MEAT & LIVESTOCK AUSTRALIA

Towards Sustainable Grazing - Soils

Healthy Soils, Healthy Profits

Workshop Notes

If you have ever wondered what is going on beneath the soil surface of your property, this workshop will help you find answers. There are processes that can help you check the health of your soils. You can expand your understanding of what is happening underground and make management decisions to avoid poor soil health limiting your production.

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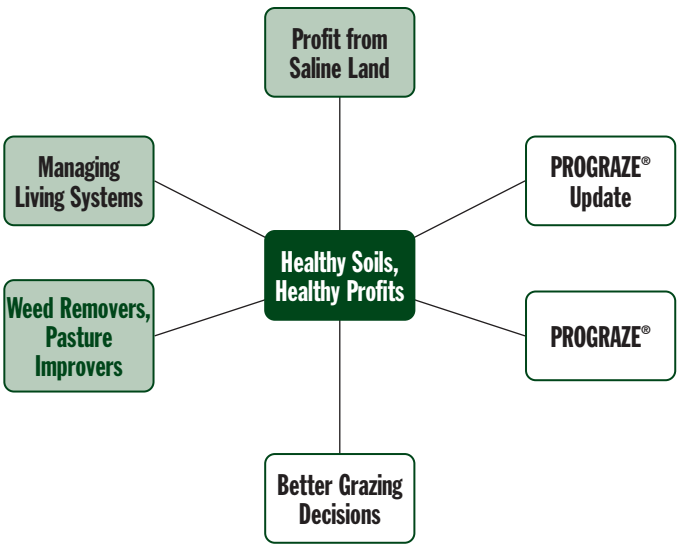

Workshop
delivered by .....

Date .....

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Introduction

Have you ever wondered if the health of your soils may be limiting your production?

Do you think you could learn more about assessing and monitoring soil health?

This workshop will help you maximise the health and productivity of your soils through a greater understanding of what is happening underground. The workshop does not aim to tell you everything about soils, if it did it would need to be a much longer and have a much less interactive approach!

This Soil Health workshop is about exploring what you need to know to manage the soil health of your own property. It is about identifying limiting factors and developing an understanding of the interactions occurring, and strategies available, to provide soil conditions favourable for optimum plant growth. For properties not suffering obvious signs of soil degradation this workshop will help identify the terms of soil health.

The workshop activities are challenge based. There is a different host property for each workshop session and you will be encouraged to identify clues, make predictions and collect evidence. You will also have the opportunity to soil test two of your own paddocks. Completing soil tests on your own property will help you relate to what is seen on the host farms, enable you to make comparisons, and allow you to make sense of soil test results in the context of observed landscape and plants.

Completing this workshop will help you to develop strategies to monitor and manage soil health. As a result of participating, you will be able to:

1. Identify property specific issues relevant to soil health.
2. Evaluate the impact of management practices on soil health.
3. Develop an action plan to address a soil health problem and specify the tools suitable to use to monitor the results over time.

This workshop is designed for completion in two separate days, approximately three weeks apart. Consecutive days are not used because it does not allow sufficient time for you to consider the materials, reflect on what is discussed, and make parallel investigations into your own paddocks.

This Soil Health workshop is one of four Natural Resource Management (NRM) courses designed as part of the delivery of products from the Sustainable Grazing Systems program. The other three NRM workshops cover the topics of weeds, biodiversity and grazing saline land. Each of these NRM workshops has received substantial input from producers throughout the development and testing phases. The combined NRM training package will assist producers to address important NRM issues and to achieve an improved understanding and direction for the management of the natural resources used in the higher rainfall zone grazing industries.

Healthy Soils

Healthy soils are an integral component of all productive ecosystems, including cropping, grazing and natural. Soils provide the foundation that physically supports plant growth as well providing essential water and nutrients. When soil health is maintained, the physical, chemical and biological needs of plants are likely to be met so that growth and production is sustained in the long-term.

Have you heard the saying 'soil without microbes is just dirt'?

