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SASRI
SOUTH AFRICAN SUGARCANE RESEARCH INSTITUTE
Unlocking the potential of sugarcane

SOIL ORGANIC MATTER

The key to the success of any crop is a soil rich in organic matter and nutrients. Organic matter improves soil health, water infiltration and water holding capacity and reduces erosion. In addition, improving soil health is imperative as soils are the foundation of our food chain, contributing to more than 90% of our food production. Soils also play a key role in the ecosystem, filtering our water, regulating temperature, absorbing carbon from the atmosphere and mitigating the impacts of extreme weather.

WANTED DEAD OR ALIVE: organic matter

Louis Titshall *(Senior Soil Scientist)*

As a farmer, you have probably heard about how important organic matter is for the health of your soil and that every effort to protect, conserve and increase it should be made. You've been told organic matter is the "oil of the engine" ensuring that chemical, biological and physical processes all work together and keep the soil functioning in a balanced manner. Soil Scientists will tell you that clay is the "King of the Soil", but organic matter is the "Queen" (and we all know who is really in charge...). It is said that, without organic matter, you'll lose crop productivity and even worse, the soil itself. Everyone seems obsessed by this seemingly insignificant part of the soil, with many telling you how to make it better and sometimes even selling products that claim to do just this.

You have no-doubt also heard that organic matter improves soil nutrition, water infiltration and holding capacity and reduces erosion. It has the ability to make heavy clay soils more workable while helping sandy soils become nutrient rich. Research shows that organic material is the food for soil organisms, which themselves add organic matter to the soil. They are also critical to help keep the soil functioning in a productive manner.

Everyone goes on about climate change, carbon emissions and that we need to capture more carbon in plants and soil if we have any hope of reducing the impact of burning fossil fuels (which itself is ancient organic matter from plants that lived many thousands of years ago). Recent estimates show that if all crop-producing soil could capture (or sequester) 0.4% more carbon every year, we could dramatically offset our carbon emissions. While not everyone is in full agreement with such an ambitious target, the benefits of improving soil organic matter and carbon stocks on your farm will reflect in benefits to your crop and you as a farmer, as well as the environment as a whole.

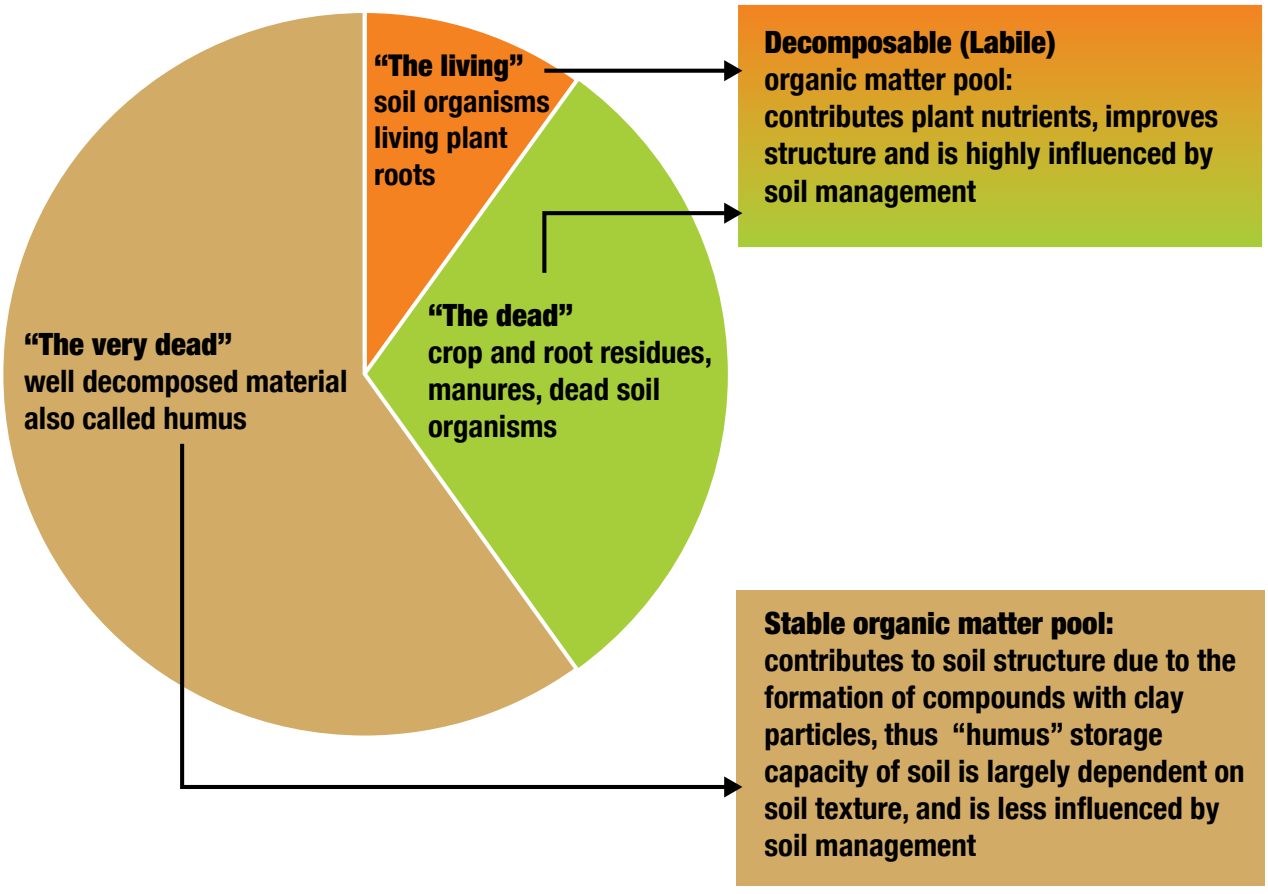
In this special edition of The Link we provide insight into the key aspects of soil organic matter (and its closely associated friend, soil organic carbon), how valuable it is to the functioning of your soil and how you can manage your soils and practices to get the best from this seemingly small contributor to your growing medium. Let us take you on a journey...

What is soil organic matter

and what does it do?

Louis Titshall *(Senior Soil Scientist)*

SOM comprises about 50 to 60% carbon (C), while the rest comprises oxygen (30 to 40%), nitrogen (2 to 4%), sulphur (1%) and minor amounts of phosphorus (P) and microelements. SOM typically constitutes between 1 to 5% of the soil on a volume basis, though it can comprise over 20%. Organic matter is broadly divided into three main fractions (closely linked with one another) that contribute in different ways to soil function and health – "living", recently dead" and "very dead".



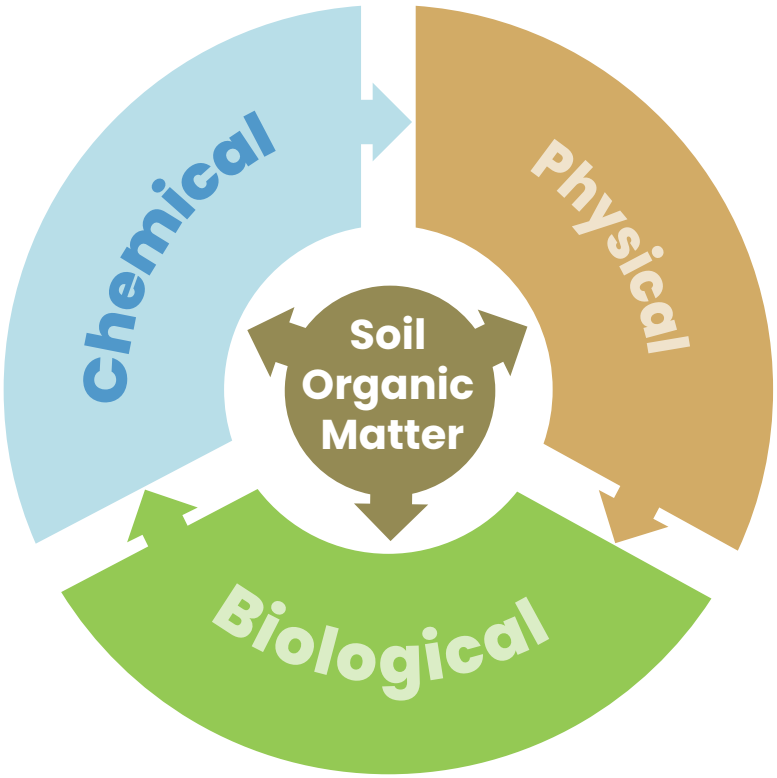
Critical functions of soil organic matter

SOM is involved in a vast number of chemical, physical and biological functions of the soil, where impacts in one area have effects in other areas.

