WATER CONSERVATION TECHNICAL BRIEFS

TB13 – Soil erosion control

SAI Platform

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WATER CONSERVATION

TECHNICAL BRIEFS

TB13 – Soil erosion control

Soil is the basis of agricultural systems; good soil management enables soils to simultaneously provide a number of key functions to support agricultural raw material production and to minimise negative environmental impacts on agriculture. Soil erosion removes nutrients from soil affecting agricultural production. This technical brief provides an overview of soil erosion and mechanisms of control which include maintaining good soil structure, protecting the soil surface by adequate crop and residue cover, and using special structural erosion control practices where necessary.

This technical brief is structured as follows: Sections 1 and 2 provide an overview of soil erosion, its causes and the benefits on controlling it. Sections 3 and 4 present the causes of soil erosion and depict ways to indentify soil erosion. Sections 5, 6, 7 provide different short and long term measures to control soil erosion. Section 7 outlines a case study of farm strategies to control soil erosion in the UK. Finally, Section 8 provides references and recommends some further reading.

Contents

SECTION 1: WHAT IS SOIL EROSION?

The soil's physical properties control the movement of water and air through the soil, and the ease with which roots can penetrate the soil. Damage to the soil can change these properties and reduce plant growth, regardless of nutrient status. [1]

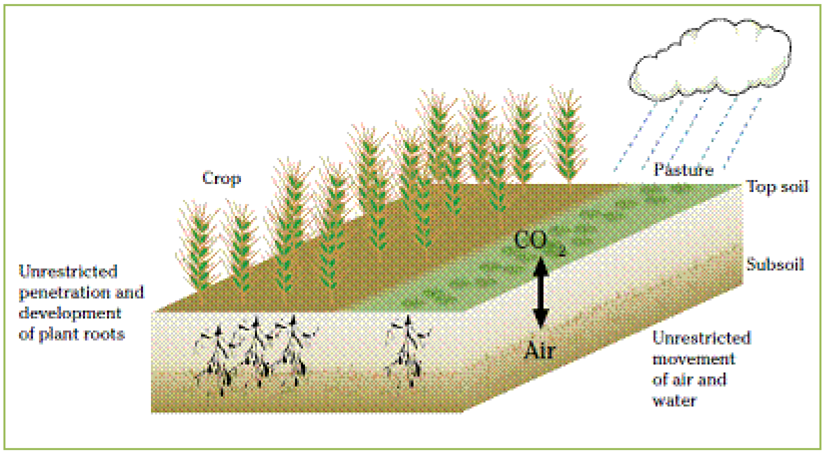

Figure 1: The primary functions of the soil are to provide plants with air, water, nutrients and a rooting medium for growth and physical support. Source: http://www.potato.org.uk/media_files/campaigns_kt/vsa.pdf

Soil erosion can have detrimental effects such as:[2]

- Erosion reduces crop yields;
- Erosion removes topsoil, reduces soil organic matter, and destroys soil structure;
- Erosion decreases rooting depth;
- Erosion decreases the amount of water, air, and nutrients available to plants; Nutrients and sediment removed by water erosion cause water quality problems and fish kills;
- Blowing dust from wind erosion can affect human health and create public safety hazards;
- Long-term soil erosion results in exposure of lighter coloured subsoil at the surface, poorer plant growth.[3]
- Saves money to farmers. The major productivity costs to the farm associated with soil erosion come from the replacement of lost nutrients and reduced water holding ability.[4]

Any land which is compacted either in the surface layers or below plough depth will have additional vulnerability to erosion because these layers will reduce water infiltration and so increase run-off. Also, situations with increased erosion risk are where soil surfaces are left bare (such as under winter cereals) on easily eroded soils (sandy soils, silts and peats) and on sloping land. [5]

SECTION 2: WHY TO CONTROL SOIL EROSION?

Controlling soil erosion can:[6]

- sustain or improve crop yields;
- reduce drainage costs;
- retain nutrients and chemicals where applied;
- reduce hazards when working on eroding soil;
- help improve water quality.

SECTION 3: HOW DOES SOIL EROSION OCCUR? [7]

In general terms wind, water and tillage can cause soil erosion.

A. Wind erosion: Soil erosion by wind or water is the physical wearing away of the soil surface and soil material and nutrients are removed in the process.[8] Wind can move particles in three ways: surface creep (rolling or sliding along surface); saltation (bouncing and dislodging other particles on impact); and suspension (continuously carried in the air).