Soil organisms (biota) are the powerhouse of the system, recycling energy and nutrients for plants and other organisms, and controlling pests and diseases. Without soil biota, soils would have no structure, little pore space, poor water holding capacity, and poor nutrition. Soil biota aid soil health physically, chemically and biologically. Some organisms dig and tunnel through the soil matrix, providing pores for water and air movement, while others produce organic glues and fillers that cement mineral particles into soil aggregates.

The top 10cm

The zone of greatest biological activity is within the top 10cm of the profile, making this area the most important for soil health. This is where the organic carbon compounds fuelling the activity of the soil biota collect, and where nutrient recycling and replenishment are most intense. Because of the importance of this zone for soil biological activity, nutrient cycling and plant root activity, it is crucial to maintain its health. Erosion, soil compaction, and chemical contamination can all reduce the health of the topsoil. If this zone of your soil is not performing, it is unlikely the pasture will either!

Healthy soil facts

The top 10cm (4 inches) of soil contains:

- 80-90% of the soil microbe and earthworm activity.
- 85% of available nutrients (phosphorous, sulphur and nitrogen).
- 20-25% of plant roots.
- At least 50% of the soil organic matter.

A loss of only 1mm of the topsoil by erosion is equal to 7 or 8 tonnes of soil per hectare.

Soil biodiversity

A variety of organisms inhabit soil. As many as 10,000 different organisms may exist in each gram of soil. Each group of organisms has their own specific roles to play in reducing plant material to mineral nutrients (or nutrient cycling). Their activities in doing so, also affect soil structural development through their physical activity and what they exude.

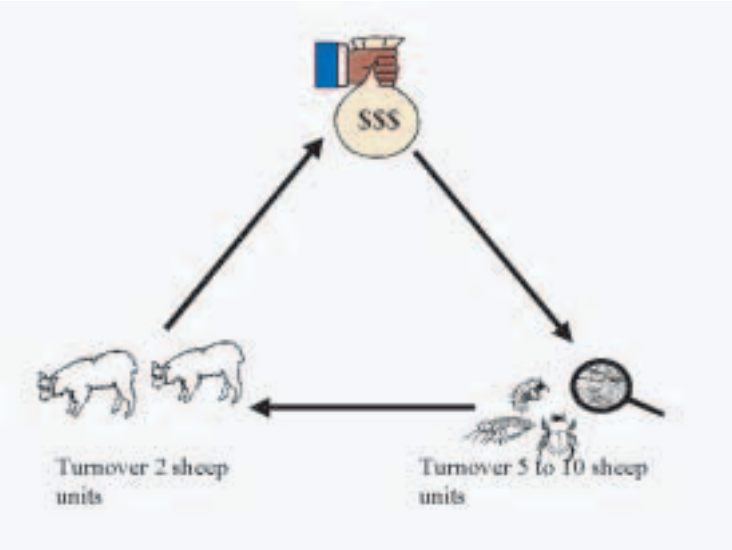
Soil organisms range from the readily visible (earthworms, cockroaches and slaters) to the virtually invisible (fungi, and bacteria). The larger organisms physically break down litter or organic matter through chewing and cutting, while the smaller organisms decompose particles of organic matter and other organisms into humus and mineral nutrients. Hence, the variety and quality of food sources will dictate their variety and abundance.

Soil microbes

Little in size but big in impact.

Soil microbes may be small individuals, but collectively they have a large impact. The reason soil biota are the powerhouse of a pasture ecosystem is that they can account for over 70% of the turnover of energy used within the system. Without a functioning population of soil microbes, a pasture ecosystem will use the water, nutrient and solar energy resources much less efficiently. Energy turnover maintains and regulates the supply of nutrients that sustain and increase pasture productivity. Without this turnover, nutrients are tied up, effectively unavailable for pasture and livestock production.

Figure 1 – Energy turnover based on oxygen use



Based on oxygen use, soil 'animals' below the ground account for more energy turnover than animals above the ground.

Animals above the ground (such as sheep and cattle) need to reproduce and thrive so they can be turned off to generate dollars.

