Reducing Tillage Erosion in Potato Production

QUICK FACTS
- Tillage erosion is the loss and gain of soil that occurs within a field due to tillage practices. It happens when tillage events move more soil down-slope than up-slope.
- More tillage passes and more intensive tillage increase tillage erosion.
- All soil types are affected.
- Severity is greatest on hilly land.
- The mouldboard plow is *not* the only tillage implement that is erosive. Any tillage practice or field activity that disturbs the soil can cause tillage erosion.

Introduction

Tillage is an important part of crop production and is known to affect wind and water erosion. However, tillage can also cause its own type of erosion. **Tillage erosion** is the net down-slope movement of soil that occurs due to tillage practices. Tillage erosion happens in the field because typically more soil is thrown down-slope when tilling down the hill than is thrown up-slope when tilling up the hill (Fig. 1). In addition, tillage downhill generally takes place at greater speeds than tillage uphill, making the situation even worse. As a result (using up-and-down slope cultivation), tillage erosion is typically seen as soil loss from the top of hills and soil accumulation at the bottom of hills.

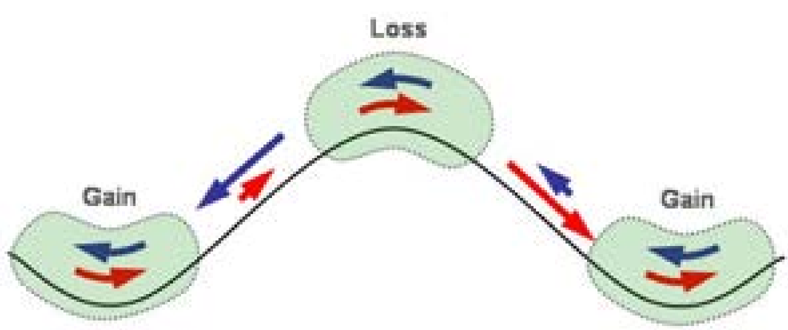

Figure 1. Example of tillage erosion in a rolling landscape, where up- and downhill tillage results in soil loss on hilltops or knolls and soil accumulation at the bottom of hills. The variability in soil movement is indicated by the size of the arrows. (Working Group on Tillage Translocation and Tillage Erosion, University of Manitoba)

If tillage practices are conducted cross-slope, tillage erosion is usually reduced. However cross-slope tillage still moves soil down the hill, because soil lifted by a tillage tool comes to rest at a slightly lower position on the slope (Fig. 2a). In fact, if a mouldboard plow is used with the furrow always thrown downhill (Fig. 2b), tillage erosion can actually be more severe under contour tillage than under up-and-down slope tillage – especially in landscapes which are divided by field boundaries such as fencelines, diversion terraces, or grass strips. In these fields, topsoil is moved down the field away from each boundary, building up at the bottom of the field above the next boundary and creating a tillage step. The more boundaries in a field, the more areas where soil can be lost, and the greater the risk of tillage erosion.

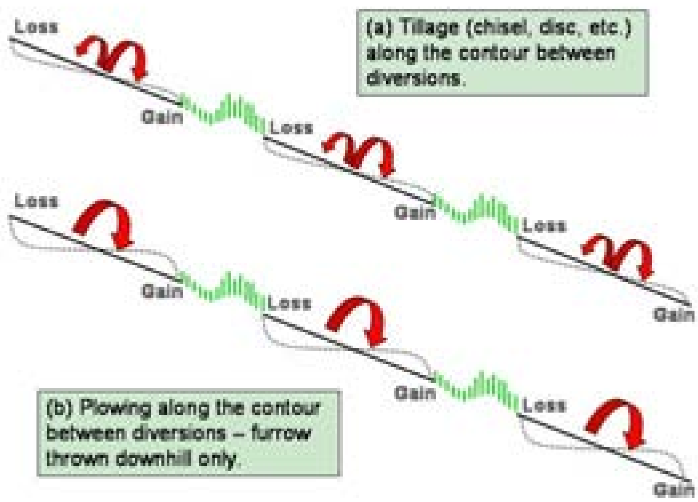

Figure 2. Example of tillage erosion on fields with diversion terraces. Tillage erosion results in undercutting of field boundaries on the down-slope side and burial on the up-slope side: (a) contour tillage using a chisel plow, offset disc, etc., and (b) plowing on the contour with the furrow thrown downhill only. The variability in soil movement is indicated by the arrows. (Working Group on Tillage Translocation and Tillage Erosion, University of Manitoba)

