Section 7. Soils as a system

Soil health management requires a holistic view of the soil. For a soil to function properly to sustain banana production, the physical, chemical and biological components of the soil need to work together. The partnership of these soil components helps soils to resist changes. There are a number of mechanisms in the soil which rely on the interaction of the different soil components, such as biological activity to access nutrients from different nutrient pools or biological activity to maintain the structure of the soil. Activities like these in the soil help to buffer the plant from changes and as a result, changes to soil properties occur slowly and often go unnoticed. However, over a long period of time or with severely degrading practices, problems with production and the health of the surrounding environment may begin to occur. Once soils have become degraded, good soil properties can take a long time to be restored.

It is important to realise what impact management decisions will have on soil health. The improvement of soil health follows some basic principles (Figure 7.1). Management practices that increase the diversity of plant and root systems, and the types of plant residue that are returned to the soil, increase the diversity of organisms in the soil. Increased biological diversity helps to build a healthier soil that is better at sustaining plant growth. There are other benefits with increased biological diversity, such as improved nutrient recycling, improved soil stability and disease suppression.

Management practices that use a lot of inputs and impose large disturbances on the soil environment, such as fertilisers, tillage and pesticides and a reliance on monocultures (single plant species) tend to decrease the diversity of organisms in the soil (Figure 7.1). The continual removal of plant residues degrades the organic matter levels in the soil, which reduces microbial activity and diversity, reducing the health of the soil. Practices that degrade the health of the soil make an agricultural system less sustainable, reducing the viability of the farming operation and degrading the surrounding environment.

Proper organic matter management plays is essential in developing healthy soil systems. Because organic matter is made up of a mixture of compounds, it performs a number of different roles in the soil. However, organic matter is continually being lost from soil as either CO₂ or as...
particles (Figure 7.2). The activities of organisms in the soil require the carbon in organic matter as an energy source. This activity causes carbon to be lost as CO$_2$ to the atmosphere. However, soil management decisions can accelerate the losses of organic matter from the soil. Practices such as burning, tillage, erosion and over fertilisation all speed up organic matter loss. Managing the systems to improve soil health requires that carbon be sequestered or saved in the soil as humus or microbial biomass. Therefore, the addition of carbon as organic matter must be greater than losses as CO$_2$ or as organic particles. However, the process of sequestering carbon may take many years.

Soil health management is not a one-off treatment, but a process of continually improving and refining management practices. The improvement of soil health through the development of good soil management systems requires a strategic process of planning, implementing, monitoring and reviewing to determine if the changes implemented are working (Figure 7.3).

- The "planning" process requires some definite aims and defined methods for addressing soil problems. The aims and methods must be realistically achievable.
- The "doing" process is the implementation of practices that may vary from what was traditionally done before.
- The "checking" is the monitoring that allows measurements to be obtained for comparisons between new practices and old practices. These do not have to be sophisticated or expensive tests. They can be done with simple on-farm tools.
- The "reviewing" of the practice changes allows a better understanding of what has worked, what has not worked and why. It is also the next stage in the continual improvement cycle and provides information for the next planning stage.

Agricultural practices can have a positive or a negative effect on the health of the soil. It is important to understand how management decisions impact on long-term soil and plant health. Soil health management requires an awareness of how physical, chemical and biological soil properties work together to sustain plant growth. Decision making for the management of soil systems needs to be balanced, integrating the physical, chemical and biological soil properties with plant productivity, while ensuring environmental sustainability.
The management of soil organic matter is an important part of developing healthy soils. A better understanding of how carbon contained within organic matter is continually lost from the soil and what practices can save soil carbon is fundamental to building healthy soils.