Without soil biota reproducing and thriving the beneficial processes in the topsoil that lead to the dollars being generated will be much less efficient. Nutrients would either be 'locked up' or leached with rainwater below the rooting zone.

For soil animal and microbial populations to be active, they require adequate food of suitable quality. Pasture litter is the main source of food for soil animals in a grazing situation. Soil animals break down the litter into smaller fragments, providing food for the microbes. In the process, organic carbon compounds that are too tough for soil biota to use are chemically processed into humus. Just as pasture quality varies between plant species, so does litter quality vary. For example, stems of native grass are less desirable than leaves of subterranean clover. Subterranean clover leaves may be decomposed within 14 days, while native grass stem material may take many months. Although fresh subterranean clover may provide more immediate food for the system, the tougher native grasses eventually produce more humus!

Soil biota form the foundation of a functioning pasture ecosystem, accounting for the majority of energy expenditure and a large proportion of the biomass. Without this foundation, plants, pastures, animals and production will all suffer. To maintain stability of the system, it is essential that soil health be maintained.

Exercise 1 – Describing soil health

Considering a range of different soil properties, write down the words that come to mind when you think of each property being 'healthy'. You may find it useful to refer to the book *Better Soils Mean Better Business*.

If you have any additional characteristics you like to use also describe them in the spaces at the bottom.

Soil health property	Characteristics associated with 'healthy'

Exercise 2 – Soil health clues

You will use the Day 1 host farm visit to complete this exercise.

Paddock A	Paddock B
Clues for performance	**Clues for performance**
Prediction of what we will see in the landscape and soil pit	**Prediction of what we will see in the landscape and soil pit**

Exercise 3 – Impact of management practices

PART A – Paddock A

Farm management practice	Impact on soil health

PART B – Paddock B

Farm management practice	Impact on soil health

Water infiltration test

Goal

To compare the rate of water infiltration into different soil bands down the soil pit profile.

How might this test identify differences in the health status of the two soils?

Soil is both a physical medium providing anchorage for roots, and a biological warehouse of nutrients and water. In sandy soils, the larger particle size of sand grains promotes freer drainage and easier access for root growth. With the exception of soils affected by water repellent plant waxes, the rate of water infiltration into a sandy soil should be comparatively high. Soils consisting of finer particles can settle over time to a much greater degree of compaction, leaving fewer channels for drainage and for root access. In some soils a fine crust develops at the surface, physically inhibiting germinating seeds and water infiltration. Lower down in the soil profile this effect may not be evident. Conversely because salt accumulates at depth, the poor water infiltration associated with sodic soils may only occur at depth. If within the rooting zone of the plant, this water-impeding layer may induce water-logging, adversely affecting root growth.

The water infiltration test simply uses water-soluble paint (yellow powder paint for example) to indicate when a reservoir of water placed at the soil surface drains completely into the soil. Differences in the time taken for this known volume of water to infiltrate reflect differences in the soil physical properties, highlighting any potential barriers to plant growth. A milo tin or canned fruit tin with both ends removed, holding about one litre of water is used as the reservoir. A sheet of plastic film is used to line the tin to temporarily hold the water, and to gently release the water over the soil surface without excessively disturbing the surface condition of the soil. The rate of infiltration should reflect differences in the texture of any different soil bands observed down the profile. If no times are recorded the paint should demonstrate channels (for example from soil animals burrowing) that the water finds or hardpan/barriers if present.

What is needed

- A spade, or shovel, to level the surface of the soil band under investigation.
- A milo tin, or canned fruit tin, with a volume of about one litre.
- A measuring cup to standardise the volume of water added to the tin.

- Water-soluble paint (yellow coloured powder paint used by play groups and kindergartens, or white house paint diluted 1 part paint to 10 parts water) and a bottle to store several litres of paint solution.
- Plastic wrap to line the inside of the tin.
- A watch capable of timing in 'seconds'.

Completing the task

- Examination of the permeability properties of the soil surface.

