



## Best Management Practices

# SOIL REMEDIATION

Rolling to hilly landforms with loamy soils are the most common type of cropland landscape in Ontario. During the planting season, even a casual glance at bare soil conditions reveals the biggest soil health challenge on these landscapes: eroded knolls.

Eroded knolls indicate the soil parent material is at or near the soil surface. Soil parent material is a poor substitute for healthy soils. Excessive droughtiness, stoniness, compaction and infertility make eroded knolls unsuitable for crop production.

Soil remediation is a relatively new technique involving the mechanical replacement of deposited soil that has moved downslope from higher to lower areas of cultivated cropland. This factsheet explains the function of soil remediation as part of a greater soil rehabilitation process.

### 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.

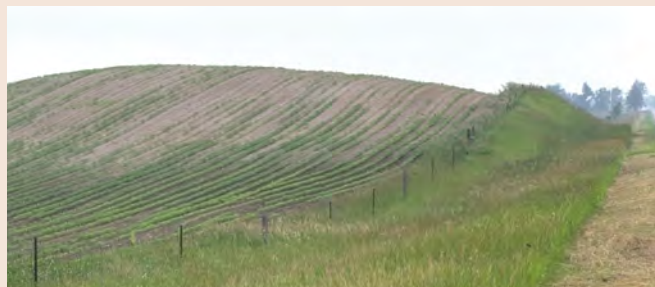
# Why eroded knolls are a problem

Eroded knolls are severely degraded, and left unchecked will only get worse.

These conditions have developed after decades of tillage erosion (see BMPs for Soil Health Diagnostic Infosheets). In these landscapes, tillage implements will move soil from the top of a slope to the bottom. This leaves the “white caps” at the top of the slope and accumulated topsoil at the mid and bottom slope positions (or depressional areas). Soil moved by tillage can be deposited where water erosion is occurring – contributing to greater soil movement or loss from the field.



**Tilling a soil up and down slope results in the net downward movement of the soil, which is termed “tillage erosion.”**



**The presence of “white caps” or eroded knolls on this field indicates a history of soil loss from tillage and water erosion. The lighter-coloured soil indicates the presence of soil parent material at the soil surface – indicating a net loss of 60 cm (2 ft) of topsoil and subsoil.**

## ERODED KNOLLS

Tillage erosion will leave knoll-slope soils in one of three states:

1. **Severely eroded** – where the parent material (often calcareous) is at the surface. See the BMPs for Soil Health Factsheet *Cropland Retirement*.
2. **Moderately eroded** – where the subsoil (B horizons, not parent material) is at the surface, or mixed by tillage with parent materials. These soils are most suitable for remediation.
3. **Slightly eroded** – where the topsoil has been removed by the forces of erosion or has been mixed with the subsoil (A+B horizons). These soils may be improved by cover crops, mulch tillage, or the addition of organic amendments.

In these conditions, knolls can produce as low as 50% of the average yield of the field, while the areas of accumulation often yield above average. Traditionally, these conditions left growers with two choices: tolerate yield loss and further degradation, or retire the field from crop use.