Physical:
- Binds soil particles into stable aggregates.
- Reduces erosive impacts of water and wind thus reducing soil loss.
- Improve water infiltration and holding properties of soils.
- Buffers against extreme temperature fluctuations.

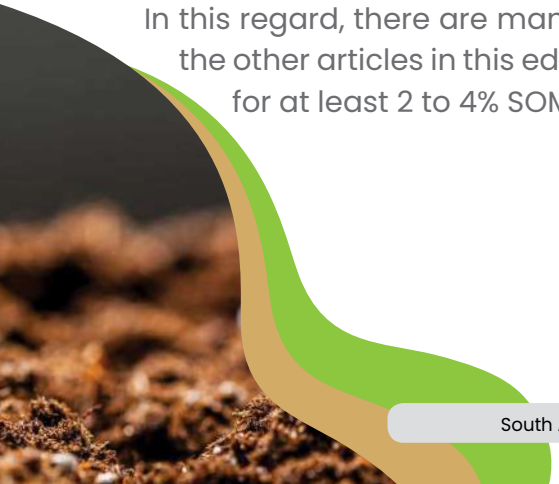
Chemical:
- Adds nutrients and helps nutrient cycling.
- Increases cation exchange capacity of soils thus improves nutrient holding ability.
- Buffers the soil pH and prevents rapid acidification or alkalisation.
- Can bind toxic elements and compounds.

Biological:
- The main food source of soil organisms.
- Encourages soil biological diversity and increases population sizes.
- Encourages nutrient cycling.



So how much organic matter is enough?

The easy answer is that "more is better". However, our ability to add organic matter and the capacity of the soil to store this is limited. Sandy soils, particularly in warmer, wetter regions tend to have much lower SOM levels than clay soils and in cooler regions. Many studies have attempted to define the optimal amount to have, but due to differences in site-specific conditions, no single ideal value exists. Generally, it takes many years to substantially change the total organic matter content of soils (anywhere from 5 to 10 years to notice a substantial content change), even with high organic matter inputs. One may then then ask, "Why bother?". Research has clearly shown that the most important fractions of organic matter for soil function are the 'recently dead' and 'living' components. In this regard, there are many ways to add and conserve these fractions, as described in the other articles in this edition of The Link. Nonetheless, a general rule of thumb is to aim for at least 2 to 4% SOM, as this range is often observed in healthy ecosystems.



And what about the bugs?

There is an ever-growing body of evidence to show that soil organisms are a critical component of soil organic matter that have profound benefits for plant growth and soil sustainability. These organisms range from the near invisible bacteria to large creatures such as earthworms and moles. They all contribute to organic matter turnover, ensuring we get the chemical, physical and biological benefit. Soil organisms are the main driver of organic matter breakdown, releasing nutrients into the soil. We see this commonly in sugarcane agriculture, where we know that high organic matter soil require considerably less N fertiliser than low organic matter soils. This is due to microbial decomposition of organic matter releasing the N. This also applies to other nutrients.

Organisms also form associations with roots and help mobilise and release nutrients from soil minerals. Perhaps one of the most beneficial associations is between roots and mycorrhizal fungi. These beneficial associations effectively increase the surface area of the root system and allow the plant to access both water and nutrients in a much greater volume of soil and even improve uptake of low availability elements such a phosphorus and silicon.

> *Soils without organisms are not sustainable.*

How big is your bucket? –The soil's capacity to store carbon

While we can increase and improve soil carbon through better management practices, the ability of a soil to store carbon is limited. Depending on the soil type, environmental conditions (mostly temperature and moisture) and organic matter input type and amounts; a specific soil will only be able to store a certain amount of carbon in a stable form. This explains why we do not see SOM levels increasing continuously even where we add vast amounts of organic material. Some soils have a high capacity to store organic carbon (clays and cooler drier climates), while others are much lower (sandy soils and warmer, wetter environments). Regardless of the carbon threshold of a soil, always remember that continuous organic matter inputs are critical to maintain the benefits associated with SOM in the soil. When this stops, you start losing those benefits. This will be particularly noticeable on naturally low organic matter soils such as many of the sugar industry's grey and sandy soils.

Some say organic matter, others say organic carbon – *so which is it?*

The terms soil organic matter (SOM) and soil organic carbon (SOC) are often used interchangeably, but they refer to different aspects of the organic material in a soil. SOM encompasses both living and dead organic material and includes other elements such as N, P and S, so SOM values are typically higher than SOC values. SOC refers to just the carbon component of organic matter. To convert SOC to SOM:

SOM = SOC x 1.72 (which assumes that 58% of SOM is the carbon fraction, a relatively consistent value).

Keep it covered:

MANAGING RESIDUES IN SUGARCANE

Rian van Antwerpen (Senior Soil Scientist)

Keeping soil covered is one of the key pillars of a sustainable soil management programme. Whether you use cover material that is 'dead' or 'alive', it is imperative to make sure that soil surfaces are always covered.

Soils with a bare surface often show signs of:

- a surface crust,
- reduced water infiltration rates,
- runoff following light rain or irrigation, and
- erosion.

Therefore, efficient use of water on soils with a bare surface is very low. In addition, the top 2 cm of the soil surface (which is the most fertile portion of the profile) is often subject to harsh heat and drying out resulting in no root growth near the surface. No roots in this layer means that the crop will not access these valuable nutrients. This is particularly important for top dressed nutrients that have low mobility in the soil like phosphorus and potassium, which means the roots have to grow towards it. Under these conditions, this thin topsoil layer becomes a barrier between these immobile nutrients and the roots.

In sugarcane, residue from the previous sugarcane crop (left behind after harvesting) and a cover crop can be used to create a mulch blanket for the surface. If a cover crop is used as mulch, then one must ensure that the crop:

- produces a high biomass,
- is an annual crop, and
- does not share the same diseases as sugarcane (e.g. Mosaic common to maize).

To qualify as a conservation agriculture practice, residue should cover at least 30% of the surface.

> *There are several advantages to retaining residue after harvest and using it as a mulch blanket*

To reduce the risk for erosion it should be seriously considered not to incorporate the cover crop but to flatten it, and to ridge and plant sugarcane without ploughing. Unfortunately, many cover crops will host pests that are also detrimental to sugarcane (i.e. YSA). Crops that are advised in sugarcane agriculture include oats (all types), sunn hemp and several beans (i.e. velvet beans, cowbeans and dolichos beans). The benefit of using a legume cover crop is that nitrogen (N) fertiliser application can be reduced for the plant crop (seek advice from your Extension Specialist about this).