  Try not to remove anything other than very coarse fragments of leaf litter, stones or twigs that might stop the base of the tin coming into contact with the soil.
- Make up several litres of the light coloured paint.
- Place the tin firmly on the soil surface (press it evenly into the ground several millimetres to prevent the liquid running out under the rim when it is added).
- Line the tin with a sheet of the plastic wrap (ensure sufficient wrap extends at the top of the tin so that it can be securely held with your hand).
- Use the measuring cup to measure a precise volume of water (sufficient to fill the tin leaving some freeboard). This volume will be used for all of the infiltration tests.
- Set the stopwatch or record the time (in seconds), before carefully removing the plastic wrap from the tin.
- Record the time taken for the paint to drain into the soil layer.

Optional: *Use the spade to expose the surface of the next visually different band of soil observed down the soil profile. Repeat the steps outlined above to record the permeability of this layer. Repeat the procedures until you have a record of the permeability of all of the different bands observed in the soil pit.*

Seedling growth comparisons

Goal

To compare the ability of seedlings to germinate and establish in soil cores collected from two paddocks (you may choose the best and worst patches of country for comparison).

How might this test identify differences in the health status of the two soils?

Soil physical, chemical and biological properties interact with the germinating seed and the developing root system of plants. Factors such as the physical resistance encountered by the growing root, the availability of nutrients such as nitrogen and phosphorus for uptake by the developing seedling, and the presence and activity of root pathogens may interact to reduce the vigour and final growth potential of seedlings. By collecting soil cores from the best and worst yielding country on your property and growing seedlings in them under the same environmental conditions, factors potentially limiting the final yield of your crops and pastures can be identified.

Extracting soil cores

What is needed

- Moist soil for the collection of soil cores.
  Use a hessian bag or old towel to pre-wet a small area for one week before sampling if Mother Nature is not cooperative.
- At least two milo or coffee tins (about 10-15cm diameter) with the basal end cut out and several holes punched downward into the lid.
  You could use similar diameter storm water pipe cut in 15cm sections with a bevelled lower edge.
- A lump of wood larger than the diameter of the tins to distribute the pressure when pushing the cylinders into the soil.
- A spade to dig the cylinders out of the soil.
- At least two ice-cream containers (or equivalent) to maintain a reservoir of water to sit each soil core in.

Completing the task

1. Use a spade and scrape across the surface of the soil to remove any pre-existing plants, large stones, twigs or other obstacles. Place the hessian bag or old towel on the surface of the soil and use a watering can or equivalent to soak the surface. Repeat the watering every day or so over the next week to ensure that the profile to a depth of about 20cm will be moist.

2. Assemble the tins with the lids on. This will provide a more substantial surface on which to apply pressure, and may reduce the likelihood of the tins distorting their shape. The lid will also make it easier to transport the soil core back to the shed or house without losing your sample.

3. Label each cylinder using a permanent marker pen (if necessary, this can be removed later using methylated spirits). Label each corresponding ice-cream container with the same identifying code.

4. Lift the wet hessian or towel and place the thin edge of a cylinder into the soil. Place the piece of timber over the lid and apply pressure. Hopefully the cylinder will slide into the soil, with air escaping through the holes punched into the lid. Keep pushing until the lid is close to the surface of the soil. Use a spade to ease the cylinder out of the soil. Once removed from the soil, use the edge of the spade to trim the soil extending out of the base of the cylinder flush with the lower edge.

5. Leaving the lid firmly in place, turn the cylinder upside down for transporting. Once at the house or shed, place the appropriately labelled ice-cream container over the end of the cylinder and invert it right side up. Remove the tin lid.

6. Repeat steps 1 to 6 for your other paddock, and for any replicate cores to be cut from each site. You may wish to record comments on the degree of difficulty encountered in removing the soil cores (cylinders) from each site. Was it easier to remove the cylinders from your 'best' country?