**Corn on eroded knolls is more susceptible to drought stress and reduced yields during low water conditions.**

**For more information on managing severely eroded soils, see *Cropland Retirement*, a BMPs for Soil Health Factsheet.**

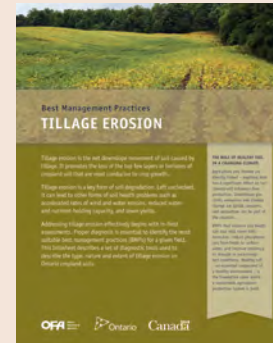




## ACCELERATED DEGRADATION

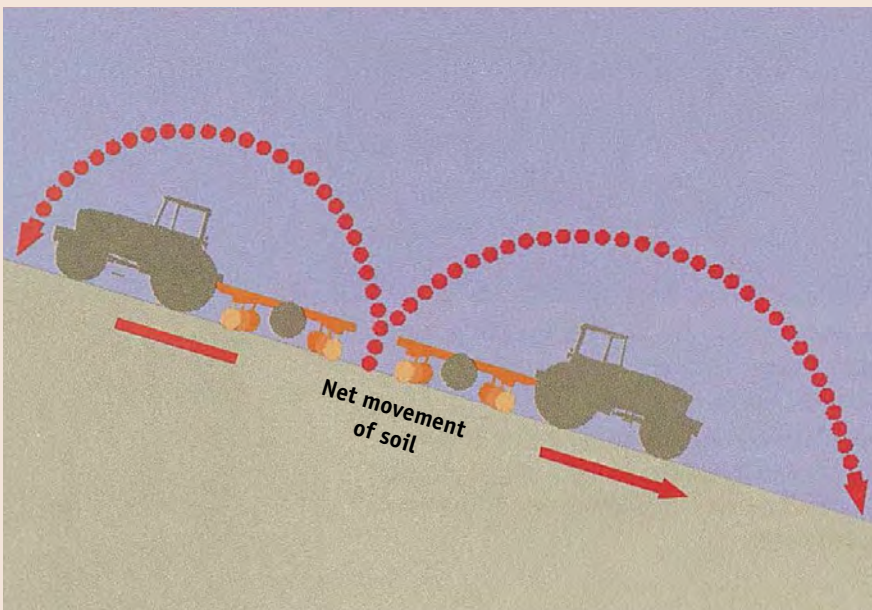


The residual subsoil or parent material exposed at the surface is at a high risk of further degradation. Exposed parent materials are more readily compacted and are highly erodible by wind and water.

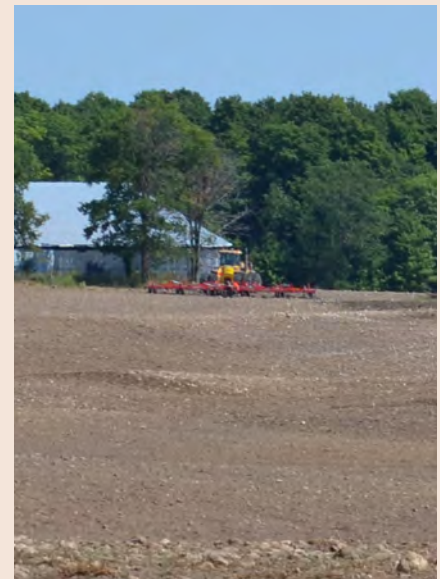


Refer to  
*Tillage Erosion,*  
a BMPs for Soil  
Health Diagnostic  
Infosheet for a  
detailed description  
of how tillage  
practices move  
soil downslope.

## TILLAGE EROSION



Tillage erosion is accelerated by the speed, direction, intensity, and frequency of tillage operations. Faster-moving equipment means the soil is shattered quickly and moved faster and farther. Tilling deeper and the use of highly disruptive tillage equipment such as the moldboard plow and chisel plow are going to affect and potentially move more of the soil. More passes over the field lead to increased soil structure breakdown and more literal movement of the soil downslope. Tillage operations down the slope will move soil farther down than upslope passes move it upwards.



Tillage erosion causes the loss of soil from knolls and upper-slope field positions (hilltops) and deposits this soil over decades of movement at the bottom of the slope (or in depressional areas). It can also occur on gently rolling and nearly level sloping fields.



## CROP LOSS



The parent material (various C horizons) is most often inhospitable for crop growth – with 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.

## LOSS OF PRODUCTIVE CROPLAND



Left unchecked, the rate of tillage erosion will increase, as can the size of the eroded knoll or the proportion of the field unsuitable for crop production.



# Soil remediation – part of soil rehabilitation

In the 1990s, innovative farmers and soil scientists developed soil remediation as a BMP to address fields with severely eroded knolls. Soil remediation is the mechanical replacement of deposited soil that has moved from areas of higher elevation of cultivated cropland to areas of lower elevation.

Remediation is really part of a soil rehabilitation process.

- Soils are checked to determine the size of the area to be remediated and the amount of soil available in lower areas to move upslope.
- Soils are moved to eroded upper-slope site positions (remediation).
- Remediation attempts to establish at least 10 cm (4 in.) or more of topsoil back onto the hilltops.
  - Typically this means moving the soil from the bottom of the slope back to where it originated, using loaders and tractors or excavation equipment.
- Soil condition is improved with applications of manure and other organic amendments.
- Soils are kept in place with residue management, cover crops or perennial crops.
- Successfully remediated knoll and upper-slope sites are indistinguishable from the rest of the field: topsoil is in place and crop performance approaches field averages.

Remediating soil on eroded knolls is like getting a second chance to do it right. Lost and damaged soils can be replaced and rehabilitated – all at a price that is cheaper than land retirement and renting new land.

Research has shown that remediated knolls yielded 10–33% more in wet years and 40–100+% more in dry years. Yields in the areas where soil was removed decreased by 10–15%.