These characteristic patterns of soil loss by tillage erosion are very different to those produced by water erosion (Table 1). Water erosion causes maximum soil loss in middle and lower slope areas of the field, and results in soil accumulating at the foot of slopes and in depressions. It is easy to see evidence of water erosion within the field because of the small rills and larger gullies that can occur in the spring or after heavy rainfall events.

Table 1. Water and tillage erosion have different spatial patterns.

Landscape Position	Water Erosion[a]	Tillage Erosion[a]
Upper slope	loss	**Loss**
Middle slope	**loss**	Loss
Lower slope	**loss** or accumulation	Accumulation
Depression	**accumulation** or loss	**Accumulation**

[a] Bolded text indicate regions of maximum loss and/or accumulation.

Tillage erosion, on the other hand, does not result in any single severe event, but works slowly over time. However, the evidence for tillage erosion is all of those eroded hilltops and knolls in the field (Fig. 3).

Figure 3. A severely eroded field located in the potato producing region of New Brunswick. Note the areas that can no longer be planted due to the shallow soil conditions caused by tillage erosion on knolls. (NBDAA)

A recent study in New Brunswick actually measured that both the mouldboard plow and the chisel plow had equal tillage erosion losses of greater than 100 t/ha/pass on knolls. The soil on these knolls had not been eroded by water as was commonly believed, but was being slowly moved downhill with each tillage event.

Even though no soil actually leaves the field due to tillage erosion, continued soil losses will result in poor soil structure, loss of organic matter, exposed subsoil and even exposed bedrock on hilltops and below field boundaries. As a result, crop growth, development, yield and quality become increasingly variable across the field and from year to year. Unfortunately, yield losses (often between 30 to 50 %) are rarely offset by higher yields in lower slope positions, because water erosion is most active in these areas. In addition, continued tillage erosion will result in increasingly inefficient use of cropping inputs, such as fertilizers and herbicides. With potatoes being extremely sensitive to soil quality, sustainable soil management is critical.

Tillage erosion and water erosion can also work together. The majority of soil moved by tillage is moved 15 to 30 cm (6 to 12 in), but some soil will be dragged anywhere from 2 to 24 m (6.5 to 79 ft), depending on the implement and direction of tillage. Since tillage erosion moves soil to the lower parts of the hills where water erosion is most severe, tillage erosion is actually a major delivery mechanism for water erosion and can increase the potential for water contamination within agricultural landscapes.

FIELD SYMPTOMS OF TILLAGE EROSION

- Soil loss from hilltops or knolls and below field boundaries.
- Poor soil structure, loss of organic matter as well as exposed subsoil and bedrock.
- Large quantities of soil accumulated at the bottom of hills and on lower slope positions.
- Subsoil overlaying organic rich topsoil at the bottom of hills.

CROP SYMPTOMS OF TILLAGE EROSION

- Stunted crop growth on hilltops or knolls and below field boundaries.
- Yield losses that can reach 30 to 50 %.
- Increasing variability of crop growth and yield across the field and from year to year.

Factors That Impact Tillage Erosion

Tillage erosion is the result of two factors: **landscape erodibility** and **tillage erosivity**. Landscape erodibility is how easily a cultivated landscape can be eroded by tillage. Rolling land (especially steep fields with many small hills) and/or land with many field boundaries is very much at risk for tillage erosion. Tillage erosion affects all soil types, but land that has shallow topsoil will see the effects of tillage erosion much more quickly. Tillage erosivity is the ability of a tillage practice, or a sequence of tillage events, to move and erode soil from that cultivated landscape, and depends on such things as:

- ***Design and type of implement -*** It is often assumed that: (i) the mouldboard plow moves the most soil of all tillage implements; and (ii) conservation tillage implements (e.g., the chisel plow) reduce tillage erosion. In fact, the chisel plow is as erosive as the mouldboard plow (Figure 4), because it drags soil much further (up to 6 m) and with greater variability across the landscape. Final seedbed tillage implements, in particular the offset disc, can also be as erosive as the mouldboard plow. Growing season field activities such as those involved in the planting, hilling and harvesting of the potato crop used to be considered non-erosive because they are not normally considered tillage practices. Surprisingly, these "tertiary" (post-plant and harvest) tillage events actually move the most soil (up to 24 m) and can be more erosive then all pre-plant tillage events combined.