7. Wet each of the soil cores to field capacity by filling the base of each ice-cream container with water – up to, but not above, the surface of the soil within the cylinder. Let the soil sit in the water for a half to one hour (depending on whether your soil is sandy or clayey). Pour out the water without disturbing the base of the cylinder and allow the excess to drain. Leave about a 2cm depth of water in each container, topping up as necessary over a week.

Growing the seedlings

What is needed

- Legume seeds preferably not dusted with insecticide or fungicide.

  If no suitable seeds are available, sprouting seeds could be obtained from a health food shop. Select summer or winter-growing species according to the time of year (for example, mung beans for summer, lucerne (alfalfa) for winter).

- A thin rod or pencil for making holes for planting the seed.

- The soil cores wetted up preferably for a week prior to sowing the seed.
- A bench or surface in the sun with similar exposure for all soil core systems.

Completing the task

1. Seed size can have a big impact on the fitness of a seed to germinate successfully. To avoid these complications select about 20 large seeds of about the same size, shape and colour. Avoid any which are shrivelled, cracked or discoloured.

2. Using the pencil or rod, make four holes to a depth of about 10mm equidistant around the surface of each soil core. Place a seed in each and ease the edges over to cover the seed.

3. Repeat step 8 in the previous section to wet each soil core to above field capacity. Drain as described, and maintain the 2cm reservoir in the bottom of each container for the six week duration of the exercise.

4. If possible, at weekly intervals, record how many seedlings have emerged in your soil. Look for any differences in the rate of emergence or the appearance of the seedlings. Write down when the first true leaves emerge, and count the number of fully expanded leaves present on each seedling at the end of each week. At this time you will also need to top up the 2cm reservoir of water in each container. Record your results in the table provided.

5. After six weeks, fill the containers again to capacity (as in Step 8 above), to thoroughly soak the soil cores. This will make the task of washing out the seedlings much easier. After half an hour to an hour, transfer each saturated core in turn into a bucket filled with water. Supporting the base of the soil in one hand, try to push the soil core and seedling down out of the cylinder. Once freed, support the soil core under the water with one hand and gently wash the soil away from the roots with the other hand. Avoid excessive force as you will break fragile roots and lose any root nodules that have formed.

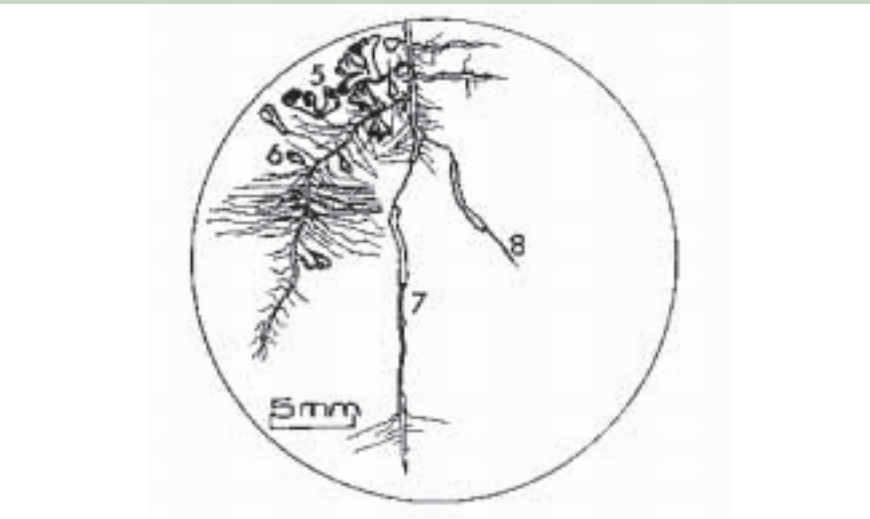
Seedling growth records

Shoot systems from soil core from Paddock A	Shoot systems from soil core from Paddock B
Week 1 – Number of seedlings emerged	*Week 1 – Number of seedlings emerged*
Week 2 – Number of seedlings emerged	*Week 2 – Number of seedlings emerged*
Week 3 – Number of seedlings emerged	*Week 3 – Number of seedlings emerged*
Week 3 – Number of leaves on each seedling	*Week 3 – Number of leaves on each seedling*
Week 4 – Number of leaves on each seedling	*Week 4 – Number of leaves on each seedling*
Week 4 – Height of each seedling	*Week 4 – Height of each seedling*
Comments on colour and vigour of seedlings	*Comments on colour and vigour of seedlings*