A farm with yields of 50% of the field average on a large eroded knoll before remediation reported an improvement to 90% of field average after remediation. The area where the soil was removed yielded 10% less. In both cases, the yield gain on the knoll was significantly more than the reduction in the depressional area.



**Heavy equipment is used to excavate soil at the bottom of a slope and move it to the top of the slope. Establishing at least 10 cm (4 in.) of topsoil on the hilltops means moving a large quantity of soil (1,035 m<sup>3</sup>/ha or 538 yd<sup>3</sup>/ac).**



**The guiding principles for soil remediation are to move the soil back to where it came from, keep it there and let it heal.**



**CAREFUL PLANNING** – Soil remediation restores normal soil profile features and the productive capacity of previously eroded upslope areas. When protected from further erosion, these upslope areas are less susceptible to other forms of localized degradation.

Research shows that soil remediation works best if a minimum of 10 cm (4 in.) of topsoil is replaced on knoll-top positions. Further, it is important to take only deposited soil: the goal is not to create a new problem in lower-slope positions. The key is to properly map and estimate the resource available. A properly trained pedologist (soil survey specialist) is best positioned to do this work.



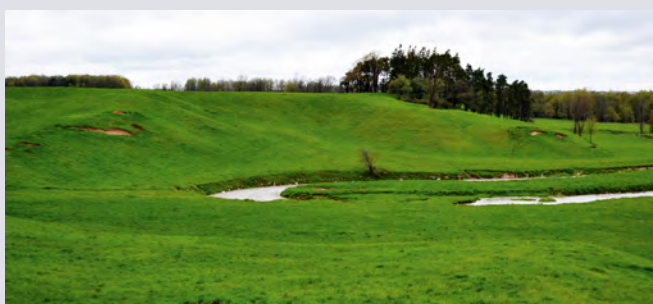
**ON-SITE VERSUS OFF-SITE** – Tillage-eroded soils are not always lost from fields. Soils in downslope depositional areas will most often have thick layers of topsoil. This is evidence of soil moved from upper-slope positions and deposited to lower-slope positions. Decades of ongoing tillage erosion will lead to buried topsoil conditions, where eroded subsoil and parent material cover the original topsoil layer. In the subsoil photo above, the lighter-coloured subsoil on the left covers the original topsoil on the right.



**FOLLOW-UP** – 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. Soil condition can be improved with applications of manure and other organic amendments, green manures and forages.



**CROPS NEED TOPSOIL** – Residual soils on severely eroded upland and crest positions are too calcareous, infertile, droughty, compact and often too stony for crop growth. Healthy topsoil has the right properties for seedling survival and crop growth: high moisture-holding capacity, good aeration, low density, balanced fertility and degradation-resistant soil structure. Healthy soil is the long-term goal of rehabilitated knoll soils.



**REPLACEMENT COSTS** – Retirement is a serious consideration when rolling cropland includes extensive areas of severely eroded soils. While afforestation or the establishment of perennial crops (such as permanent pasture shown above) is not overtly expensive, the costs of cropland replacement can be quite expensive in some regions in Ontario.



# What to consider

## NATURE AND EXTENT OF THE PROBLEM

### *What is exposed – subsoil or parent material?*

- Check the site. If there is not much evidence of soil loss, residue management may be enough to prevent further erosion.

### *How much area in the field has been degraded by tillage erosion?*

- If the area is less than 1% of the field, annual additions of organic amendments combined with soil cover may provide an alternative to remediation.
- Where tillage erosion covers only a small area, some innovative producers will adjust management by reducing population, matching hybrids to site conditions, and changing input rates to account for expected yield losses.

On the other hand, if the degradation is severe, covering greater than 30% of the cropland area, and most of the eroded topsoil has been lost from the field, then BMPs such as retirement should be considered.

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 indicates a site subjected to severe tillage erosion.**



**Calcareous parent materials on the soil surface will bubble and foam up when 10% hydrochloric acid (HCl) is applied.**



## AVAILABLE SOIL RESOURCE

### *Where did the soil go?*

- Check the depth of topsoil in the downslope depressional areas to see if most of the soil remained onsite.

### *What volume of soil is available for knoll remediation?*

- Work with a pedologist or trained soil specialist to determine the size of the depositional area and the depth of the deposited soil.