The susceptibility of a soil to wind erosion depends on factors including soil moisture and wind velocity, surface roughness, organic matter content and particle size. Soils that have low volumes of organic matter and have lost their structure through compaction and over-cultivation are pulverised to dust on further cultivation, making them vulnerable to wind erosion if un-protected. [9] Wind erosion reduces the productive potential of soils through nutrient losses, lower available water-holding capacity and reduced rooting volume and depth.[10]

B. Water erosion: Water erosion is the detachment, movement and removal of soil from the land surface by precipitation leaving the landscape as runoff. Soil erosion is affected by surface texture, organic matter content, size and shape of soil aggregates and the permeability of the least permeable horizon.

The susceptibility of a soil to water erosion depends on factors including the amount and intensity of rainfall, the degree of slope, and the soil infiltration rate and permeability. The latter two are governed by soil structure and texture. For more information on soil structure and texture see Technical Brief 5: The importance of soil to water use.

C. Tillage erosion: Tillage erosion is the progressive downslope movement of soil by tillage causing soil loss on hilltops and soil accumulation at the base of slopes (depressions). Tillage erosion is described in terms of erosivity and landscape erodibility. Large, aggressive tillage implements, operated at excessive depths and speeds are more erosive, with more passes resulting in more erosion. Landscapes that are very topographically complex (with many short, steep, diverging slopes) are more susceptible to tillage erosion.

SECTION 4: HOW TO IDENTIFY SOIL EROSION?[11]

Visual, physical, chemical, and biological indicators can be used to determine soil surface stability or loss as shown in the figure below.

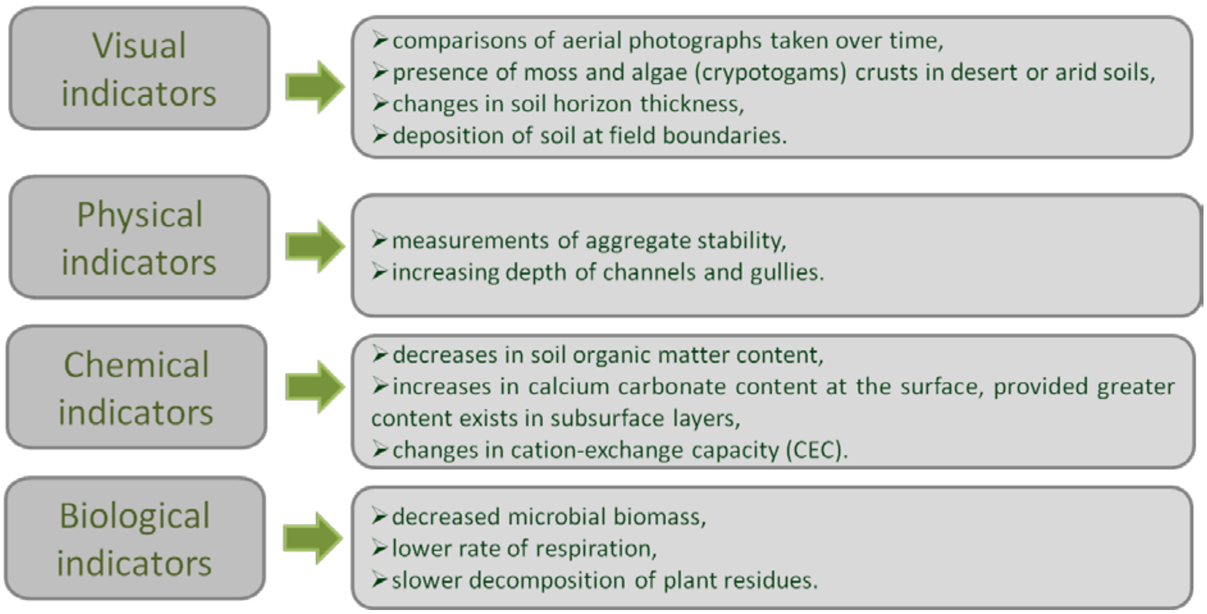

Figure 2: Visual, physical, chemical and biological factors to soil surface stability or loss. Source: Adapted from(USDA, 1996). Soil Quality Resource Concerns: Soil Erosion http://soils.usda.gov/sqi/publications/files/sq_two_1.pdf

To assess the susceptibility to wind and water erosion the UK Soil Management Initiative recommends to:[12]

- Assess, based on knowledge of the area or visual observations during the season, whether the amount of wind erosion during and after cultivation has become a concern.
- Take into account the size of the dust plume or clouds raised during or after cultivation, and whether the material stays within the field, within the farm, or is blown into the surrounding area.
- Determine the severity of water erosion by augering or digging holes to compare the difference in topsoil depths between the crest and the bottom of the slope, and by observing the amount of sheet and rill erosion, as well as sedimentation into surrounding drains and streams.