One of the best characteristics of sugarcane is the volume of biomass produced by the plant – a feature not shared by many of the other annual food crops grown in South Africa. This biomass can be beneficially used to greatly reduce wind and water erosion of the soil. This plant residue left behind after harvesting sugarcane is a major source of material to create a mulch blanket to protect the soil. First prize is not to burn sugarcane fields at harvest and to use all the residue as a mulch. However, not all is lost to those burning at harvest, as long as a cool burn is practised and the remaining residue is retained for spreading - much of the benefit can be received. A rule of thumb is that this residue is still enough to cover approximately 70% of the soil surface if stalk yield was 70 t/ha.

Advantages of a mulch blanket

There are several advantages to retaining residue after harvest and using it as a mulch blanket:

- **Water availability:** Under rainfed conditions, the crop has additional water of 90 mm/year due to reduced evaporation losses. During the recent drought, a mulched farm in a rainfed area reported a yield loss of about 10% while neighbouring farms that regularly burnt at harvest reported yields that declined by almost 60% from the normal. This benefit is immediately available to fields where applied.

  Under irrigation, savings of 15% on water and electricity costs can be expected although savings of up to 25% have been recorded!

- **Yield benefit:** The average yield benefit due to mulching (with no burning) under rainfed conditions is 9 t/ha. With burning at harvest and the unburnt residues (tops) spread, the yield benefit relative to fields with a bare surface is approximately 7 t/ha under normal weather conditions. During the recent drought, yield benefits of mulched fields were up to double that of fields with bare surfaces.

- **Soil temperature:** Soil temperature at the surface under the mulch blanket is approximately 3 to 7 °C

cooler in summer and warmer in winter. Together with more water in the soil, this creates favourable conditions for roots to explore the contact zone between the top layer of the soil and the residue – thus exploring the most nutritious part of the profile.

- **Soil structure:** In the absence of a mulch blanket, the destructive forces of water droplets (especially heavy rain) will cause dispersion and the creation of a surface crust leading to runoff and erosion. The mulch blanket protects the soil surface leading to sustained higher infiltration rates, and reduced runoff and erosion leading to clean (not muddy) dams.

- **Biological effects:** The mulch is a source of food for the army of micro-organisms in the soil working for you to maintain soil quality and productional potential.

Cautionary notes

If not managed correctly, mulches can also lead to problems:

- When mulching is practised, for the first time, N lock-up by microorganisms might occur leading to deficient N uptake by the crop. To overcome this problem, 20 to 30% additional N (as LAN) should be applied. The soil will require about 3 – 5 years to equilibrate to the new practice after which additional N will no longer be required. To avoid large N losses, take note not to use urea on a mulch blanket unless 5-10 mm irrigation will be applied immediately.

- Mulch blankets from high yielding crops (i.e. more than 100 t/ha) could be detrimental to ratoon regrowth due to the volume and thickness of the mulch layer. In these cases, the crop might take too long to grow through the residue leading to a shortage of sunlight required for normal growth. However, for most fields in the sugarcane industry, the latter should not be a problem. Areas where growers should take note of this potential problem is where the crop is often harvested at ages older than 18 months (i.e. the Midlands) and irrigated regions. Where possible, consider raking the residue off the crop row to increased its exposure to sunlight during germination.

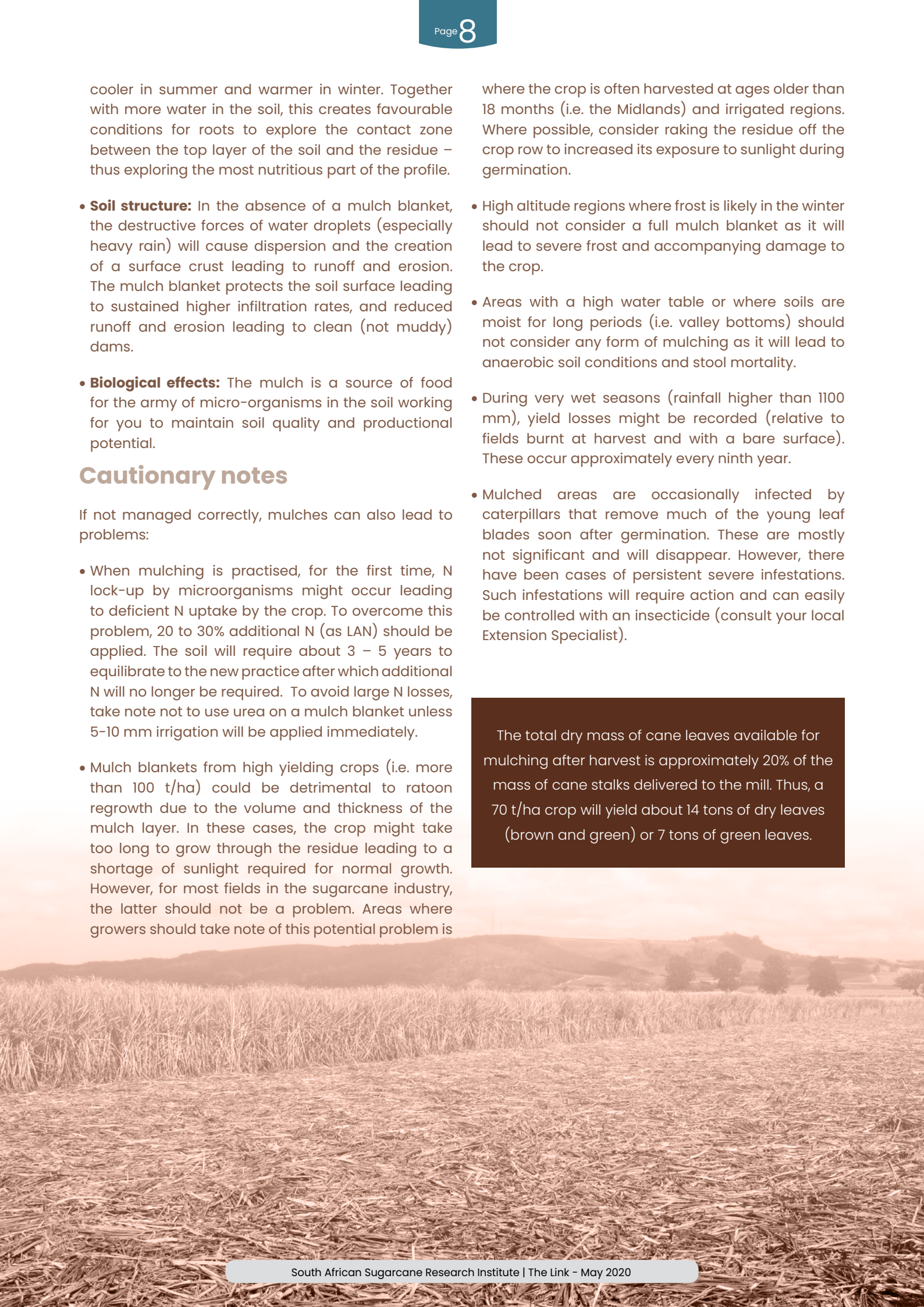
- High altitude regions where frost is likely in the winter should not consider a full mulch blanket as it will lead to severe frost and accompanying damage to the crop.

- Areas with a high water table or where soils are moist for long periods (i.e. valley bottoms) should not consider any form of mulching as it will lead to anaerobic soil conditions and stool mortality.

- During very wet seasons (rainfall higher than 1100 mm), yield losses might be recorded (relative to fields burnt at harvest and with a bare surface). These occur approximately every ninth year.

- Mulched areas are occasionally infected by caterpillars that remove much of the young leaf blades soon after germination. These are mostly not significant and will disappear. However, there have been cases of persistent severe infestations. Such infestations will require action and can easily be controlled with an insecticide (consult your local Extension Specialist).

