Information Sheet

6.1 Soil quality and degradation

Sugarcane monoculture has been practised for many decades in South Africa and recognised as a leading contributing factor to sugarcane yield decline. This is a serious threat to the long-term sustainability of sugarcane production. Sugarcane monoculture has been linked to soil health degradation, that contributes directly to declining production and lowered resilience of the soil system against unfavourable conditions. In sugarcane production systems, soil degradation is associated with:

- loss of soil organic matter
- soil loss (erosion)
- soil crusting and compaction
- degradation of soil structure
- soil acidification
- waterlogging
- saline and sodic conditions
- poor nutrient management

In this information sheet, key concepts of soil health are introduced, with brief overviews of the dominant types of soil degradation common to the sugar industry. More detail on specific issues are provided in separate information sheets.

What is soil potential and soil health?

There are many concepts used to describe how well a soil performs its desired function. In agriculture, we focus on aspects related to growing a crop sustainably and for the long-term.

Soil potential

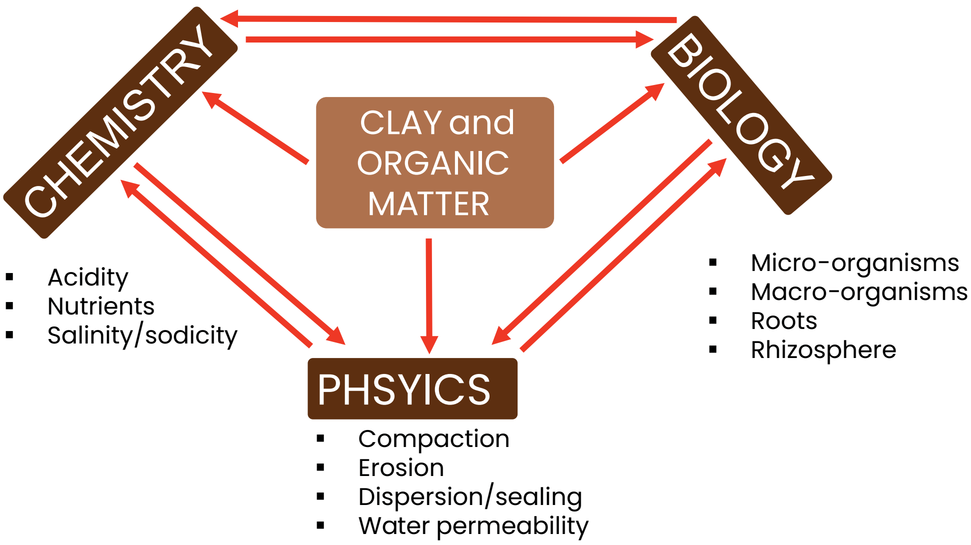
Soil potential describes the ability of the soil to support sustainable crop production. Key properties used to describe soil potential include texture, colour, effective rooting depth and structure, this usually within the context of a suitable agro-climatic zone for the chosen crop. Deep, well drained soils with no limitations are considered to have the highest potential, while shallow and poorly drained soils are considered lower potential. In some cases, soil potential can be increased through management practices, such as deep ripping or ridging to increase effective rooting depth or use of ameliorants and amendments to overcome inherent limitations (such as naturally occurring acidity).

Soil health

Soil health (sometimes also referred to as soil quality) relates to the condition of the soil at a point in time and in relation to its current use and management applied. In agriculture, soil health focuses on factors that are readily influenced by management, where poor or inappropriate management can lead to the lowering of the ability of a soil to function optimally and sustain production. These would include management considerations such as impact of mechanisation, residue management, harvest removal, fertilisation and irrigation.

Indicators and measures of soil health

Soil health indicators can be divided into the physical, chemical and biological properties of the soil (see Figure 2). These properties are strongly linked and a decline in one aspect will invariably result in decline in others. For optimal production, all these aspects must be managed together ("agro-ecosystem" management).



▲ Figure 2. Soil health indicators include chemical, physical, and biological properties, all interacting through complex feedback loops. For optimal and sustainable production all components must be cared for to prevent a decline in soil health.

Soil chemical properties are commonly used to gauge soil health for regular management. Most growers will be familiar with these as part of the routine soil fertility testing. They include soil pH, organic matter and nutrient availability, acidity and salt levels.