SECTION 5: HOW TO CONTROL SOIL EROSION?[13]

The following three principles should be followed to control erosion effectively: maintain good soil structure; protect the soil surface by adequate crop and residue cover; and use special structural erosion control practices where necessary. [14] This section presents different practices that farmers can implement to adhere to the principles stated above and to control soil erosion caused by wind, water or tillage.

Some practices to avoid water erosion include reducing the erosive impact of rainfall and maintaining soil infiltration rates so that surface flow is prevented. This can be achieved by:[15]

- Protecting the soil from rain impact, either with permanent vegetation cover or, in arable rotations, by timely crop establishment and by surface retention of crop residues.
- Avoiding smooth, flat finishes to bare field surfaces, so that good water infiltration rates are maintained.
- Avoiding tramlines, wheelings or cultivation features that can channel surface flow.
- Improving the stability of the soil in the longer term by actively seeking to increase the organic matter content.

Specific practices to avoid wind erosion include maintaining a cover of plants or residue, planting shelterbelts, stripcropping, increase surface roughness, cultivating on the contour, maintaining soil aggregates at a size less likely to be carried by wind.

Practices to control soil erosion?[16]

Seedbed preparation, direction of cultivations, use of mulches and organic manures can help to control soil erosion as detailed below:

A. Seedbed preparation[17]

Soils are most vulnerable to erosion when a fine seedbed has been prepared but a crop cover has not yet developed. It is important to avoid cultivations which produce an unnecessarily fine seedbed, particularly when the crop will develop slowly (e.g. with a late drilled grass re-seed or winter wheat crop).

Rolling should be avoided after autumn drilling on vulnerable land, especially if the soil is wet, as it will tend to reduce water infiltration and increase surface run-off.

On many soils, crops can successfully be established without ploughing, by using tines, discs, or shallow one pass systems (sometimes known as conservation tillage). These techniques can reduce erosion risk by leaving chopped straw and stubble on the surface, and, in the longer term, by increasing organic matter in the surface layers of soil.

Deep ploughing should generally be avoided on erosion prone soils, as this will bury organic matter at greater depths, and increase the risks of causing a compact layer at plough depth (plough pan). Shallower ploughing will tend to keep organic matter nearer the surface, thus increasing stability.

Various purpose-built implements are available to produce a pitted surface which will improving water retention and infiltration in specific situations. These can be valuable for protecting seedbeds during crop establishment, and for tying potato ridges to reduce run-off during rainfall or irrigation. Such techniques require careful application as incorrect use may make problems worse.

B. Directions of cultivations[18]

In many parts of the world, cultivation, sowing and planting crops "on the contour" are recommended for controlling erosion. This has limited applicability for mechanised agriculture where slopes are often complex, and failed attempts at following the contour can result in water being channelled forming rills and gullies. Additionally the operation of machinery across steeper slopes can be dangerous and less efficient (e.g. root crop harvesters).

In general, working across the slope is likely to be beneficial on gently sloping land with uniform slopes. In other situations the benefits of working across the slope are more questionable. Where ploughing is carried out across the slope, the use of a reversible plough to throw the soil upslope will help to counter the effects of erosion and of "tillage creep".

C. Irrigation[19]

Care should be taken when irrigating land which is susceptible to erosion. Always adjust application rates to suit field and soil conditions so that the risk of surface run-off is minimised.

Water droplet size is an important factor. The larger the droplet size, the greater its erosivity. If a large droplet size is combined with an excessive application rate, soil particles can be detached and carried away by surface water run-off.

When operating a mobile irrigator with a "raingun" type application system, always where practically possible, set it to operate across the slope not up and down it. Always ensure that the application rate is low enough to prevent surface run-off and take care that there are no leaks from supply pipework. The machine itself and all associated pipework should be carefully drained down before moving, since surface flow can initiate a rill in loose soil.

Rainguns can irrigate very unevenly, especially in windy weather. Boom irrigators are more consistent, produce smaller drops and apply them close to the ground, so that erosion by irrigation is reduced significantly. The use of trickle (drip) irrigation can result in even more efficient use of water with minimal erosion risk.