The total dry mass of cane leaves available for mulching after harvest is approximately 20% of the mass of cane stalks delivered to the mill. Thus, a 70 t/ha crop will yield about 14 tons of dry leaves (brown and green) or 7 tons of green leaves.



ORGANIC WASTES AS ALTERNATIVE SOURCES OF NUTRIENTS

Rian van Antwerpen (Senior Soil Scientist)

We all know that it is essential to add organic matter to soils to maintain its function and sustainability. There are numerous organic products available to growers that can be used to add organic matter and nutrients to the soil, each with its specific characteristics. The table summarises typical nutrient contents (N, P, K, C:N, etc.) of several organic products available in the sugar industry. However, these products can vary greatly in quality so before application, always obtain an analysis of any organic products or other nutrient sources to determine the economic viability and to ensure that the correct amounts will be applied. This can be done through the FAS Agricultural Laboratory.

Considerations for Nitrogen

Nitrogen (N) release from organic sources ranges between 30 and 60 % depending on the C:N ratio, which means that, in the first year after application, only 30 to 60 % of the total N content will gradually become available for uptake by the plant. This is generally not a problem for crops fertilised with organics in winter because N demand by the crop is initially low. The initial N demand of crops in a summer cycle however, is high and the slow and partial release of N from these products may result in an N deficiency (November to February). This will lead to reduced cane growth as well as RV% cane. A small amount of inorganic N fertiliser (i.e. 30 – 50 kg/ha) should be applied at plant to reduce the C:N ratio to below 20:1 to overcome this problem.

A negative N period (no N available for cane growth for a month or two) will result if any organic material with a high C:N ratio (>30:1) is applied. The microbes required to break down the organic matter and release the nutrients need a fair amount of N in their diet. If there is insufficient N, they will simply bind all the N they need leading to a short-term shortage of N in the crop. This immobilisation (lock-up) of N normally happens when the applied organic matter is in a fresh state, with a high C:N ratio. The C:N ratio of the material is an important factor that will determine how quickly the organic N is converted to mineral N for the plant to take up. The release of N will progressively slow down with an increase of the C:N ratio, especially where this ratio is above 20. C:N ratios should thus ideally be kept as low as possible (at least below 20) with the addition of inorganic N or through composting.

In areas prone to eldana infestation, special care should be taken with the type and amount of organic material that may be applied. N release from organics increase only about three months after application and the rate of N release may be maintained for the rest of the season. It will also interfere with natural ripening leading to reduced RV. The rate of N release is also temperature and therefore seasonally related, with larger amounts released per day in summer compared to the cooler winter months.

Liquid organic fertilisers

A potential disadvantage of non-liquid organics is the bulkiness or light weight of these products, which will impact on transport costs and add to the nutrient costs per ton of product. It is thus advisable to find a source of organics as close as possible to where it will be applied.

Several organic liquid sources are available to sugarcane growers, however their potential value as a fertiliser depends on how diluted the product is. The solution is thus to concentrate the product (at a cost) either through evaporation or enrichment with soluble inorganic nutrient sources. However, viscosity (thickness of the liquid) increases with a decrease in water content resulting in some application challenges. Due to the high biological oxygen demand (BOD) of the liquid organics listed in the table, care should be taken to avoid spillage into water sources as it might cause the death of fish and other forms of aquatic life. Note should be taken of the water content in liquid fertilisers as it can costly to cart a lot of water over long distances.

A list such as this one can never be complete and we are aware of several other potential organic fertiliser sources that might be available in certain regions. Examples are pig slurry (vile material but a valuable source of nutrients), effluent from the beer brewery, wattle wood ash from charcoal furnaces and waste products from the abattoir such as blood (rich in N) and bone meal.

Organic material	Typical Composition				Notes
	N %	P %	K %	Other	
Cane residue	0.54	0.08	1.33	Ca 0.16% Mg 0.18% S 0.13% C:N 60-120	A major advantage is that there is no transport cost associated with this product. Where residue is baled and sold to augment income, it is important that at least a third is retained in the field to utilise the considerable agronomic benefits of mulching.
Filtercake	1-2	0.5-2.5	0.2-0.3	Si 1-4% Ca 1-5% Mois 50% C:N 20-30	Filtercake is an organic source of P and an excellent product for use in sugarcane production but currently mostly unavailable. Approximately 50% of the N in filtercake is immediately available for plant uptake – therefore care needs to be exercised in terms of potential eldana damage due to excessive N supply. Typical C:N ratio ranges between 20 and 30.
Flyash	0.11	0.7	0.7	Si 14% Ca 2.6% Mg 0.61% pH 8.2 Mois 40% C:N 30-150	High C:N ratio, but no decomposition is required as the carbon is present as charcoal and is of little value as a source of food to microbial life in soils. It is, however, a valuable source of Si and micronutrients. The relatively high Ca content and high pH reflects the value of this product as an amendment for soil acidity. Where flyash is derived from coal-fired boilers, there is a danger of boron contamination of soils (analyses should be carried out to monitor metal contents).
Bagasse	0.34	0.27	0.21	Ca 3.6% Mg 0.11% C:N 60-120	Its high C:N ratio of greater than 60 means that decomposition and therefore nutrient release will be much slower relative to filtercake and extra N needs to be applied where this material is used. An excellent product for improving soil physical properties (lowering of bulk density, improved water infiltration rates and gas exchange rates).
Chicken manure / Chicken litter	2.0-4.0	1.0-1.8	1.1-1.6	Ca 2-6% Mg 0.7% C:N 10-15	This product is rich in available N, and applications range between 8 and 12 ton/ha. The high pH and large amounts of Ca render these products useful in the amelioration of both top and sub-soil acidity. Moisture content is generally highly variable.
Farmyard or kraal manure	2.4	0.86	1.5	Ca 1.2% Mg 0.8% Mois 14% C:N 15-20	This product is highly dependent on the type of animals kept in the kraal, what they eat and the age of the manure (or compost). Use these values only as a rough indicator. It is highly recommended that these samples are analysed. Application ranges between 8 and 12 ton/ha.
Compost	0.66	0.09	0.55	Ca 0.6% Mg 0.2% Mois 55% C:N <20	Composts are highly dependent on the type and combination of organic materials used. Use the value given here only as a rough indicator but analyse your source for correct values. Application is limited to about 12 ton/ha due to cost.