Any decisions about developing a “healthier soil system” should be structured with the aim of continually improving soil management and not relying on “one-off” treatments with the expectations that this will fix all soil and production problems. The benefits from healthy soil practices may not occur immediately, and will not solve all production problems, but will eventually result in sustained productivity and environmental protection.
Section 8. Soil health case studies

8.1. Reducing cultivation

Traditionally cultivation in banana production is used to:
- Eradicate old blocks – 3 to 5 passes with large trailing discs to knock down and chop up the crop residue
- Prepare land for planting – 10 to 12 passes to flatten beds, break compaction layers, reform beds and prepare a suitable tilth
- Maintain good surface drainage in the plantation interrows – mostly done late in the year with a v-blade to ensure unimpeded surface drainage and repair “bog holes”

In recent years banana growers have been investigating methods of reducing the amount of cultivation used in each of these aspects of banana production. Some of these practices are now well established, and provide benefits in reduced cost, more flexibility in timing of operations and reduced environmental impacts.

- Herbicide crop eradication – banana crops are being eradicated by injecting or spraying with the systemic herbicide glyphosate. The plants go yellow in about two weeks (Fig 8.1), and progressively die leaving plant residues to decompose in place until conditions are ready to prepare the land for the next crop (Fig 8.2). This method has a number of advantages:
  - Reduced cost as smaller machinery and fewer passes (reduced from about 6 to 2) are required because residue is decomposing
  - Reduced cultivation helps reduce impacts on soil physical, chemical & biological properties
  - Reduced population of pests such as burrowing nematode because very few volunteer plants occur with the herbicide treatment
  - The decomposing crop residue protects the soil surface from erosion during periods of heavy rainfall
  - The beds used in the previous crop can be retained and used for the next crop, reducing the amount of cultivation use in land preparation

- Permanent beds/zonal tillage – eradicating blocks with glyphosate provides the opportunity to retain the beds from the previous crop, significantly reducing the cultivation needed for land preparation. The advantages of this practice are:
  - Reduced cost because only cultivating the bed area (about 40% of the paddock), and using less cultivation
Reduced cultivation helps reduce impacts on soil physical, chemical & biological properties, and compacted soil from the interrow is not mixed into the row area each time a block is replanted.
- Improved flexibility in planting time, particularly if weather conditions are limiting, because fewer cultivations means planting can occur more quickly.
- Fallow crops can still be used by growing in the bed area until it is ready to be planted.
- Ground cover can be maintained in the interrows of plant crops, which is a stage in the crop with a high risk of soil erosion.
- Establishing drainage lines and contour banks can be retained, and the retention of grass and other vegetation in the interrow helps to maintain the shape and function for surface.

By implementing these 2 practices growers can reduce the tillage operations needed to eradicate blocks and prepare the land for new banana plantings from 12-15 to less than 7, and:

- Conserve organic matter
- Reduce risk of soil erosion
- Reduce the disturbance of soil biology
- Improve soil structure
- Allow greater flexibility of farm operations
- Save money.

### 8.2. Managing ground cover

Ground cover management is an important part of the health of banana soils because ground covers have been shown to:

- slow the speed of water moving across the soil surface,
- reduce the impact of raindrops hitting the soil surface
- provide root channels to assist with the movement of air and water into the soil,
- increase the organic matter in the soil
- increase the biological diversity in the soil.

Ground covers may include living plants such as a cover crops during a fallow period (Figure 8.5), interrow ground cover (Figure 8.7) or residues from the banana crop (Figure 8.8).

There are 4 main opportunities in banana production to maintain ground cover to prevent soil erosion and improve the health of the soil. They are:

- **Crop eradication** – the use of glyphosate herbicide to eradicate blocks provides the option to leave the crop residue as ground cover on the soil surface during the wet season when the risk of soil erosion is highest. The crop
residue is also a valuable source of organic matter and nutrients.

- **Fallow periods** - cover crops can be established in the fallow period between banana crops, and by choosing a cover crop that has some resistance to burrowing nematodes, such as Rhodes grass, it can help will reduce the numbers of the nematode in the soil before the next banana crop is planted (Figure 8.5). Growing a thick cover crop will also help to suppress weeds and put additional organic matter back into the soil. The fine roots of grasses are able to penetrate compacted soil aggregates improving the soil structure. By removing cover crops with herbicides some ground protection can remain in place (Figure 8.6). The dying cover crop is also able to provide a mulch to suppress weeds while the next banana crop is being established.