Soil physical properties are those that relate to soil structure and water relationships. These include texture, aggregate stability, structure, bulk density, penetration resistance, porosity, and water infiltration, retention and drainage. These properties are used to quantify conditions such as compaction, risk of soil loss, crusting and waterlogging. The methods to measure these properties are generally time-consuming and often must take place infield, so they are less commonly used when compared to the chemical properties. However, some of the conditions such as surface crusting, erosion, and evidence of ponding can readily be observed in the field, thus provide a good indication of possible physical problems.

Soil biological measures are the least commonly used, although they are considered by many as the most suitable. This is because soil organisms respond to the environment that they are in and represent the overall condition at a given time. Some are also sensitive to small changes, thus can quickly reflect management changes. Measures include direct measures of soil organisms (earthworms, fungi, bacteria, nematodes, plant roots) or their activity (respiration, enzymes, organic acids) or indirect measures associated with their occurrence (mostly measures of total and reactive organic carbon). However, they are also the most complex of the indicators to quantify, requiring specialised methods and interpretation. No definitive suite of biological indicators has been established yet.

Organic matter loss – a key driver in soil health decline

Soil organic matter is a key component of soil health. This serves as a primary source of food and energy for soil organisms and contributes to nutrient cycling and improved soil physical properties. Numerous studies have shown that mono-culture sugarcane, especially when managed with intensive practices that promote loss of organic matter, leads to sharp declines in the organic matter levels in the soil. More conservative practices, such as green cane harvesting, mulching, green manuring, cooler burns (where used) and reduced soil disturbance have been linked to increases in soil organic matter levels, especially biologically active components.

See Information Sheets 6.2 and 6.3 for more information on organic matter and soil biology.

Main types of soil degradation

Poor management of the soil resource can lead to soil degradation. The most common types of degradation are:

Soil loss (erosion)

Soil loss is arguably the worst form of soil degradation as it often means that productive soil has been permanently lost. Soil loss is a consequence of erosive forces (erosion) and is the process of soil particles being removed from one location by either water or wind and deposited elsewhere. While erosion is a natural process occurring over geological time scales to produce the landscapes we see today, poor agricultural management has greatly increased the rate of erosion. The impact is the permanent loss of valuable topsoil and nutrients from fields, exposing subsoils that are less suitable for crop production (and that require great expense and effort to remediate). In addition, erosion leads to sedimentation and nutrient enrichment of waterbodies and rivers, affecting downstream users and the ecology of those water systems. The risk of erosion and soil loss increases sharply when:

- The steepness and length of slopes increase.
- The frequency and intensity of rainfall increases.
- The lack of surface cover or vegetation that protects against raindrop impact and slows water flow down.
- Poor surface permeability of the soil (due to crusts and seals) and compacted layers that limit drainage.
- Breakdown and loss of soil structure due to loss of organic matter and excessive tillage.
- Soils are susceptible to erosion, particularly low clay and organic matter soils with low natural cohesiveness between particles.

A clear tell-tale sign of erosion taking place is muddy water flowing from fields and waterways.

See Information Sheet 6.10 for more information on soil loss and erosion.

Crusting

The breakdown of soil aggregates into constituent soil particles occurs during raindrop impact. This leads to the development of a dense, low permeability layer that can be a few millimetres thick. This layer inhibits infiltration and air permeability, increases run-off and may retard sprouting of sugarcane. It is often associated with uncovered and bare soils, and is made worse with excessive tillage and sodic conditions. This type of soil crusting is frequently a precursor to soil erosion. Biological crusts are another type of crust, though these are linked to soils that remain very wet near the soil surface allowing algae to grow and form water repellent mats on the soil surface as they dry out.

See Information sheets 6.9 and 6.10 for more information on crusting.

Compaction

Compaction is simply an increase in the density of the soil due to compression by wheels of infield equipment, typically up to a depth of 30 cm. This leads to dense, low permeability layers that reduce water and air movement and impede root growth. While harvesting and crop extraction are a necessity of sugarcane production and can cause compaction, adopting practices that limit the extent of the impact and using practices that aim to remediate compacted soils will minimise negative consequences.

These include:

- Reducing infield traffic (especially on wet soils).
- Adopting controlled traffic systems.
- Avoid working on wet soils (particularly near field capacity moisture content).
- Traffic over the cane row has a more severe effect on yield than traffic in the interrow due to stool damage.

Amelioration is expensive and may have limited success where it is not undertaken properly.

See Information Sheets 6.9 and 6.11 for more information on compaction and infield traffic management.