Green manure	1.6-2.9	0.25	1-3	Depends on plants used. C:N 10-30	Legumes should be used if N is required. Nutrient supply lasts normally for only one crop. The amounts of nutrients contained in the green manure are highly dependent on the amount of biomass produced (See SASRI manual on Green Manuring).
Pine bark chips	0.32	0.11	0.14	C:N >200	Very high C:N ratio, which means that decomposition will be slow. These products will result in a lock-up of a significant portion of the applied inorganic N, which means that the crop will suffer from N deficiency. An application of 30 t/ha moist material will require 300 kg N/ha to reduce the C:N ratio to 30. It is best to apply this product 3 to 6 months before plant with 10 kg N/ha for every ton material applied to ensure some degree of decomposition before the crop is planted. The main use of this product is as a conditioner for soil physical properties (i.e. structure, bulk density).
Pith (Tune)	0.35	0	0.07	C:N >130	This product contains about 45% carbon but has a very high C:N ratio. This means that decomposition of pith will be slow and a significant portion of the applied inorganic N could be locked-up leading to the crop suffering from N deficiency. An application of 30 t/ha moist pith will require 210 kg N/ha to reduce the C:N ratio to 30. It is best to apply this product 3 to 6 months before planting with 7 kg N/ha for every ton material applied to ensure some degree of decomposition before the crop is planted. The main use of this product is as a conditioner for soil physical properties.
Molasses	0.65	0.12	2.77	Ca 0.21% Mg 0.13% S 0.28% C:N 30-60	The viscosity of this product is high which means that it does not flow easily and application could thus be a problem. The density of molasses ranged between 1300 to 1400 kg/m^3. It is corrosive and care should be taken to use application equipment.
Vinasse	0.2	0.09	1.15	Ca 0.17% Mg 0.13% S 0.2% Cl 0.9% Mois 95% C:N 15-30	Transport of this product is expensive considering the amount of water in transport. Use of this product is not supported unless the transport cost could be substantially reduced. An application of 10 tons/ha (or 10 000 L/ha) vinasse will on average supply about 115 kg K/ha. Vinasse has a typical brix value of between 10 to 13%.
CMS	1.0	0.16	5.5	Ca 1% Mg 0.8% S 1.1% Cl 3.8% pH 5.0 Mois 45% C:N 20-50	Best results are obtained where CMS is applied 'as is' directly over the cane row using a wide fan nozzle. In early season, a quarter of the N could be mixed into the CMS and the remainder top-dressed in spring. For best results, the product should be agitated during transport and applied immediately. On very sandy soils (<10% clay), CMS applications containing N and K should be split to minimise nutrient loss through leaching. Care should be taken not to over-apply CMS to poorly drained soils as saline conditions might develop. CMS has a typical brix value of 60% and is a cost-effective source of K. It is corrosive and care should be taken to use quality equipment. Bulk density is about 1200 kg/m^3.

Grow your own organic matter: Green Manuring for healthier soils

Louis Titshall *(Senior Soil Scientist)*

At a glance...

- Adequate amounts of soil organic matter (SOM) and the associated carbon and nutrient flows are key to healthy, sustainable, and resilient agricultural systems.
- Loss of SOM negatively impacts the soil's ability to support key soil functions, including the capacity to deliver N.
- Managing carbon requires a long-term view, benefits will only become apparent after several years of adopting practices that promote soil organic matter conservation.
- Building SOM stocks at higher rates is possible through adopting management practices that maximise carbon inputs and minimise loss pathways.
- Adopting several practices together will speed up the process of improving soil health and provide for longer term benefits than any single practice used on its own.

Green manuring is an ancient practice dating back to over 2000 years. During the 1920s, it was actively promoted in sugarcane agriculture in South Africa. Unfortunately, this drive was lost in our push for ever-higher yields, which coincided with the large-scale commercial production of fertilisers in the early 1930s. However, a key driver for the practice regaining popularity is the ongoing decline in global soil health. Poor soil health has been shown to be a major cause of "yield decline" in sugarcane and other monoculture crops. Green manures are considered a key step to reverse this trend. As it turns out, they provide us with many on-farm benefits that can help keep our soils productive, crops healthy and farms sustainable.

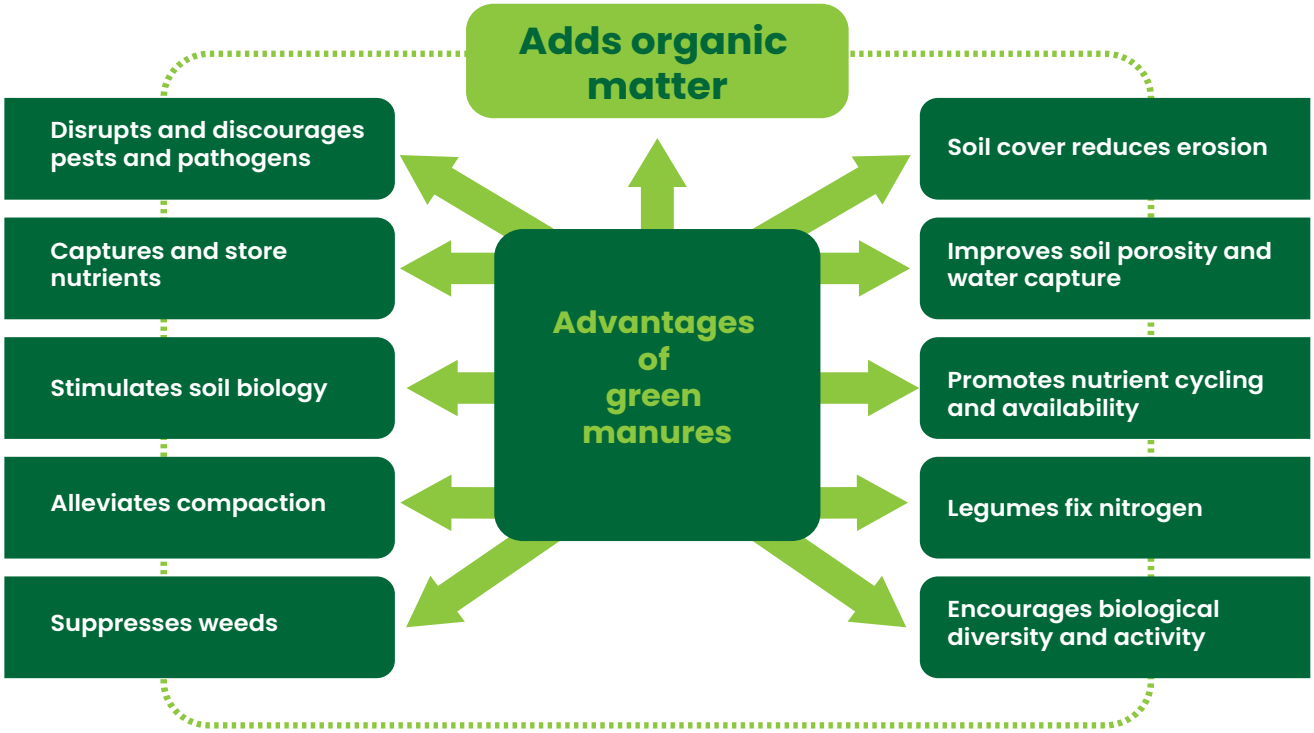
What is green manuring?

Green manuring is the practice of growing a sacrificial forage or legume cover crop in the fallow period during a replant cycle that is returned to the soil before the main crop is replanted. The key principle is that, by breaking the cycles of monoculture, one is able to disrupt pest and disease cycles, while the green manure itself acts as a source of organic matter and nutrients encouraging a more diverse soil biological population. This has benefits for subsequent crop growth.

What do green manures do?

The benefits of green manures are extensive (see diagram below). High biomass green manures contribute large amounts of organic matter while legume green manures help fix atmospheric nitrogen. Some have deep, fibrous root systems that encourage soil aeration; and there are those that can mobilise nutrients and capture them to prevent losses. A few species release chemicals into the soil that discourage pests, disease and weeds. A common feature is that they provide a living soil cover, while contributing to organic matter both when alive and when they die. From a soil health perspective, these two key features make them so valuable.

The collective benefits of using a combination or mix of green manure species must also not be overlooked. Each plant species has its own special characteristics that provide unique benefits to the soil. By selecting a combination of species that provide a range of benefits, you can more holistically improve soil health. So-called "meadow mixes" are gaining popularity, with up to seven species being used in some parts of the world (e.g. Brazil). It may not be necessary to use this many species at one time, but three to four could provide the range of benefits required.



When the green manure is killed off prior to sugarcane replanting, most of the stem, leaf and root biomass is returned to the soil as organic matter. This fresh plant material is easily decomposed and provides food for the soil organisms that remain. Much of the benefit comes from the favourable carbon to nitrogen (C:N) ratios of green manures (particularly legume species). Absolute increases in total organic matter in the soil tend to last for short periods, but the reactive fractions of organic matter that improve soil health increase as the material decomposes.