- **Interrow vegetation** - ground cover in the interrows is able to reduce soil compaction, sediment movement and soil temperatures, and increase water infiltration and biological diversity. (Figure 8.7). Most plantations begin with any natural interrow vegetation that establishes and through slashing or wick application of herbicide will select for low growing species like sour grass (*Paspalum conjugatum*) or blue couch (*Cynodon dactylon*). Records from one NQ producer show that the extra cost in slashing or mowing interrows is offset by the savings made in reduced herbicide application. The use of wick application equipment attached to bagging machines can significantly reduce the amount of slashing required in plantations.

- **Placement of leaf/stem residue** - regular harvest and leaf disease management practices produce leaf and stem residue that is retained in the field. The retention of this crop residue around the base of the banana plant helps to suppress weeds, re-cycle nutrients, provide organic matter, suppress plant-parasitic nematodes, increase soil biological diversity and reduce erosion.
8.3. **Optimising nutrient use**

For profitable banana production with optimum yields it is necessary to apply nutrients to the crop in the form of fertilisers. However, applying more fertiliser than the crop really requires can have negative impacts on soil health, and on broader environmental issues like water quality. Optimising nutrient use is based on applying only enough nutrient to produce profitable banana yields, and the nutrients are applied in such as way as to reduce impacts on soil health and losses from the farm. Excessive applications of nutrients should be avoided because they can have a negative impact on soil health by reducing biological diversity and making it harder to increase and retain organic matter in the soil.

Producers wanting to optimise their nutrient use can be guided by the basic principles of good nutrient management:

- **Match nutrient inputs to crop needs** – knowing the amount nutrient that the crop needs to grow and produce a profitable bunch allows producers to set target amounts of nutrient that need to be applied. Information on crop removal figures, the amount of nutrient exported from the farm in fruit is also important to refine application rates to replace the lost nutrient. Information is available on crop requirements for nitrogen, phosphorus and potassium under north Queensland production systems.

- **Apply leachable nutrients in small amounts regularly** – this reduces the risk of leaching occurring during periods of heavy rainfall, ensuring more of the total nutrient applied is available for the crop to use. During wet periods when irrigation is not required the use of granular fertilisers spread by machinery is the most common method of application (Figures 8.9 and 8.10). However, during drier periods of the year, the application of fertiliser through the irrigation systems can be much more efficient (Figure 8.11) Reducing leaching can also have an impact on soil health as nitrogen from ammonium-based fertilisers has an acidifying affect on the soil which affects nutrient holding capacity and biological diversity.

- **Maximising crop uptake** – the safest place for nutrients to be is in the crop. Managing factors that reduce crop uptake such as poor irrigation, root and corm damage from pest and disease or soil compaction affecting the plant’s root mass, ensure that more of the applied nutrient is available for the crop to use.

- **Monitor nutrient status and plant performance regularly** – the use of regular soil and leaf tissue analysis helps producers know if they need to adjust their target amounts. Optimal ranges for nitrogen and potassium in leaf tissue analysis has been well correlated with yield, allowing
Figure 8.12: Electronic recording systems can help schedule better fertiliser applications

producers to adjust nutrient inputs based on the results. Monitoring plant yields and pack-out figures provides feedback on any effect that changing nutrient inputs might have. Some soil nutrient tests can provide valuable information on key soil health indicators like organic carbon and phosphorus levels over time.

- **Record-keeping to assist farm management** – accurate records of fertiliser applications, yield and pack-out data and results of soil and leaf testing are all part of optimising nutrient use. Good sets of records allow producers to examine yields and pack-out with respect to nutrient inputs and nutrient monitoring (Fig 8.12). Soil test results over time can provide valuable information about trends in key soil health indicators like pH, organic carbon and phosphorus.

