Information Sheet

6.9 Soil Loss: Management of erosion

Soil is a primary, non-renewable resource for field crop production, and must be protected and conserved. Soil loss is one of the most severe forms of soil degradation encountered in agricultural systems. It is considered a permanent loss and is the result of erosion removing valuable and productive soil from fields and depositing it elsewhere, usually where it is not needed or wanted.

According to the South African Conservation of Agricultural Resources Act (No 43 of 1983), it is a requirement to undertake measures that protect and conserve natural resources, including soil. As such, it is imperative that measures to remediate, minimise and prevent the negative impacts of erosion be undertaken. This information sheet discusses the impacts of erosion and soil loss, the main forms of erosion and drivers causing them. It also provides guidance on detecting and preventing erosion, as well as remedial strategies to repair the damage.

Impacts of erosion and soil loss

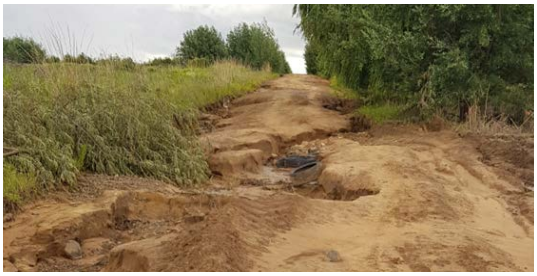
The consequences of erosion can be devastating to any agricultural production, where the loss of topsoil leads to the lowering of the ability of land to support crop growth. A loss of 1 mm of soil over one hectare is the equivalent of between 10 and 14 tons of soil. Some have estimated that this is the loss of about 20 kg sucrose per hectare. Unfortunately, the loss of one or two millimetres of soil is not readily observed in fields, and so often gets ignored. However, if you consider that the soil surface layers are the most important in terms of supplying nutrients and water to a crop, it becomes very apparent why erosion must be prevented. When losses become noticeable (see Figure 1), it indicates soil loss may be over 150 tons per hectare (about 15 mm of topsoil). This can easily occur on unprotected soils on steep slopes and under high-intensity rainfall events, a common feature in large parts of the sugarcane growing region.

▲ Figure 1: Loss of soil due to erosion exposed stones that was imbedded in the soil.

The impacts of this loss include:

- Lost nutrients, organic matter and water holding capacity reducing the productive capacity of the soil. This increases input requirements to maintain yields.
- Exposure of subsoil layers that are lower productivity soils. It is both costly and a slow process to return them to productive condition.
- Loss of productive area due to the formation of gullies (see Figure 2) limiting your ability to access or cross lands and reducing the area that can be planted. Gully repairs are costly, and it is a slow process for the area to recover.

▲ Figure 2: This area has become unproductive due to erosion creating gullies.



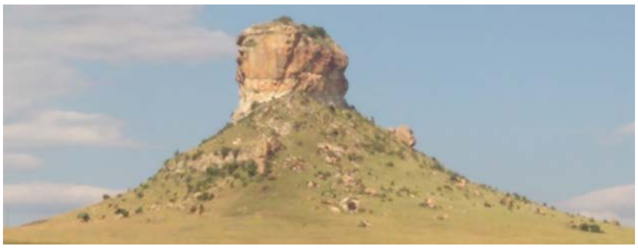
▲ Figure 3: Unusable road due to soil erosion.

Erosion impacts are not just limited to fields and affect the surrounding and downstream areas as well as users, both within and beyond the farm boundaries. These include:

- Damage to roads (see Figure 3) reducing field access (lost time and efficiency) and requiring repairs (time and cost).
- Sedimentation, silting and blockage of ponds, dams, rivers and waterways. This lowers the water storage capacity of dams, and increases flooding risks and water treatment costs, while negatively impacting the ecology of these water ecosystems. Dredging, excavating and removal of sediment build-up is costly and can also lead to further damage.
- High nutrient loads in erosion sediments that are introduced into water bodies lead to nutrient enrichment (eutrophication) which promotes algal blooms and encourages invasive water plant to proliferate, negatively affecting water quality and stream flow.
- Ultimately erosion sediments can reach the sea, where plumes of cloudy water are evident from river outlets after large inland rainfall events, this adversely affecting near-shore ecology.