How does the sugarcane crop benefit?

Several studies have demonstrated between 40 to 50% better yield after a green manure crop with 20 to 25% benefit in the following two ratoons. If a legume was grown, N fertiliser is typically not required (and sometimes P and K too), while pest loads in the soil are also diminished.

> *"Several studies have demonstrated between 40 to 50% better yield after a green manure crop"*

How do I start?

To get the best from your green manure it is important that you consider what your key goals are. For instance, if you want to build organic matter then high biomass species may be better, whereas legumes are a good option for increasing soil nitrogen content.

It is also worth keeping in mind that by adopting green manuring practices you are taking steps toward improving the overall health of your soil. Thus, it is important that you plan properly. You must be sure you are willing to commit to the effort of green manuring and ensure you select the right species for your region and purpose. The following are key questions to ask before you start:

- Which soil health and management objectives are my priority (e.g. soil erosion, organic matter, compaction, nitrogen supply, pest control)?
- Do I have specific problems in my fields that may affect establishing a green manure (excess acidity, salts, poor fertility and steep slopes)?
- What season will I fallow (winter/summer) and for how long (3 months, 6 months, longer)?
- What management capability (e.g. equipment, labour) do I have to establish and manage a green manure?

The table below provides an overview of considerations of species choice for different management objectives. Consider combining different species to more holistically achieve soil health goals.

Objective	Consideration	Example species
Increase soil organic matter	Choose high biomass species, ideally grown for extended periods of time.	Sunnhemp, forage sorghum, pearl millet, lupins, black oats, birdsfoot trefoil, annual ryegrass, vetiver.
Increase soil N	Plant legumes or species with known associations with N-fixing soil organisms.	Sunn hemp, cowpeas, soybeans, dolichos beans, velvet beans, serradella, lupins, grazing vetch, sanfoin, mung bean, pea.
Scavenge nutrients / reduce losses	Select species with deep and vigorous root systems. Deep rooted species help cycle nutrients from deeper in the soil profile to the surface.	Oats, barley, wheat, cereal rye, mustard, canola, radish, turnip, beet, lucerne/alfalfa, sunflower.
Alleviate compaction/ improve aeration to depth	Select deep rooted and tuberous species that can penetrate and break open compacted layers. Species with vigorous, fibrous roots systems are also advised for opening soil up.	Radish, sugarbeet, turnip, Lucerne, triticale, sunflower, sweet clover, sorghum.
Reduce erosion	Plant fast-growing, high cover green manure species, preferably with strong, vigorous root systems. Avoid ploughing in to maintain soil cover.	Most species will provide benefit to this, just ensure early establishment and dense cover (e.g. oats, rye, sorghum, most grass species). Vetiver is useful for permanent erosion control where this is required.
Bio-fumigation	Select species that produce chemicals that discourage soil pests or are not preferred food plants for pest.	Forage sorghum, kale, radish, mustard, sunnhemp, rapeseed, rye, select non-host species.
Suppress weeds	Select fast growing, high cover green manure species or species with known allelopathic effects (chemical inhibition of weed growth).	Sorghum, cowpeas, oats, rapeseed, mustards, annual ryegrass, cereal rye.
Salt affected soils	Choose salt-accumulating species, noting that biomass should be removed off the field to prevent surface salt build-up.	Oats, barley, spelt (triticum), triticale, wheatgrass, alkaligrass, birdsfoot trefoil (Note: To prevent salt accumulating on soil surface, remove biomass after harvest. This may be suitable as forage for livestock).

The living root systems of green manure crops help open the soil up, scavenge nutrients, reduce erosion and promote biological activity in the soil

Killing off the green manure crop and either leaving on the soil surface or incorporating will add organic matter and nutrients back to the soil

DO NOT disturb

Minimising tillage for soil conservation

Rian van Antwerpen (Senior Soil Scientist)

Disturbance of the soil is not a major issue in sugarcane agriculture as soils are only ploughed in preparation for replanting after several years of ratooning. This adheres perfectly to the no or minimum soil disturbance requirement to sustain the viability of soils. However, the sugar industry will probably never adopt a zero-tillage policy because soil disturbance to varying degrees is required occasionally. This minimal soil disturbance is necessary for the purposes of crop eradication, establishing cover crops (crop rotation), incorporation of lime, ridging for planting cane and alleviation of crust and compaction layers. Other reasons such as a high water table, improved drainage and mixing of alluvial layers are once off operations and will not be covered in this article.

Crop eradication

Operations here include the following:

***Plough-out*:**

The result of this is a disturbance of the total area to a depth of about 25 cm. This causes an explosion of micro-organisms which will decompose organic matter contained in the soil. Even a sandy soil (15% clay) has the potential to release about 30 kg N/ha due to this level of disturbance. It therefore accelerates the decomposition of organic matter and is not a sustainable practice in the long run. Immediately after ploughing, the site is extremely vulnerable to erosion and should be planted to a quick germinating crop such as oats or sunn hemp. The latter will cover another soil conservation requirement which is to practice crop rotation.

Where soil acidity is identified as a major growth limiting constraint, the most effective manner to ameliorate the soil is the application and incorporation of lime, which requires ploughing and disking to promote lime mixing. While lime topdressing can be used, this can take a very long time to alleviate severely acid topsoils. As such, ploughing lime in remains the preferred approach.

***Root cutting*:**

To improve the success rate of killing stools after the last harvest, the crop is sprayed with a herbicide soon after germination and the roots cut with a shear plough. This operation is less disturbing compared to ploughing but large portions of the surface are loosened to a depth of about 20 cm, and although not inverted it is still vulnerable to erosion. This operation should therefore be reserved for the drier months. A winter cover crop such as oats could be planted in the interrow while the stools are decomposing. It will also create an opportunity to eradicate volunteers.

***Minimum tillage*:**

The germinating crop is chemically killed at the age of about 6-10 weeks. The soil is not disturbed and the dying crop is still attached to its roots. This creates an erosion resistant surface – even if the interrow is not planted to a cover crop.

Establishing cover crops and ridging for planting sugarcane

To establish cover crops and to ridge for planting sugarcane, significant soil disturbance will take place, which is unavoidable. This will lead to enhanced soil organic matter decomposition, but because it is practised only at replant (i.e. once every 10 years) the effect in the long run is minimal.

Compaction

Sugarcane is a bulky crop and vehicles must be used infield to extract the crop. During this process soil compaction is unavoidable. To alleviate compaction, the soil can be ripped (subsoiled) to a depth not more than the compaction depth plus 10 cm (between 15 cm for soils with a high clay content and 30 cm for sandy soils). This operation is regarded as a minimum soil disturbance operation because no inversion takes place and only the interrow is disturbed when practiced between ratoons. Another option is to practice controlled traffic in which case no soil disturbance will be required, as long as the wheels stay in the interrow area (traffic zone).

Using a ripper is an effective method to get rid of a compacted layer with little soil disturbance.

Crusting

In the absence of a surface mulch layer, most soils in the sugarcane industry will develop a thin surface crust layer (1-2 mm thick). This layer reduces water infiltration leading to runoff and soil erosion. To stop this from happening, the surface can be disturbed to a depth of 1-5 cm using a range of equipment as options. However, subsequent rain or irrigation will again lead to the formation of a crust layer. Therefore, it is advised to spread the available residue on the surface. If the field was burnt at harvest and the fire was hot leaving little residue, concentrate what is left over in the interrow to prevent the development of a crust. Crusts on the cane row are constantly disturbed by the expanding stool, presence of senesced leaves and bioactivities and is therefore not regarded as a serious problem.