By implementing a fertiliser program based on these principles some banana producers in north Queensland have already made savings in fertiliser costs by reducing their application target for some nutrients by 30-50%, while maintaining marketed yields of 51t/ha.

### 8.4. Using amendments

Different amendments can be applied to the soil to try and correct limiting soil factors. Amendments applied to the soil can be from organic sources or inorganic. Most amendments used in agriculture are waste products, either from other industries or from households.

Careful consideration is needed when deciding to use amendment on bananas. Amendments may be able to correct limiting soil properties in some circumstances, but not all farms are the same so you need to evaluate your own circumstances before applying the amendments. The things you need to consider are;

- What is the limiting soil factor that I am trying to correct by applying an amendment?
- What is the best amendment to use to correct the limiting factor?
- How much will you need to correct the soil properties?
- What are the hazards of applying the amendments such as heavy metals, weeds etc?
- Is it cost effective to use an amendment or is their an alternative?
- How will you evaluate if the amendment is working or not?

While the application of amendments has many benefits it may not be the answer in every circumstance. There are also
many different types of amendments that could be used in the banana industry.

Composting organic wastes is a method of stabilising the organic matter and ensuring that no harmful organisms or weeds are passed onto the farm. Because organic amendments are made up of different organic material they can have different nutrient contents which can effect how they work in the soil. However, not all banana farms have the facility to make their own compost or access to waste organic material. If composts need to be brought in they may become expensive if there is large distance between the source of compost and the farm.

Amendments from other industries or waste from packing sheds are available around banana growing areas. Mill ash and mill mud, by-products from processing sugar cane have been used to amend banana soil. However, these products can be difficult to obtain as more agricultural industries realise the value of waste products to supplement

Generally large amounts of amendments are required to have an effect on changing soil properties. If large amounts are needed it may be worth considering using a fallow crop and using cover crops to help improve soil health. Because bananas are grown in warm, wet areas biological activity is usually high. This means that many organic amendments are decomposed rapidly and need to be replaced regularly if they are to have a lasting effect on improving soil health.
### Section 9. Soil health recording and calculation sheet

#### SOIL HEALTH: Data record sheet

**Date:** __________

**Name:** __________

**Farm:** __________

**Field:** __________

### Large ring (150 mm) in the field:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Infiltration 1 (min:sec) (A)</th>
<th>Infiltration 1 (secs) B = min x 60 + sec</th>
<th>Infiltration dry (cm min⁻¹) C = 150 / (B)</th>
<th>Infiltration 2 (min:sec) (D)</th>
<th>Infiltration 2 (secs) E = min x 60 + sec</th>
<th>Infiltration wet (cm min⁻¹) D = 150 / (C)</th>
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</table>

### Large ring (150 mm) in the shed:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Height of sampling tube (cm) (A)</th>
<th>Diameter of sampling tube (cm) (B)</th>
<th>Volume of sampling tube (cm³) C = (A) x 3.14 x ((B)/2)²</th>
<th>Root weight (g) (D)</th>
<th>Root Mass (g l soil⁻¹) E = 1000 x (D)/(C)</th>
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</table>

### Soil moisture and bulk density:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Weight of sampling tube (g) (A)</th>
<th>Height of sampling tube (cm) (B)</th>
<th>Diameter of sampling tube (cm) (C)</th>
<th>Volume of sampling tube (cm³) D = (B) x 3.14 x ((C)/2)²</th>
<th>Wet soil + sampling tube (g) (E)</th>
<th>Dry soil + sampling tube (g) (F)</th>
<th>Gravimetric soil moisture (g g⁻¹) G = (E) – (F) – (A)</th>
<th>Bulk density (g cm⁻³) F = (F) – (A)</th>
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### Soil chemical properties:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sampling depth (cm) (A)</th>
<th>Soil weight (g) (B)</th>
<th>Dilution factor (C)</th>
<th>EC (mS/cm)</th>
<th>pH</th>
<th>P (mg kg⁻¹) (from soil tests) (D)</th>
<th>Nitratenitrate (ppm) (E)</th>
<th>Nitrate (kg ha⁻¹) D = (A) x (B) x (C) bulk density</th>
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</table>
Section 10. My soil health records