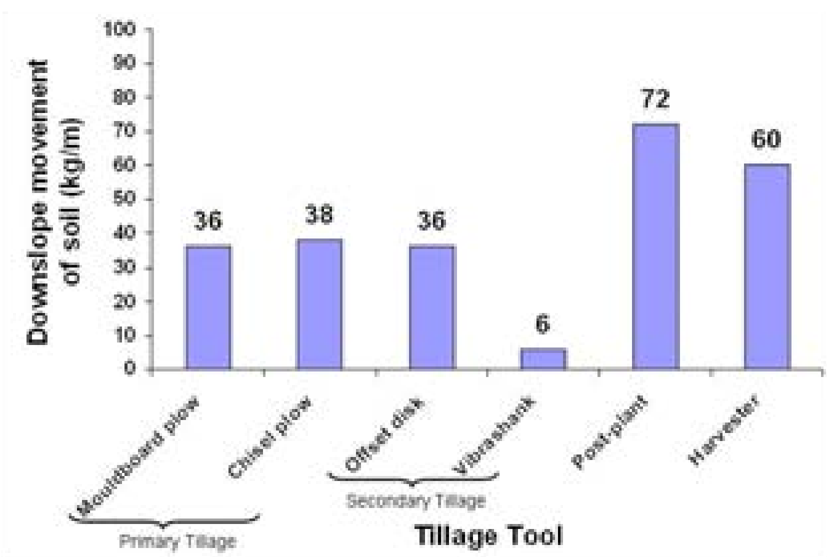

Figure 4. Tillage erosion – the net downslope movement of soil – by primary, secondary (pre-plant) and "tertiary" (post -plant and harvest) tillage practices used in potato production in New Brunswick (assuming tillage practices are conducted equally up and down a field with a 10% slope). Note: Post-plant includes the planting of potato with discs, followed by one pass of in-row cultivation and one pass with hilling tools (horse-hoe).

- ***Depth and speed of tillage -*** Tillage depth determines how much soil is moved, while tillage speed affects how far that soil will move. Tillage erosion usually increases as tillage depth and speed increase. Also, under normal operating conditions, tillage depth and speed will vary across the landscape, and this greatly affects the amount of soil moved up versus down a hill. For example, it is an extremely erosive practice to increase tillage speed going down the hill to make up for lost time going up the hill.

- ***Number of passes -*** The greater the number of tillage events used in a year, the greater the risk of tillage erosion. In potato production, there may be one pass with a mouldboard plow, one or two passes before planting, and then at least one more pass after harvest – not to mention the soil moved during the growing season. This is why the potential for tillage erosion within potato production systems, regardless of whether conventional or conservation tillage implements are used, is considerably larger than that for corn-based production in Eastern Canada and cereal-based production in Western Canada.

- ***Tillage direction and pattern -*** Tillage direction, especially when tillage is conducted over and over in the same pattern for many years, will also affect which areas of a field will lose or gain soil. As mentioned earlier, cross-slope tillage can result in more tillage erosion if a mouldboard plow is used and the furrow is always thrown downhill. Similarly, splitting the field with a mouldboard plow and constantly moving soil in one direction (e.g., to the middle of the field) can be an erosive tillage pattern. It is also highly erosive to conduct tillage practices straight down the steepest hills.

Options to Reduce or Correct Tillage Erosion

Fortunately, tillage erosion can be controlled by modifying tillage practices. Potato production will always involve some form of soil disturbance. Therefore, it is extremely important to conduct tillage practices in ways that minimize tillage erosion.

- ***Reduce tillage frequency -*** Eliminate **unnecessary** tillage. Avoid tilling when soil conditions are unsuitable, for example when soils are too wet. Rutting and compaction that may then occur require more tillage to correct, resulting in more tillage erosion. The best way to decrease the number of passes in potato production is to increase the length of the rotation. Inclusion of grains and forages in the rotation may decrease the number of passes even more, by allowing for the use of reduced till or no-till methods.