Ploughing and green cane harvesting

Several growers have expressed concern that where they undertake green cane harvesting during the crop cycle and plough the soil at replant, all the benefit of previous mulching efforts are lost. This concern is unfounded and is often practically very necessary. While it is true that ploughing will increase the decomposing of organic matter it is also true that it will not deplete the reserves built up during the previous crop cycle (i.e. all ratoons before ploughing out = crop cycle). Should a green manure crop be grown before replanting, organic matter gained from this source will be more than that lost due to ploughing.

FARMING for the Future

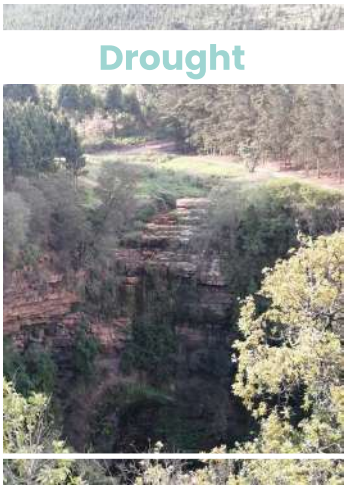
"The nation that destroys its soil destroys itself" Franklin D. Roosevelt

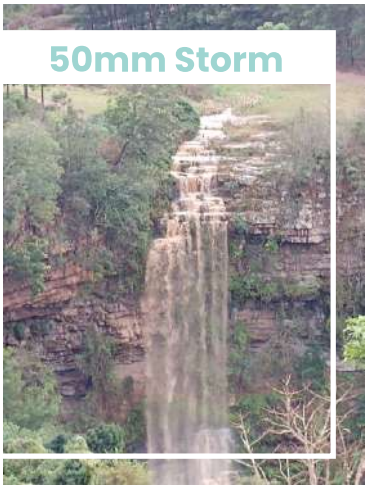
Kerisha Raghunandan (Publications Officer)

Crop monoculture and the over-application of agrochemical products have become the norm in modern day farming, often caused by an increase in pest and disease incursions with a consequent decline in soil nutrition. The long-term effects however, are far more dire than one would expect... Several case studies have presented the effects of monoculture cropping and its negative impact on biodiversity, soil compaction (hardening) and the consequent drain on soil nutrition since the crop repeatedly requires the same types of nutrients, at the same concentration every time it is grown. Higher yields have also led to greater nutrient removals. In time, this causes soil degradation and leads to yield-decline, forcing one to over-supplement the soil with fertilisers and other nutritional products in an effort to maintain production. The availability of numerous products on the market that claim huge benefits is also temptation to try out 'quick-fixes' to improve production. These, coupled with pesticides, herbicides and other agrochemicals, suggest a bleak future for soil health and its organic matter content.

One grower in the midlands, however, has decided to change these seemingly normal farming behaviours. By using the principles of REGENERATIVE AGRICULTURE, Deon Schröder is transforming his family farm into one that farms with nature while sustainably improving productivity and ensuring soil longevity.

Deon's family farm comprises sugarcane, timber and cattle. He describes the sugarcane aspect of his farm as "the typical midlands farm with nice two-year old cane and sometimes not so nice two-year old cane". To grow sugarcane successfully, the business became dependent on chemicals and synthetic fertilisers, like most other farms. Monoculture was also a regular practice with some fields supporting 50 years of sugarcane growth with little to no crop rotation. These fields in particular experienced yield losses and an increase in pests, diseases and weeds. As these problems multiplied, even more agrochemicals were applied. "I was beginning to feel like I was on a hamster's wheel. The situation was getting out of control and I was desperate for a change", says Deon.





During the drought of 2013, rainfall dropped to 70% of the average for the midlands area. This caused a yield decline from 102 t/ha to 65 t/ha (36% loss), bringing the farm to its knees. During this dry period there was a 50 mm rainfall event in a short space of time. "After the rain I got into my bakkie and took a drive to see how much was soaking into the soil. I expected the land to be so thirsty that it sucked up all the moisture. To my horror, all of the precious water together with top soil and fertiliser was running over our waterfall, making its way to the sea. This really got me thinking", he says.

Deon had come to the realisation that a turnaround strategy was necessary for the farm. He invested his time in research, spending hours on videos and books on sustainable and conservation farming practices. He then came across the term REGENERATIVE AGRICULTURE. This farming model has become a global trend and focuses on practices which revive biodiversity, enhance ecosystems and consequently improve soil structure and organic matter. The benefits of implementing this system include a soil which is more likely to withstand the effects of erratic weather events and a crop with decreased pest and disease incursions due to other plant life becoming host plants.

He describes this shift in consciousness as "looking through the world through a regenerative paradigm where you recognise that you are working with a degraded resource and believe you can make a difference". Here are five principles Deon has applied to his farm to improve organic matter in the soil and regenerate his farm. These principles form the basis of Regenerative Agriculture:

1. Minimise soil disturbance

With soil acidity being a common problem, lime and gypsum application is a high priority. However, the only way to effectively remedy high levels of acidity are to plough lime into the soil. By testing soils regularly, Deon has resorted to ploughing only those fields that have top soil acid saturations above 20%, this is done to ensure thorough mixing of lime and gypsum.

2. Keep your soils covered

Delivering burnt cane to the local mill is a requirement to ensure that growers supply "clean" cane. In addition, low winter temperatures in the midlands can promote increase incidence of frost pockets and cane damage where residues are mulched. Therefore, burning of sugarcane and crop residues is common practice in the area. To ensure that there is minimal loss of residues during burning, Deon carries out a 'cool burn' in the early hours of the morning. The remaining residues are then scattered across the harvested fields to create a uniform layer.

3. A living crop is best

Roots, particularly live roots, are critical for proper soil function, promoting binding and nutrient cycling, providing habitat for soil organisms and providing essential carbon based molecules and organic matter as they work and eventually die. Fortunately, with sugarcane being a perennial crop that is ratooned for several cycles, roots will be present for longer periods than is the case with many annual crops.

4. Encourage diversity.

Finding a way to bring diversity onto a farm that has steeped in monoculture dogma was a real challenge. One of the ways Deon overcame this was by planting cover crops. He also introduced crop rotation which, brought with it a whole lot of challenges. He now uses several different combinations of cover crops designed to meet specific requirements; species included in these mixes are sunflower, millet, cowpeas, maize, forage sorghum, radish, sun hemp, clovers, oats and mustard. He is also experimenting with intercropping. "The results in the soil were amazing! Just to add, this field only received 100 kg Potassium, no nitrogen, no phosphorus and no chicken litter".