10.1. Bulk density

10.2. Water infiltration

10.3. Root mass
10.4. **pH**

- Date
- Nitrate nitrogen (kg ha\(^{-1}\))

10.5. **EC**

- Date
- pH

10.6. **NO\(_3\)**

- Date
- Nitrate nitrogen (kg ha\(^{-1}\))
10.7. Phosphorus (Colwell)

[Graph showing phosphorus levels over time]
## 11. Building a soil health kit

### 11.1. Field equipment

<table>
<thead>
<tr>
<th>Item</th>
<th>Photo</th>
<th>Test</th>
<th>Supplier</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 mm diameter ring, 125 mm in height</td>
<td><img src="image1.png" alt="Image" /></td>
<td>Infiltration Root mass</td>
<td>Irrigation suppliers or plumbing supplies</td>
<td>We used aluminium irrigation pipe, but you could use PVC if soil is not stony. One edge should sharpened to make it easier to go into the soil.</td>
</tr>
<tr>
<td>75 mm diameter ring, 75 mm in height</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Bulk density</td>
<td>Irrigation suppliers or plumbing supplies</td>
<td>We used aluminium irrigation pipe. One edge should sharpened to make it easier to go into the soil.</td>
</tr>
<tr>
<td>Rubber mallet</td>
<td><img src="image3.png" alt="Image" /></td>
<td>Infiltration Root mass Bulk density</td>
<td>Hardware store</td>
<td>Drive in measuring rings.</td>
</tr>
<tr>
<td>Wood block</td>
<td><img src="image4.png" alt="Image" /></td>
<td>Infiltration Root mass Bulk density</td>
<td>Hardware store</td>
<td>Drive in measuring rings.</td>
</tr>
<tr>
<td>Paint scraper</td>
<td><img src="image5.png" alt="Image" /></td>
<td>Bulk density</td>
<td>Hardware store</td>
<td>It is important to scrape all soil off the sides of the bulk density rings so as not to get extra soil in the sample.</td>
</tr>
<tr>
<td>Spade</td>
<td><img src="image6.png" alt="Image" /></td>
<td>Bulk density</td>
<td>Hardware store</td>
<td>Used to collect soil samples and dig soil rings out of the soil.</td>
</tr>
<tr>
<td>Soil sampling tube</td>
<td><img src="image7.png" alt="Image" /></td>
<td>pH, EC, NO$_3$-N, P</td>
<td>Agricultural supply outlets</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Photo</td>
<td>Test</td>
<td>Supplier</td>
<td>Notes</td>
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<tr>
<td>Plastic bags, clip board, recording sheets, pencil and labels</td>
<td></td>
<td>Root mass, Bulk density, pH, EC, NO₃-N, P</td>
<td>Super-markets, packaging suppliers</td>
<td>It is important to label and date all samples and record this information.</td>
</tr>
<tr>
<td>Electronic timer</td>
<td></td>
<td>Water infiltration</td>
<td>Electronic stores</td>
<td>Count up and count down timers are more useful.</td>
</tr>
<tr>
<td>500 ml measuring cylinder</td>
<td></td>
<td>Water infiltration</td>
<td>Agricultural supply outlets</td>
<td>If possible drill a small hole at 445 ml. This makes it easier to add the right amount of water into the water infiltration rings.</td>
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<td>10 l jerry can</td>
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<td>Water infiltration</td>
<td>Variety stores</td>
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<td>10 l water</td>
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<td>Water infiltration</td>
<td>Tap</td>
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