- ***Reduce the variability in tillage depth and speed -*** Use a tractor that has enough power to pull the tillage implement. This will help to maintain a constant depth and speed across the field.

- ***Reduce tillage intensity -*** Till at **minimum** recommended depths and speeds according to the equipment manufacturer's specifications.

- ***Reduce implement size -*** The larger the tillage implement, relative to the size of the hills, the more rapidly the landscape will be eroded. Therefore, tillage implements that are very long and/or wide should be avoided on highly erodible landscapes.

- ***Use less erosive tillage patterns -*** Alternate tillage direction from year to year. Also, cultivate up the slope on less steep hills, or at an angle up the steepest slope on steep hills to maximize upslope movement of soil, especially if cross-slope tillage is limited by the steepness of the slope and/or the ability of the potato harvester to work properly on side hills.

- ***Use a reversible/rollover/two-way plow -*** Contour tillage using a reversible mouldboard plow (or a regular mouldboard plow with the furrow turned up-slope) will help to offset the down-slope movement of soil by other tillage practices, while still minimizing water erosion. A reversible plow can also save travel time, reduce compaction from running over the same headland ground more than once, and is often more efficient in odd shaped fields.

- ***Landscape restoration -*** Although it is possible to slow and eventually stop tillage erosion, sometimes drastic measures are needed. Landscape positions that are generally most susceptible to tillage erosion (i.e., knolls and below field boundaries) are also often those areas that regenerate soil the slowest. Fortunately, the soil moved by tillage erosion is not degraded by the tillage process as it is by water erosion (water erosion separates out the finer soil particles and washes them away). Therefore, in fields that have been badly degraded by tillage erosion, the best option may be to take soil that has accumulated at the base of hills and apply it to the severely eroded landscape positions.

Conclusion

In Canada, soil degradation by tillage erosion is of greatest concern in regions where intensively tilled crop production is carried out on topographically complex landscapes – such as in the potato growing regions of Atlantic Canada. It is estimated that over half of the cropland in New Brunswick and 75 % of the cropland across Atlantic Canada is at risk for unsustainable levels of soil loss (> 6 t/ha/yr) by tillage erosion. In order to minimize tillage erosion, both the frequency and intensity of all field activities that disturb the soil must be reduced. Simply leaving crop residue at the surface does not control tillage erosion.

One of the best ways to reduce tillage erosion is by increasing the length of the rotation. The inclusion of a grain or forage in the rotation may further decrease the number of machine passes. Also, these crops allow for the adoption of reduced or no-till methods.

In New Brunswick, combining contour tillage and diversion terraces with a reversible mouldboard plow (furrow turned up-slope), used in the spring of the potato year of a 3 or even a 4 year rotation, may be one of the best management plans that can be used to fully integrate soil conservation planning for the control of both water and tillage erosion in the province's potato production systems.

Additional Reading

Lobb, D.A. 2005. *Tillage Erosion*, p. 101-107, *In* A. Lefebvre, et al., eds. Environmental Sustainability of Canadian Agriculture: Agri Environmental Indicator Report Series - Report #2. Agriculture and Agri-Food Canada, Ottawa, ON.

Tiessen, K.H.D., G.R. Mehuys, D.A. Lobb, and H.W. Rees. 2007. *Tillage erosion within potato production systems in Atlantic Canada: I. Measurement of tillage translocation by implements used in seedbed preparation*. Journal of Soil and Tillage Research 95: 308-319.

Tiessen, K.H.D., D.A. Lobb, G.R. Mehuys, and H.W. Rees. 2007. *Tillage erosion within potato production in Atlantic Canada: II. Erosivity of primary and secondary tillage operations*. Journal of Soil and Tillage Research 95: 320-331.

Tiessen, K.H.D., D.A. Lobb, G.R. Mehuys, and H.W. Rees. 2007. *Tillage translocation and tillage erosivity by planting, hilling and harvesting operations common to potato production in Atlantic Canada*. Journal of Soil and Tillage Research 97: 123-139.

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