Types of erosion

Erosion is the general term used to describe several processes that lead to soil loss. It is a natural process, though certain conditions and practices can greatly increase the risk and rate of it occurring. Erosion is divided into three types: 1) Mass Movement (see Figure 4). 2) Wind (see Figure 5). 3) Water erosion (see Figures 1 to 3). Water erosion is the most commonly encountered form in the South African sugar growing areas.



▲ Figure 4: Mass erosion due to gravitation.

▲ Figure 5: Soil erosion by wind.

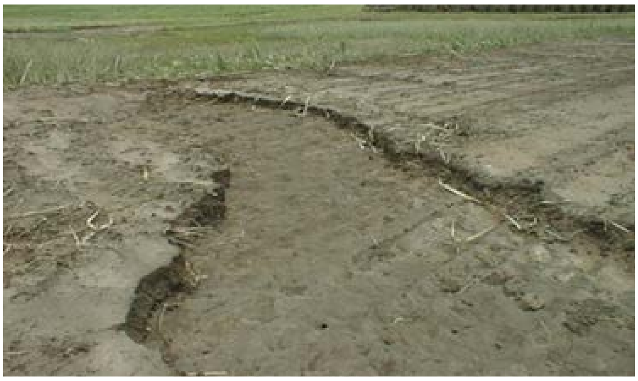
Mass Movement: This refers to the downward sliding of sections of soil and rock from steep slopes. This may be seen as soil creep and slumping in sections of a slope, and in severe cases, become landslides where entire slopes collapse and move down a hillside. It is associated with unstable soils on steep slopes. It is often triggered by prolonged rainfall and saturation of the soil. In most farming situations, the impact tends to be localised to the affected slope and is more likely to occur in hilly areas.

Wind erosion: This is the detachment of fine soil particles from dry soils by wind. It is most common in the flatter, more arid regions where strong winds can uplift large amounts of dust from exposed dry soil surfaces. This is not considered a major problem in the South African sugar industry, though can be observed at a minor scale on bare, fallow fields or during ploughing of dry soils on windy days.

Water erosion: This type of erosion is the effect that water drop (rain or irrigation) impact and water flow has on soil particles. It is the dominant form of erosion in the sugarcane growing areas, particularly the rainfed regions on hilly terrain. There are a few different types, though often one form may be a precursor to a more severe form.

- **Splash erosion:** The first stage of water erosion is when water drops hit a bare soil surface and detach soil particles. The impact is explosive, particularly with larger drop sizes, and cause fine particles to be dislodged and displaced. These fine particles can seal the soil surface thereby forming a crust which lowers water infiltration and promote run-off.
- **Sheet erosion:** This is the removal of the fine particles from splash erosion in thin layers due to shallow surface water flow (see Figure 1). Typically, the finest, most nutrient rich particles are removed by sheet erosion, though it can be difficult to detect and observe at a field scale (though muddy run-off water is a clear indicator of sediment wash). Over time and in larger areas, the impact can be quite large.

- **Rill erosion:** This is the next step after sheet erosion, where the amount of water run-off increases and begins to form small channels as the speed of water flow increases (see Figures 3 and 6). It is most common in bare exposed soils, especially if recently tilled or disturbed. The rills will often start where water flow is concentrated in shallow depression or channels, thus giving the water more energy to move soil particles. Rills are usually shallow and can be removed with farm equipment, though suitable strategies to prevent them reforming must be taken.



▲ Figure 6: Sheet erosion due to surface water flow.

