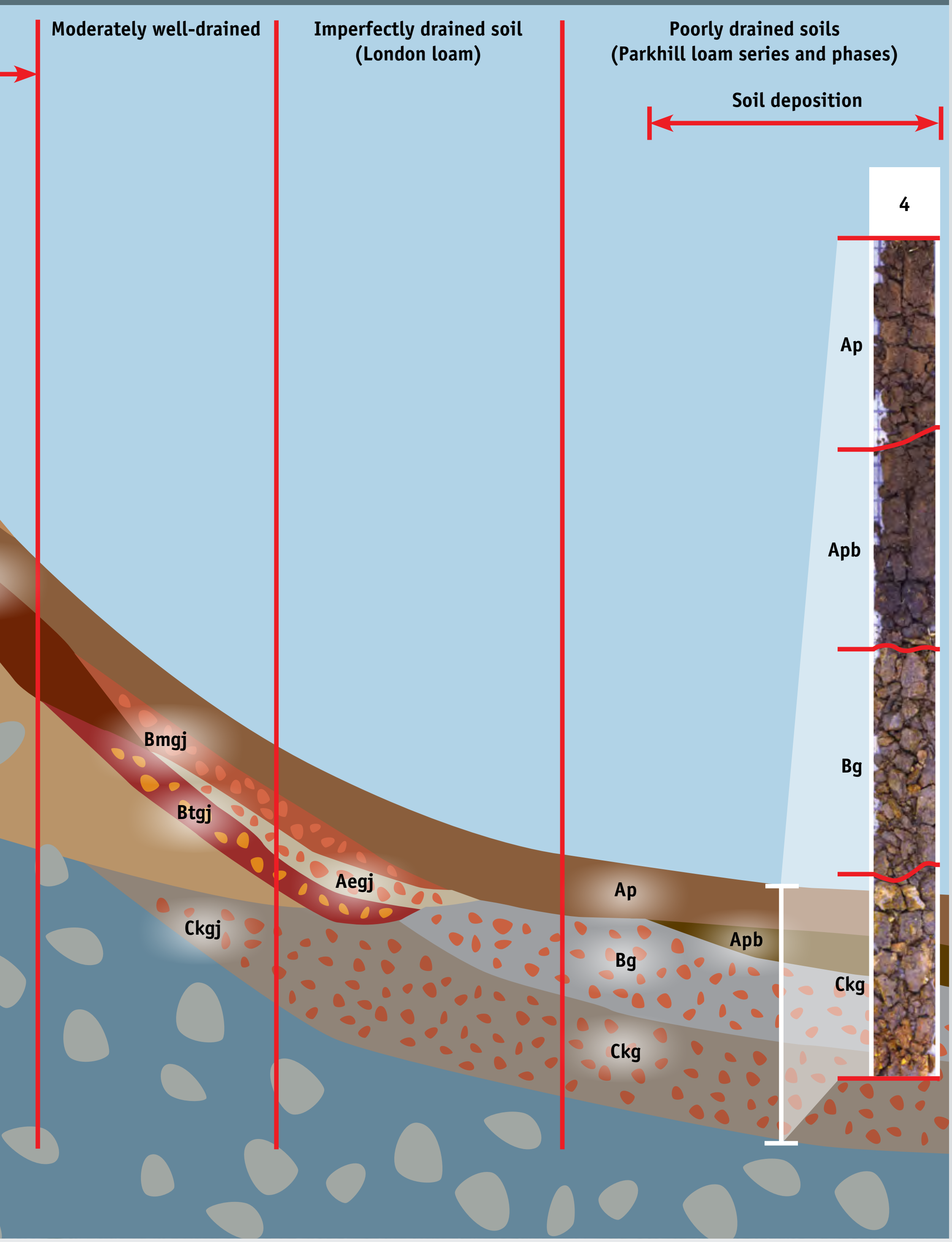



**1**

Non-eroded well-drained loamy soils found on upper-slope positions of Ontario cropland exhibit a normal profile that starts with topsoil (Ap horizon), followed by a modified subsoil horizon (Bm), a slightly leached layer (Ae horizon), a clay-enriched later (Bt horizon), and high-lime parent material (Ck horizon).