D. Mulching[20]

Mulching refers to covering the ground with organic material, such as crop residues, straw or leaves, or with other materials such as plastic or gravel. The objective of mulching is to improve infiltration, protect the soil from water and wind erosion and from dehydration, prevent high ground temperatures, increase the moisture level in the soil, and, when mulching with organic material, to increase or retain the level of organic matter in the soil, better utilise the nutrients from chemical fertiliser, stimulate soil organisms.

Agromisa foundation recommends to apply mulch before the rainy season begins, because the soil is then most vulnerable. The seeds can be sown through the mulch layer by making small openings in the mulch through which the seeds are planted. After planting each seed the opening must be closed, otherwise birds will become aware of the presence of the seed. The mulch layer may not be too thick. A sufficient amount would almost completely cover the soil from sight. If the layer is too thick, it will be difficult for the sprouted plants to reach the surface. The seeds can also be sown in rows that have been cleared by ploughing or removing the mulch.

E. Organic manures[21]

Stability of topsoils can be improved by the regular use of bulky organic manure, to increase soil organic matter, though care should be taken to avoid excessive amounts of nitrogen or phosphorus. Slurries and solid manures applied to erosion susceptible sites should be incorporated soon after application to minimise ammonia and odour emissions, leaving a rough field surface.

The risk of causing pollution due to run-off from land spread with organic manures should be considered at all times. Other organic materials, including composted “green waste” and crop residues incorporated into topsoils, can help to increase the stability of topsoils. It is recommended to make adjustments to farm fertiliser programmes in order to consider the nutrient content of the applied organic manures/crop residues.

Section 6: Measures to control soil erosion involving changes to farm layout[22]

In some situations it may be necessary to consider changes in the farm layout to reduce erosion and its off-farm effects. These could include installation of new drainage systems, relocation of gateways to the upper parts of fields, relocation of farm tracks and changes to field layout. The grassing of valley bottoms may be an option where these accept large flows of surface water run-off. Existing hedges and field boundaries may provide important protection and consideration should be given to improving these where practicable.

A. Drainage

Adequate control of water on the farm is essential for minimising erosion risks. Run-off from buildings, concreted areas, roads and tracks should be effectively channelled into ditches and drains so no excess water flows over field surfaces.

On fields where drainage is necessary, piped underdrainage systems and ditches should be installed and maintained. Particular attention should be given to removing sediment that has been deposited in ditches and drains. Whenever possible this should be returned to the top of the field from which it eroded.

Poorly drained land will easily become waterlogged and prone to surface run-off. Soils will be slow to dry out and so will be especially vulnerable to compaction, caused by trafficking or cultivating the land under wet soil conditions.

B. Introduction of breaks on long slopes

Breaking long slopes by a ditch, hedge or wide grass strip on the contour will reduce the chances of surface water flow building up and causing rilling. If field shape is changed so that the long side is across the slope, cultivations will tend to follow this and help reduce erosion risk.

On longer slopes, it may be appropriate to install a new ditch across the slope to intercept water part-way down. This will help stop the accumulation of large volumes of surface water run-off.

The ditch should have a grass strip a few metres wide on its upper side to filter sediments from run-off and reduce discharge to watercourses.

Hedges give a long-term slope break, and if additional drainage is not required, they are more effective if planted on a wide bank running along the contour to help retain sediment and prevent fine particles from reaching watercourses.

Where long slopes are unavoidable or cannot be broken by planting hedges, consideration should be given to contour strips. These work on the principle that a close ground cover such as creeping grass will both slow surface flow from above, and increase infiltration rates.

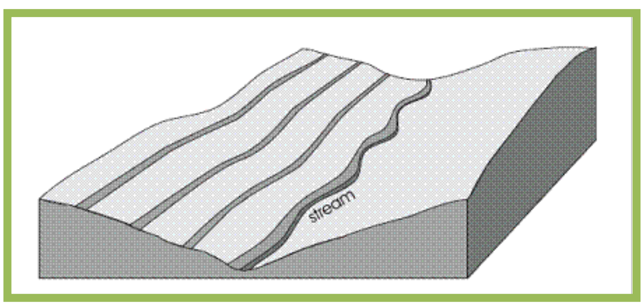

Figure 3: Grass, stubble, or set-aside countour strip will reduce water scouring and reduce rilling risk. A buffer strip protects the stream in the valley bottom.