- **Gully erosion:** This can be considered a more severe form of rill erosion, where water flows have concentrated to the extent that it can excavate deep channels into the soil (typically >30 cm depth) (see Figure 2). In the worst cases these may develop into channels that can be several meters deep and wide. They have the potential to alter the topography and can severely affect access to fields. The loss of productive land is high (and sometimes permanent), while remedial costs are high and can take many years to reverse. The sides or banks are often steep and near-vertical and can be dangerous areas for people and livestock. Control of surface water flow from roads and water control structures are critical to prevent concentrated water flows from causing gullies to form and grow.
- **Pipe or tunnel erosion:** This occurs where subsurface water flows (in cracks or animal burrows) can remove soil material from unstable, dispersive subsoils (often in duplex soils, particularly if affected by sodicity). Over time the tunnels can be enlarged allowing ever more water to flow through them (see tunnel towards the right in Figure 2). Eventually, the tunnel roof will collapse and lead to the formation of sinkholes and gullies. This form of erosion may initially be more difficult to observe, but signs include water seepage from the soil at downslope positions, often with fine clay fans appearing downslope of the seepage or drainage outlet.
- **Streambank erosion and collapse:** Streams and rivers can erode their streambanks where these are not adequately protected by vegetation and exposed to regular disturbances at the water edge (livestock trampling or watercarts). In high flow situations large amounts of sediment and soil can be scoured away, and over time banks may be undercut leading to collapse. The impact may not directly affect a sugarcane growing field, but it will lower water quality and cause sedimentation of dams and rivers.

Causes of erosion and soil loss

Erosive forces are a combination of several factors and conditions that, when they occur in the right combination and intensity, can lead to soil loss. These include natural factors related to the characteristics of the landscape, and soil and climatic conditions as well as the management factors that can affect the risk of erosion and rate of soil loss.

Natural factors

The dominant drivers include:

- **Steepness of slope:** Steeper slopes increase the rate of run-off and reduce time for infiltration, thus leading to greater energy in water flow to move soil particles downhill.
- **Length of slope:** The longer a slope, the more water can accumulate and the greater the energy it can have to dislodged and remove particles.
- **Soil texture:** Clay soils tend to have lower erodibility than sandier soils, this is due to the higher cohesiveness of higher clay soils. However, in clay soils that lack cohesion when wet (often dispersive and sodic soils), erodibility can be high. Freely draining sandy soils, while lacking cohesion between soil particles, tend not to erode easily due to high infiltration and drainage rates. However sandy soils associated with poor drainage are more susceptible to soil loss. Silty soils tend to be the most erodible due to low cohesion and small particles that can be easily moved by water.

- **Soil structure and aggregate stability:** The clay type and amount influence the soil structure. Soils with good structure and stability will resist erosive forces as the particles are held together more strongly. Some management practices can adversely affect soil structure.
- **Organic matter content:** High organic matter soils tend to be less erodible than low organic matter soils. Management can have a dramatic impact on organic matter levels.
- **Soil permeability and water content:** In soils that have poor ability to absorb and drain water, there is a greater risk of run-off leading to erosion.
- **Climatic variables:** In general, wetter regions are more likely to experience higher levels of erosion over time, where both the frequency and intensity of rainfall events are key factors. Frequent rainfall events can lead to soils becoming very wet thus reducing water infiltration and increasing the amount of run-off and thus the risk of erosion. High intensity rainfall events can increase the effect of raindrop splash and also overwhelm the ability of soil to absorb water leading to considerable soil dislodgement and run-off. If these events occur on sites that are more susceptible to erosion, the negative impacts can be greatly increased.

Management factors

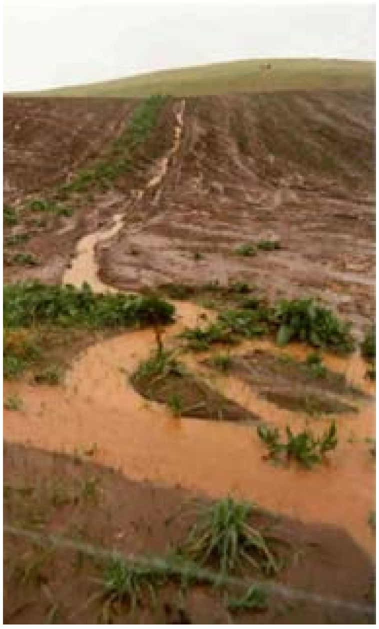
Any practice that adversely affects the stability of the soil or increases its direct exposure to erosive forces greatly increases the risk of erosion. When combined with the natural factors that increase erosion risk, the interaction effect can lead to large soil losses. Key management factors include:

- **Water flow control structures:** Poor planning, design and maintenance of roads, waterways, drains, culverts, contour berms and terraces all contribute to the concentration of water flows that increase the erosive power of the water.
- **Field layout:** Poor row alignment in fields can lead to the concentrating of water flows. Rows and terraces that do not follow contours and are inappropriately spaced for the steepness and shape of slope and erodibility class of the soil will increase erosion risk. Excess water flow should be directed toward suitably designed grassed waterways that can control the flow. Roads in fields must also follow contours and their design should not lead to excessive concentrating of water flow.
- **Poor drainage:** Compaction and the development of sodic conditions are leading management induced causes of poor drainage. Poor drainage increases the risk of excess water run-off and it may be necessary to install drainage or remedy the condition limiting drainage (e.g. rip compacted soils) to reduce erosion risk.
- **Soil preparation and disturbance:** While a necessity to prepare lands, ploughing, tilling, ripping and other forms of soil disturbance all increase the risk of erosion. This is due to the break-up of soil aggregates, increased exposure of bare soil surface to erosive forces, as well as promoting the breakdown and loss of organic matter. Where such disturbances coincide with other factors driving erosion, the risk increases substantially (e.g. ploughed fields on slopes have higher risk of erosion if they are present during high intensity rainfall events). Plan fields that will be left bare for the dry winter period to reduce the risk of soil loss through erosion.
- **Soil cover:** Bare soils are highly susceptible to erosive forces. Soil cover, in the form of live vegetation (green manures during fallows and sugarcane in the crop cycle), or biomass mulches (green cane harvesting with much retention or cool burns with retention of tops (see Figure 7)) are required to protect the soil surface from water drop impact, to slow water flow down, and to improve infiltration as well as soil structural stability. Long bare fallows and unnecessary delays in replanting a crop or green manure greatly increase erosion risk and should minimised as far as possible.
- **Loss of organic matter:** Practices that lower soil organic matter levels will increase the erodibility of soil. Excessive tillage, cane and mulch burning, bare fallows and lack of organic inputs are the main contributing factors to organic matter decline.
- **Poor root health:** Roots play a pivotal role in holding soil together, particularly in the upper soil layers. Poor soil health leads to poor root health, thus reducing the ability of roots to help protect against erosive forces.

▲ Figure 7: This field was burnt at harvest and the unburnt residue (mainly the green leaves) spread evenly.

Detecting and monitoring soil loss and erosion

While some forms of erosion are observable and unmistakable (e.g. gullies, muddy streams and drainage lines), there are many less obvious indicators that, if noticed and acted on, can prevent unnecessary soil loss and costly remediation to reverse the impacts. Key indicators to look for include:



▲ Figure 8: Early signs of rill erosion.

- Bare soil is a good indicator of erosion risk.
- Crust development.
- Formation of soil pillars (small columns of soil topped with a stone or rock).
- Thin, gravelly surface layers (fine material has been washed away) (see Figure 1).
- Signs of rills forming (small channels developing in fields) (see Figure 8). Rills appearing on the lower sections of slopes may indicate that the terrace spacing is inappropriate for that slope and soil type.
- Exposed roots and rocks.
- Cracked or scarred appearance on hillslopes caused by minor slumping and channels developing.
- Cloudy and muddy run-off water from fields and waterways (see Figure 8). The more erosion that has occurred, the more muddy the water will be.
- Sediment fans (thin layers of clay fanning outward from a water outlet) at foot-slopes seepage areas and from drainage channels indicate fine material is being eroded. This could signify tunnel development on soils with unstable subsoils.
- Sediment build-up behind obstructions such as berms, depressions, rocks, trees and fence-posts that slow water flow down. These indicate movement of material from further up the slope.
- Silting and sediment build-up in dams and ponds.