**2**

Moderately eroded upper-slope soils show loss of several near-surface horizons (Bm and Ae horizons) following decades of tillage and water erosion.




Soil profiles change dramatically following decades of tillage erosion. Loamy soils on a rolling landscape – similar to the ones illustrated to the left – will reveal a net reduction in soil horizons and depth to parent material in upper-slope positions (i.e., well-drained soils) and a net accumulation of soil material in lower-slope and depressional slope positions (i.e., imperfectly and poorly drained soils).

3

Severely eroded soils are shallow-to-parent material and often only have a lime-rich topsoil layer over parent material. Remnants of these eroded horizons have been incorporated into the current plow layer.

4

Soils located in lower-slope and depressional-site positions on tillage-eroded fields usually have a very thick topsoil layer, which is actually a deposited layer of topsoil from upslope over a buried Ap horizon.

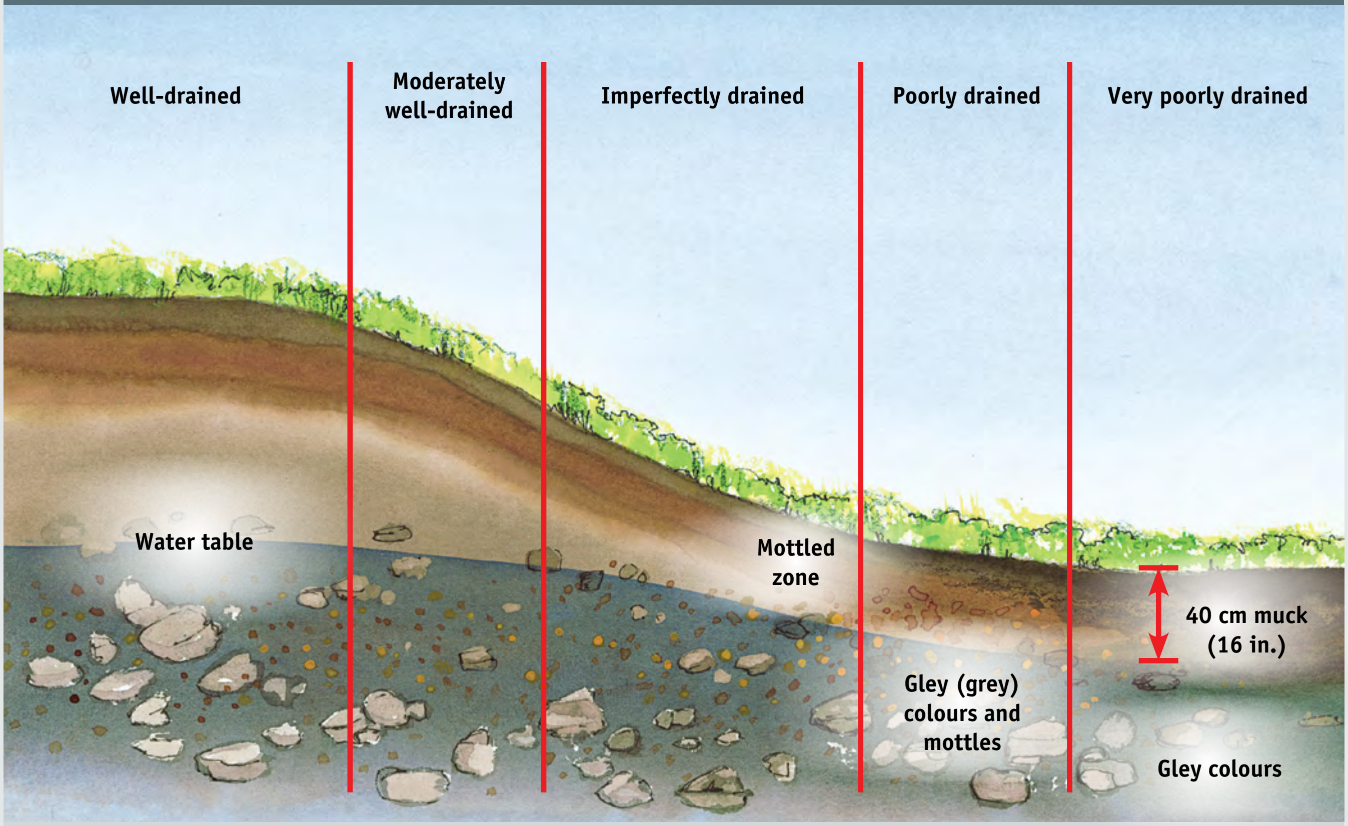
### HOW TILLAGE ERODES SOIL ACROSS THE LANDSCAPE