Guidelines from the UK Department for Environment, Food and Rural Affairs (DEFRA) suggest that strips 5-15 metres in width positioned every 50-150 metres down the slope, should be effective on most erosion susceptible areas. On steeper slopes, the width should increase and the distance between strips decreases. The advantage of contour strips over mechanical methods (earth banks or terraces) is that inaccuracy in construction will not result in further problems. It is safer, therefore, to encourage their establishment, even if specialist technical help is not available.

Some of the benefits of contour strips will be lost if they are compacted and rutted by farm machinery, so they should not be used as additional trackways. In some situations, these strips may form part of land which is under permanent set-aside.

C. Buffer strips

Buffer strips differ from contour strips in that they are located at the bottom of fields, against a watercourse or ditch, and are usually wider. They should not be seen as a primary tool for controlling soil erosion, but as a water protection measure. Surface flow cannot usually be broken, but heavier sediment particles can be intercepted, rather than flowing through to watercourses. According to DEFRA, grass strips 20 metres wide have been used successfully as buffer strips, though narrower strips may be beneficial in some situations. See Technical Brief 11: Use of Conservational Riparian Buffer for more information.

Some benefits to the farmer of buffer strips include:

- Restricting the migration of harmful weeds from hedgerows
- Cost savings by not farming field margins with poor yields
- Bank stabilisation to prevent loss of land
- Enhanced numbers of game birds and improved fisheries
- Establishment of beetle banks and habitat for crop pest predators
- Possible access using grassed areas, but traffic on buffer strips could diminish their effectiveness.

Section 7: Short term measures

The measures listed in this section are short-term measures to tackle the symptoms of erosion and not the cause. Where changes to cropping and management practices have not been carried out, or have proved insufficient, in extreme situations, it may be necessary to introduce temporary emergency measures to minimise damage. These aim to reduce the flow of run-off below an eroding area to settle-out the coarser sediments.
It is recommended to implement more preventative measures In subsequent seasons. It should not be assumed that the erosion event was a one-off and will not be repeated.

Bunds (embankments) may be constructed to trap silt-laden water. The bund should be built so that overflow is diverted around the ends of the bank and not over the top. Materials available for construction are likely to have a high sand or silt content and are, therefore, inherently unstable. Blind ditches are less likely to collapse, but may become a safety hazard when full of water.

Straw bales have been used in emergencies to hold back water and sediment, but they must be securely anchored.

It is common in constructing emergency measures to overlook the required design input. As a consequence, storage volumes are often inadequate and contingencies for overflow may be absent. Bunds in wet soil and poorly secured straw bale barriers can collapse, causing severe flood damage. Expert advice should be sought before proceeding with any emergency measures.

SECTION 8: CASE STUDIES

Controlling water erosion on a combinable crop farm in UK[23]

The problem: The farm (320 ha cultivated with winter wheat, winter oilseed rape, winter oats, winter and spring beans located in Worcestershire, UK) has followed the minimum tillage route for the last ten years, with notable success achieved in reducing costs and benefits to soil structure. Changes in rainfall patterns, with extreme rainfall events especially in autumn, led to problems with soil erosion on some land (approx 20ha). Here infiltration was not sufficiently rapid and some problems with water erosion were noticed-

The solution: Cultivation, soil management strategies and sowing date all have a major influence on soil structure, stability and resilience. This comes to a head during periods of prolonged rainfall in winter months or during intense rainfall events in early spring. Non-inversion tillage is one of the important mitigation pathways to prevent soil erosion and minimise diffuse pollution. This, together with good ground cover techniques implemented here, minimise the time soil is vulnerable during these weather induced risk periods. The range of strategies employed has successfully combated and minimised soil erosion.

Current soil strategy:

- Avoid spring cropping if possible, although this has been useful for controlling grass weeds
- As much crop residue as possible is retained on the land to increase soil organic matter levels in an attempt to improve soil structure and water infiltration
- All tramlines run across slopes to reduce erosion down the wheel marks
- All cultivations are carried out across the slope or at an angle of no more than 30° to the slope
- Soil structure is monitored regularly throughout the growing season so problems can be identified before the next crop is established
- Deep loosening (up to 200mm) is only carried out if a crop or cover crop is to be established immediately – the root system will then stabilise the loosened soil profile
- Direct drilling is used whenever possible
- Traffic is kept to a minimum to reduce compaction (and potential run-off)
- Land drain outfalls are regularly checked to ensure land does not become waterlogged
- Oilseed rape and beans are established in one pass behind a subsoiler – the crops' tap root benefits from the loosened soil profile
- The resulting soil profile following the break crop provides an excellent entry for cereal crops which are either direct drilled or min tilled with a Kuhn four-metre triple disc drill