It is also worthwhile to monitor soil organic matter levels as decreasing amounts may indicate decline in soil structural stability. In some areas it is also necessary to monitor the development of sodic conditions as this adversely affects soil stability.

A simple soil loss monitoring device consists of a 30 to 50 cm steel peg hammered into the soil so that the top of the peg is level with the soil surface. Record the location of installed pegs and periodically check if the soil level is dropping relative to the top of the stake that represents the starting soil surface. This provides an indication of the rate of erosion and soil loss from that area.

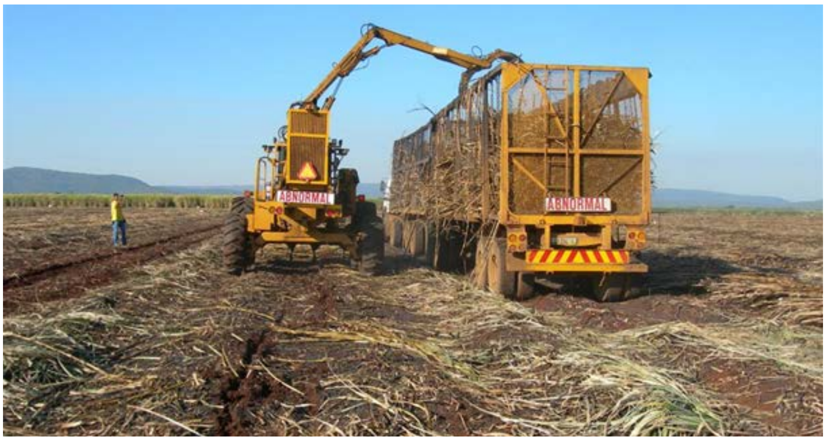
▲ Figure 9: A simple soil loss monitoring device.

Prevention and remediation

While it may not be possible to change natural factors affecting erosion, understanding how they contribute to erosion is the first key step in minimising risk, as it allows appropriate management decision to minimise the potential risk and impact. There are numerous best practices to consider which include:

- Do not plant areas unsuitable for cultivation (notably steep slopes, shallow soils and wetlands).
- Ensure proper design and maintenance of water control structures and roads (both off and in field) and row alignment to contours (see Figure 10) on slopes.
- Minimise in field traffic and soil disturbance – adopt controlled traffic (see Figure 11) and minimum tillage practices.
- Remediate conditions that promote run-off (compaction, sodicity, poor drainage).

▲ Figure 10: Contour structures designed to control surface water flow and to reduce the risk of soil erosion.



▲ Figure 11: Wheels of all vehicles kept off the crop row in a controlled traffic system.

- **<u>KEEP THE SOIL COVERED</u>**:
  - Adopt green manure fallows.
  - Reduce soil preparation time to lower time soil is bare and exposed.
  - Green cane harvest and mulch (or where burning, retain tops and scatter) (see Figure 7).
  - Use strip planting and harvesting, especially on slopes (see Figure 12).
  - Keep unplanted areas vegetated with suitable ground cover (see Figure 7).
  - Promote good soil health as this improves root health of any live cover (see Figure 7).
- Use weather forecasting tools to try and avoid major soil preparation operations coinciding with high rainfall events. In areas subject to unexpected storm events, it may be better to move soil preparation operations to parts of the season where these events occur less frequently.
- Repair eroded areas immediately and act on any indication of developing erosion to prevent it developing further.
- Apply organic amendments where possible to promote build-up of soil levels and improve soil stability and overall health.
- Do not over irrigate.
- Inspect and monitor continuously for signs of erosion and act immediately if detected (see Figure 8).

▲ Figure 12: Strip cropping on a steep slope to reduce the impact of soil erosion.

Numerous resources are available to guide the layout and design of fields, roads and other water flow structures, as well as guidance on practices that minimise risk and promote soil health. Consult your regional Extension Specialist or SASRI specialist for specific guidance or visit the eLibrary on the SASRI website for downloadable content. Useful guidance on implementing conservation practices is also available in the SUSFARMS guidance material
(visit https://sasri.org.za/susfarms/).

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