Waterlogging
Waterlogging occurs when water cannot drain from field leading to a saturated soil and puddling on the soil surface. It is often associated with over irrigation of poorly drained soils but can also be caused by poor surface water management of the surrounding fields. The main consequence is that it creates anoxic or anaerobic (i.e. low air, stagnant) soil conditions. This promotes loss of nitrogen as gas (volatilisation of nitrous gases) and stunts root growth. Waterlogged soils are also very susceptible to compaction.

Acidification
Soil acidity refers to excessive lowering of soil pH (typically below 4.5 in a dilute salt extraction) and the associated increase in the levels of toxic aluminium. It is also linked to the loss of calcium and magnesium and reduced microbial activity. When acidity levels are high, stunting of root growth occurs which further limits water and nutrient uptake. It is most pronounced in the rainfed regions and tends to be accelerated where excessive amounts of ammonium-based fertilisers are used and poor liming practices implemented. Leaching of base cations and decomposition of organic material can also contribute to increasing acidification. Acidity can be a problem in both top and subsoils, thus regular monitoring is advised to detect developing problems. Remediation using liming and gypsum materials remains one of the most effective methods to lower and maintain optimal soil acidity levels. Adopting practices that reduce the rate of acidification are advised for longer term sustainability.

See Information Sheets 6.4, 6.5 and 6.6 for more information on acidity management and use of liming and gypsum materials.

Salinity and sodicity
A primary cause of soil salinity (build-up of excess salt) is the development of high water tables, which allow capillary rise of saline ground water into the rooting zone of the crop. This is caused by excessive irrigation and lack of drainage. The problem is made worse by using poor quality irrigation water with high salt loads. The main consequence is to induce water stress in the crop (osmotic stress), while excess salts can negatively impact the uptake of nutrients by the crop.

Sodicity is when there is excess sodium relative to calcium and magnesium. This can lead to soil structural collapse leading to low infiltration and drainage, waterlogging and poor plant growth. Excess sodium may also negatively affect uptake of plant essential nutrients, or become toxic at high levels leading to crop failure.

Installation of drainage is key for long-term remediation of excess salts, while incorporation of organic materials will improve permeability. In sodic soils, gypsum is required to displace excess sodium. Flushing with good quality water is a key requirement to leach excess salts out of the rooting zone.

See Information Sheets 5.11 and 5.12 for more information on management of salinity and sodicity and water quality for soil health.

Nutrient supply imbalances
Sugarcane is a high nutrient demand crop, and regular application and management of nutrient supplies is key for optimal production. However, over or under supply of nutrients can lead to direct yield losses and wasted expenditure, and can also contribute to soil health decline. Nutrient mining is when insufficient nutrients are supplied through amendments and fertilisers to replace those removed from harvesting and removal of the crop. This impairs the growth of the crop, often leading to an increase in pathogens as the crop becomes stressed. On the other hand, over supply of nutrients can lead to nutrient imbalances that can become toxic or reduce uptake of other nutrients. Inappropriate use of nitrogenous fertilisers is also a leading cause of acidification in agricultural soils. Ensuring a balanced nutrition plan is key to the optimal use of your nutrient investment and to minimise negative impacts.

See Information Sheets in Series 7 for more information on nutrient and fertiliser management in sugarcane.

General practices that promote optimal soil health include:

- Regularly assess and inspect fields and soil for signs of degradation: occurrence of crusts, erosion, exposed subsoils or rock layers, ponding and waterlogging, hard-setting on drying, discolouration of plants despite receiving adequate nutrients (e.g. chlorosis) or other signs of crop stress.
- Ensure field layouts and planning are designed to minimise soil loss and soil degradation (land use planning).
- Minimise soil disturbance as far as possible (e.g. adopt minimum or conservation tillage).
- Develop and manage a balanced crop nutrition plan.
- Use green manures during fallows.
- Adopt green cane harvesting where possible to create a mulch on the soil surface (or use cool burns and retain the tops). Avoid trash/mulch burning.
- Apply organic amendments where available.
- Keep soils vegetated or covered as far as possible.
- Adopt strip harvesting, particularly on hill sides.
- Manage infield traffic and adopt controlled traffic systems.
- Ensure adequate drainage and proper irrigation scheduling.
- Manage soil acidity and build-up of salts.
- **DO NOT** rely on quick fixes and wonder products that claim to restore soil health.

Louis Titshall (Senior Soil Scientist)

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