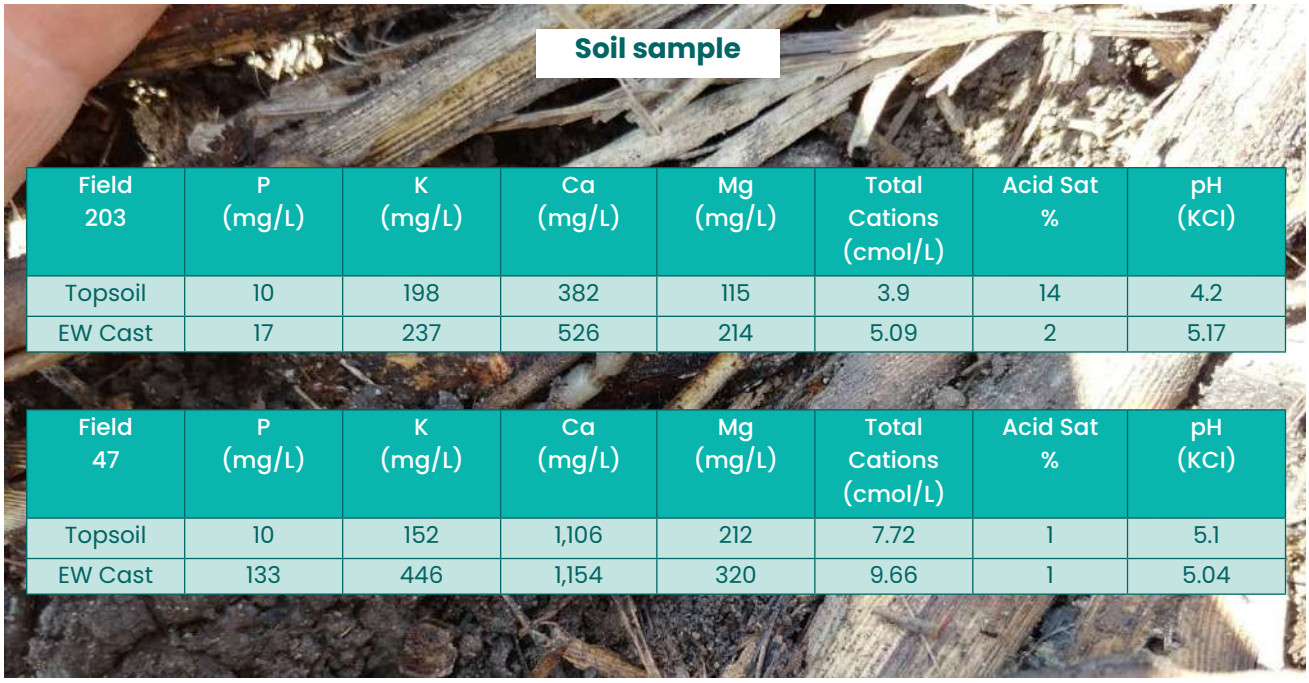
> *Soil fungi was high and aggregates were forming. The soil had come alive!* **says Deon.**

5. Introduce animals to the farm.

Introducing cattle onto his farm was the final piece of the regenerative puzzle for Deon. Cattle are herded onto the fields of cover crops and allowed to graze. The general well-being of the animals was astounding. They had begun to fatten up, were no longer requiring to be fed bales of hay and they required far less salt-lick. The cattle also trample the cover crops creating a mulch cover and promotes cycling of nutrients, while their dung and urine feed the soil microbes.

Some of the benefits...

Earthworm casts are now found more abundantly on the farm, they are essential for organic matter turnover, making nutrient available for plants. To evaluate the benefits of these casts, Deon submitted a normal soil sample of a field and a sample of the earthworm cast found in the same field to the FAS Agricultural Laboratory. "The results were incredible", says Deon:



Field 203	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Total Cations (cmol/L)	Acid Sat %	pH (KCl)
Topsoil	10	198	382	115	3.9	14	4.2
EW Cast	17	237	526	214	5.09	2	5.17

Field 47	P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Total Cations (cmol/L)	Acid Sat %	pH (KCl)
Topsoil	10	152	1,106	212	7.72	1	5.1
EW Cast	133	446	1,154	320	9.66	1	5.04

Deon took samples from two separate fields to compare the analyses of the earthworm casts with the soil in the field. These casts are enriched with nutrients.

"Credit is not only to cover crops but also due to SASRI's plant breeding programme which is producing great varieties that are making a huge impact", says Deon on the recent yield improvements on his farm. Since implementing the principles of regenerative agriculture, Deon has noticed an overall improvement in his farming operations. Cover crops have attracted a host of beneficial insects such as ladybirds which are known to control aphid populations. His advice is, "Focus on your soil biology rather than physically fixing the soil. Soil biology holds the key". It is clear that an increase in organic matter content is key to making a turnaround on the farm and to ensure that future generations benefit from these precious farmlands.

> *"Focus on your soil biology rather than physically fixing the soil. Soil biology holds the key"*

Cane planted in 2007

Cover crop for 1 year

This image reveals the impact of cover crops on soil compaction after just one year of planting. Two distinct layers can be seen in the profile on the right. The top 5 to 8 cm of soil has softened with visible aggregates. The lower part of the profile is still showing compaction however, this will also loosen in time as roots grow deeper and the soil biology improves.

Weather

Phillemon Sithole *(Agrometeorologist)*

Review

The 2019/20 summer rainfall season started with well-below average rainfall in October 2019 for most rainfed parts of the South African sugar industry. This was followed by good rainfall from November 2019 to February 2020 across the industry, with the exception of January when below-normal rainfall was recorded in the North Coast and Zululand regions (Fig 1). Extremely low rainfall was then recorded across the industry as the summer rainfall season drew to a close in March.

Irrigation water supply during the summer season was generally good for most irrigated areas, but severe restrictions remained in place for the Umhlatuze and Crocodile systems in Zululand and Mpumalanga, respectively, until November 2019. Relief in these systems only came in December as dam levels and river flows improved significantly.

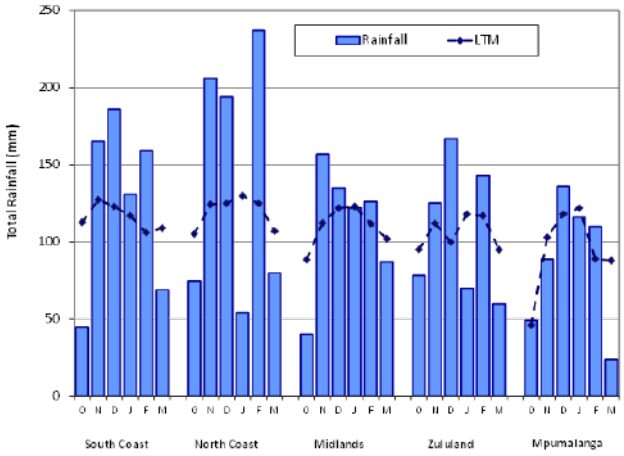


Figure 1: Regional average monthly total rainfall for October 2019 to March 2020, compared to the monthly long term mean (LTM).

Outlook

The El Niño-Southern Oscillation (ENSO) is currently bordering between weak El Niño and neutral states and expectations are that it will remain in the borderline for the rest of the 2020 winter season. This will have little impact on rainfall over eastern South Africa. The *South African Weather Service and the International Research Institute for Climate and Society* predict near normal rainfall during the autumn to winter months of 2020 while *European Centre for Medium-Range Weather Forecasts* predicts slightly below average rainfall for the same period. Mild to above average winter temperatures are expected.

Caution: Favourable conditions for flowering this season!

Indications are that conditions were favourable during the flowering initiation period in March so we anticipate possible widespread flowering this season in coastal areas of the following regions: South Coast, North Coast and Zululand (up to and including Umfolozi).

In the Northern Irrigated regions, the model suggests a reduction in the extent of flowering due to a few cold nights that interfered with flower initiation. Flowering is therefore predicted to be much less than 2019 and below-normal for those areas.

Harvesting guidelines

- Flowered fields will generate higher sucrose yields in June, July and August than non-flowered fields.
- Cane should be harvested before Sept/Oct if the number of flowered stalks is more than 20% per field.
- If flowering is less than 20% then it can be carried over to the next season, but stalk yield will be lower than non-flowered cane.
- If the cane has an eldana infestation, do not carry over the cane. Harvesting of those fields is a priority.
- Be careful not to overestimate the stalk yield of flowered cane.
- Profuse flowering crops (more than 20%) will not respond favourably to chemical ripeners.

Please visit the SASRI weather web https://sasri.sasa.org.za/weatherweb/ for links to up-to-date seasonal climate forecasts and also for the latest rainfall and other weather data.

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