## TIMING OF OPERATION

### *Are conditions suitable for moving the soil?*

- Unfortunately the best time to move the soil may interfere with the growing crop. Moving a dry soil is much cheaper and faster than moving a wet soil. Additionally, there is less damage to the soil when it is handled in a dry state. The driest time of the year in Ontario is in the summer, which coincides with a growing crop. The best time to do remediation may be after a cereal or early harvested crop.

## SYSTEMS APPROACH

### *What else needs to be done to keep the soil in place and allow it to rehabilitate?*

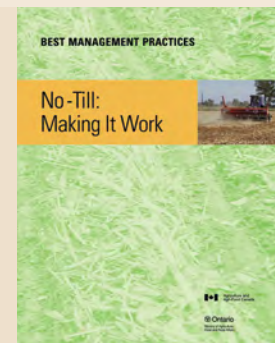
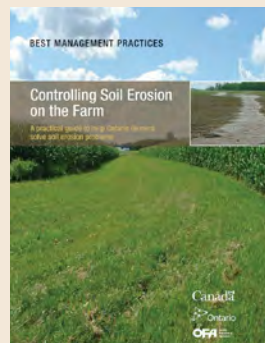
- Keep soils in place and covered with mulch tillage, no-till or cover crops. Rebuild the soil with the addition of organic soil amendments (composted manure, etc.) and perennial systems with forage crops.

### *Will soil remediation address all forms of erosion on the field?*

- Look for evidence of runoff from upslope fields, concentrated flow in draws onsite, or the risk of wind erosion. Surface water management BMPs, erosion control structures or field windbreaks may be necessary to complete the BMP system for soil health on this field.



**A professional pedologist will be able to describe the soil, note the depths, and map the areal extent of the deposited topsoil in the depressional and lower-slope areas.**



**For more information, see BMP titles, *Controlling Soil Erosion on the Farm* and *No-Till: Making It Work*.**

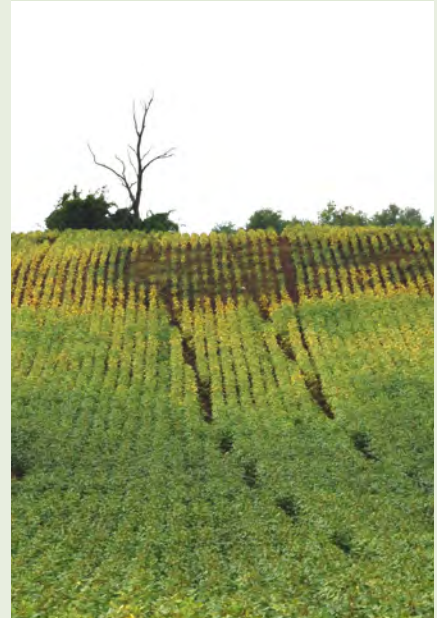


# Techniques and tips

**Work with a trained soil specialist to map out the area of topsoil deposition and depth of topsoil deposited.**



**Use yield GPS information and field soil investigation to determine where yield is suffering.**



**In the case of moderately severe tillage erosion, soil from the bottom of a slope can be moved back to the top of the knoll or slope. In this photograph, a trained soil specialist is adding 10% hydrochloric acid to verify that calcareous (high lime) parent materials have been exposed at the soil surface – an indication that the site has been severely eroded by tillage.**





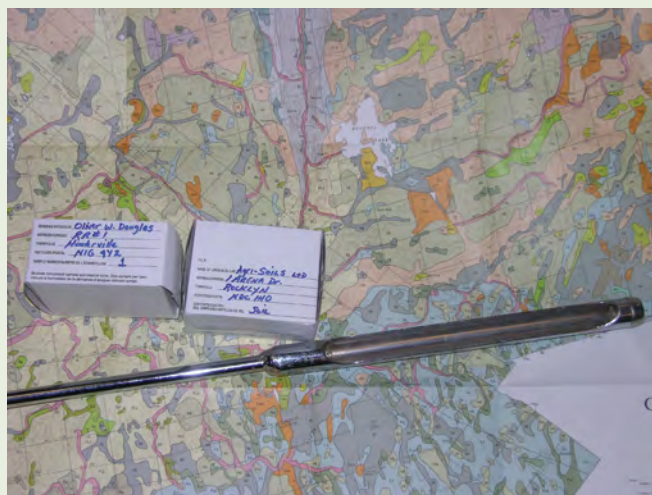
Topsoil can be removed from depressions using front-end loaders and hydraulic landscapers, and applied at a depth of 10 cm (4 in.) to the eroded upper-slope position.