Tillage erosion is site-specific. Rates of soil loss are greatest on crest and shoulder (upper-slope) landscape positions. The rate of tillage erosion decreases at mid-slope positions. Eroded soil materials are usually deposited in depressional areas or are carried offsite by water erosion and runoff.

Soil profile characteristics in tillage-eroded fields reflect this pattern of soil loss and deposition across sloping cropland landscapes.

The illustration below portrays soil profile features on a forage-covered sloping field that has not been subjected to tillage erosion.

### SLOPE POSITION AND SOIL DRAINAGE CLASS




This illustration shows a cross-section of non-eroded loamy soils (from top to bottom of the slope) on rolling topography. These soils all have the expected sequence of A, B and C horizons normally associated with relatively undisturbed soils.

The soils at the top of the slope are classed as well-drained, as there is no evidence of water table activity in the soil profile (i.e., no rust spots or dull grey colours).

Moving downslope, mottles can be found in the bottom of the soil profile and these soils are classed as moderately well-drained.

Imperfectly drained soils may have gley (grey) colours in the lower part of the profile and are often mottled throughout.

Farther downslope, soils that are gley in the upper 50 cm (20 in.) of the soil profile and are often mottled throughout are classed as poorly drained.

Soils that are permanently saturated with a very high water table are classed as very poorly drained – with dull grey (gley) colour and without spots (or orange mottles) throughout the soil profile.

# Best management practices (BMPs)

Generally speaking, BMPs are classed as preventative or remedial. It is often the case that a combination of two or more BMPs (or suite of BMPs) is the most effective approach to resolve soil degradation problems.

Addressing tillage erosion is no different. The most successful combinations include BMPs that prevent further loss (e.g., no-till), rebuild the soil (e.g., soil remediation and adding organic amendments), and protect the surface (e.g., cover crops, forage-based rotations).

Choose the most suitable suite of BMPs from the following list:

- ✓ Reduce tillage frequency – avoid unnecessary passes.
- ✓ Adjust tillage timing – tilling when soils are too wet can lead to compaction and accelerated rates of tillage and water erosion.
- ✓ Reduce the size of tillage implement – larger-sized equipment increases the amount of soil moved.
- ✓ Reduce speed and intensity of tillage.
- ✓ Alternate tillage direction to reduce the number of up and down passes.
- ✓ Adopt reduced tillage systems, e.g., no-till, minimum tillage.
- ✓ Use crop rotations to alternate tillage requirements.
- ✓ Plant upper-slope positions to forage or pasture.
- ✓ Retire fragile land as an alternative to farming soil parent material – plant knoll and upper-slope field positions to trees.
- ✓ Undertake landscape restoration or soil remediation – map and move deposited soil from downslope back to upper-slope positions.
- ✓ Switch to contour tillage – till along the measured topographic contours of long sloping fields.
- ✓ Plant cover crops on hilltops – works best after landscape restoration project has been completed.
- ✓ Add organic amendments to hilltops.

**Remediation is really part of a soil rehabilitation process. Following remediation, soils need to be protected and improved. Remediated soils can be protected with BMPs such as residue management, cover crops or perennial crops. Soils condition can be improved with applications of manure and other organic amendments, green manures and forages.**

**Mapping and moving soil from depositional areas back upslope to the eroded area may help to restore soil health. Fall or late summer after winter wheat is the most suitable time to move the soil.**

**Switching to cross-slope tillage will substantially reduce the risk of tillage erosion.**

# For more information

## ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Many sources of supplementary information are available.

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

- *Agronomy Guide,* Publication 811
- *Soil Erosion: Causes and Effects,* Factsheet 12-053

**Best Management Practices Series**

- *Controlling Soil Erosion on the Farm*
- *No-Till: Making It Work*
- *Soil Management*





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

- #15, *Soil Management*

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