SECTION 9: REFERENCES AND FURTHER READING

Agricultural and horticultural research forum

This website contains a range of case studies on best practice soil management and signposting to further soil information.
http://www.appliedresearchforum.org.uk/content.output/213/213/Joint%20Projects/Soil%20information%20gateway/Case%20studies.mspx

Visual soil assessment

This document contains guidelines on how to conduct a visual soil assessment. http://www.potato.org.uk/media_files/campaigns_kt/vsa.pdf

Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England.
http://archive.defra.gov.uk/environment/quality/land/soil/documents/soilerosion-lowlandmanual.pdf

Soil management fact sheet

Environment Sensitive Farming – practical advice for land managers
http://www.kentdowns.org.uk/KDRASToolkit/defra_soil_factsheetv4.doc

SOWAP (Soil and Water protection)

This website contains advice on sustainable soil management and no-tillage.
http://www.sowap.org/

UK Soil Management initiative (SMI) website.

This website contains information on improving soil quality and some case studies.
http://www.smi.org.uk/casestudies/index.html

Defra (2010) Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers

This guideline consolidates and updates the UK former three separate codes for water, soil and air.
http://archive.defra.gov.uk/foodfarm/landmanage/cogap/documents/cogap090202.pdf

Soil fertility management

Agromisa Foundation, Wageningen (2004) Laura van Schöll, Rienke Nieuwenhuis
This document provides information about appropriate crop husbandry practices and the use of organic and chemical fertilisers.

http://journeytoforever.org/farm_library/AD2.pdf

ATTRA National Sustainable Agriculture Information Service
Overview of Cover Crops and Green Manures
http://attra.ncat.org/attra-pub/PDF/covercrop.pdf

ATTRA National Sustainable Agriculture Information Service
Sustainable soil management
This publication covers basic soil properties and management steps toward building and maintaining healthy soils.
http://attra.ncat.org/attra-pub/PDF/soilmgmt.pdf

Robert P. Stone - Engineer, Soil Management/OMAFRA; Neil Moore - Soil and Crop Advisor/OMAFRA (2010)
This website contains different measures to control soil erosion.
http://www.omafra.gov.on.ca/english/engineer/facts/95-089.htm

Natural Resources Conservation Service (NRCS)
Controlling Soil Erosion
http://www.in.nrcs.usda.gov/smallscalefarmers/Small_Farms_Soil_Erosion(IN)-web.pdf

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[2] http://www.in.nrcs.usda.gov/smallscalefarmers/Small_Farms_Soil_Erosion(IN)-web.pdf
[3] USDA, 1996. Soil Quality Resource Concerns: Soil Erosion http://soils.usda.gov/sqi/publications/files/sq_two_1.pdf
[4] http://attra.ncat.org/attra-pub/PDF/soilmgmt.pdf Pg16.
[5] http://www.appliedresearchforum.org.uk/publications/documents/Soil_Management_and_CLimate_change_final_report.pdf
[6] Robert P. Stone - Engineer, Soil Management/OMAFRA; Neil Moore - Soil and Crop Advisor/OMAFRA (2010), http://www.omafra.gov.on.ca/english/engineer/facts/95-089.htm
[7] http://www.gov.mb.ca/agriculture/soilwater/soilmgmt/fsm01s07.html
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[14] Robert P. Stone - Engineer, Soil Management/OMAFRA; Neil Moore - Soil and Crop Advisor/OMAFRA (2010), http://www.omafra.gov.on.ca/english/engineer/facts/95-089.htm

[15] Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England. http://archive.defra.gov.uk/environment/quality/land/soil/documents/soilerosion-lowlandmanual.pdf

[16] http://soils.usda.gov/sqi/publications/files/sq_two_1.pdf

[17] Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England. http://archive.defra.gov.uk/environment/quality/land/soil/documents/soilerosion-lowlandmanual.pdf

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[20] http://journeytoforever.org/farm_library/AD2.pdf

[21] Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England. http://archive.defra.gov.uk/environment/quality/land/soil/documents/soilerosion-lowlandmanual.pdf

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[23] http://www.appliedresearchforum.org.uk/publications/documents/ARF_Bullock_9_V4.pdf