Don't remove too much of the topsoil from the depressional area. Maintain a minimum depth of 15 cm (6 in.), or future crops won't grow as well.



Plant a cover crop or mulch the soil on the knoll to prevent soil loss until it stabilizes.



During the following spring or fall, check nutrient and pH levels of the remediated soil and the areas where soil was removed.



Use minimal and where possible no-till post remediation. Consider the use of less aggressive coulters as well.





**Add organic amendments over the entire area to increase soil organic matter.**



**Fall or late summer after winter wheat is the most suitable time to move the soil.**

## THE SPECIFICS

A depth of 10–15 cm (4–6 in.) is recommended to restore productivity to the knolls and reduce crop yield variability in the field.

There is a 3–6-year payback period for all of the costs (approximately \$800/acre) associated with putting the soil back on a hilltop. It only pays to remediate moderately to severely eroded knolls.



**Adding organic materials to the recently remediated hilltops helps the soil to aggregate and restore topsoil functions by increasing organic carbon in the soil faster than if no amendments were applied. Applicators need to be careful not to compact or disturb the newly moved soil.**



# 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](http://ontario.ca/omafra) or ordered through ServiceOntario.

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

### Best Management Practices Series

- *Controlling Soil Erosion on the Farm*
- *Establishing Tree Cover*
- *Field Crop Production*
- *Soil Management*



### Environmental Farm Plan (4<sup>th</sup> ed.) and EFP Infosheets

- #15, *Soil Management*

### Inquiries to the Ontario Ministry of Agriculture, Food and Rural Affairs

Agricultural Information Contact Centre  
Ph: 1-877-424-1300

Email: [ag.info.omafra@ontario.ca](mailto:ag.info.omafra@ontario.ca)

Web: [ontario.ca/omafra](http://ontario.ca/omafra)

## ORDER THROUGH SERVICEONTARIO

Online at ServiceOntario Publications – [ontario.ca/publications](http://ontario.ca/publications)

By phone through the ServiceOntario Contact Centre

Monday–Friday, 8:30 am–5:00 pm

416-326-5300

416-325-3408 TTY

1-800-668-9938 Toll-free across Ontario

1-800-268-7095 TTY Toll-free across Ontario

## ADDITIONAL RESOURCES

*Tillage Erosion and Landscape Restoration: Effects on Soil Properties and Crop Yields*

[sdaba.org/pdfs/Papiernik.ppt.pdf](http://sdaba.org/pdfs/Papiernik.ppt.pdf)

*Soil Management Guide*

[gov.mb.ca/agriculture/environment/soil-management/soil-management-guide/soil-erosion.html](http://gov.mb.ca/agriculture/environment/soil-management/soil-management-guide/soil-erosion.html)

## ACKNOWLEDGEMENTS

This factsheet was developed by the OMAFRA Soils Team: Adam Hayes (Chair), Doug Aspinall, Andrew Barrie, Sebastien Beillard, Dave Bray, Christine Brown, Adam Gillespie, Christoph Kessel, Kevin McKague, Jake Munroe, Deanna Nemeth, Nicole Rabe, Jim Ritter, Daniel Saurette, Stewart Sweeney, Ted Taylor, Anne Verhallen

**Technical Coordinators:** H.J. Smith, Ted Taylor

**Research and Writing:** Ann Huber, Don King, Margaret Ribey, Soil Research Group (SRG)

**Editorial Coordinator:** Alison Lane

**Design:** Neglia Design

AF183

ISBN 978-1-4606-9424-4 (Print)

ISBN 978-1-4606-9426-8 (HTML)

ISBN 978-1-4606-9428-2 (PDF)

### BMPs for Soil Health Factsheet Series:

Adding Organic Amendments

Buffer Strips

Contour Farming and Strip Cropping

Cover Crops and Manure Application

Crop Rotation for Vegetable Crops

Cropland Retirement

Erosion Control Structures

Field Windbreaks

Inter-Seeding Cover Crops

Mulch Tillage

No-Till for Soil Health

Perennial Systems

Pre-plant Cover Crops

Residue Management

Rotation of Agronomic Crops

Soil Remediation

Subsurface Drainage

Wind Strips

Winter Cover Crops

### BMPs for Soil Health Diagnostic Infosheet Series:

Cold and Wet Soils

Contaminated Soils

Droughtiness

Excessive Fertility

Low Fertility

pH Extremes

Salinity

Soil Erosion by Water

Subsidence

Subsurface Compaction

Surface Crusting

Tillage Erosion

Wind Erosion