6. After you have washed all of the seedlings out of one soil core, clean the ice-cream container and place about 2cm of water in the bottom. Measure the height of each seedling (from the stem to the growing tip) and record your results. Make comments on the appearance, the intensity of green colour, any yellowing on leaf veins, leaf margins, on older or younger leaves, the size and appearance of the leaves. After you have completed your visual assessment of the shoots of the seedlings, place the seedlings horizontally into the water.

7. Repeat steps 5 and 6 until all washed seedlings have been placed into the ice-cream containers. Now compare the root systems of seedlings grown in the two soils. Has the 'worst' soil produced seedlings with a poorer root system? Is there any evidence of fewer finely branching roots, fewer larger branching lateral roots? What about the number and colour of legume nodules? Are the legume nodules a rich pink colour inside? Only those with a rich pink colouring will be actively fixing nitrogen. Is there any evidence of root disease? Have the roots lost their outer shell (cortex)? Is there any blackening or browning? Is there any spear-tipping where microbes have removed tissue, causing the root to break? Use the line drawing provided below to help in describing the root systems from your 'best' versus 'worst' soil. Write down your observations.

Enlarged view of a portion of a plant root system



On a healthy root system you should see lots of finely branched roots (6), emerging from the main laterals and tap root. Healthy legumes may have nodules present (5). However, only those with a rich pink pigment inside, will be actively fixing nitrogen. Unhealthy roots will have few fine roots, with brown or black discoloured patches, sections missing from the outer root tissue (7), and evidence of spear-tipping (8). The ability of the plant to compensate for and to replace damaged roots, will determine the health status of the plant.

8. Use the results recorded in the tables to compare the emergence and vigour of the seedlings growing in the two different soils. Is there any evidence of your 'worst' soil performing to a lesser degree than your 'best'? If so, in which area of plant growth? Is the rate of seedling emergence less – suggesting possible differences in the physical resistance encountered, or the water available for the seed to imbibe? What of the rate of leaf initiation? Once the seedling has exhausted the nutrients stored in the seed, the rate of growth will depend on the availability of nutrients in the soil. Any evidence that your 'worst' soil has less? What of the presence of a higher disease burden? Have you observed any differences in the appearance and density of roots? What of the size, number and internal colour of the legume nodules that should be present on the roots?

Root system growth records

Root systems – Paddock A soil	Root systems – Paddock B soil
Presence of fine branching roots.	*Presence of fine branching roots.*
Presence of strong, cream lateral roots.	*Presence of strong, cream lateral roots.*
Numbers of legume nodules on each root system.	*Numbers of legume nodules on each root system.*
Comments on the internal colour of a sample of nodules from each root system.	*Comments on the internal colour of a sample of nodules from each root system.*
Evidence of spear-tipping on the roots.	*Evidence of spear-tipping on the roots.*
Evidence of black or brown staining on the roots.	*Evidence of black or brown staining on the roots.*
Other comments on the appearance of the root system (eg any knotting that might indicate nematode attack?).	*Other comments on the appearance of the root system (eg any knotting that might indicate nematode attack?).*

9. Conclude your seedling growth comparison by reflecting on your findings. Did you obtain any evidence to support your designation of one patch of soil as a 'good performer', and the other as a 'poor performer'? If seedlings grew to much the same extent in each, is it possible that site differences (aspect, prevalence of frost, drying winds, excessive stock trampling, different burning regimes, differences in cultivation, irrigation frequency, the timing of sowing, harvesting or other management practices) might explain your initial field observations?

Microbial activity comparisons

Goal

To compare the ability of microbes to degrade cellulose in the form of rectangular strips of calico buried in soil cores collected from your best and worst patches of country.

How might this test identify differences in the health status of the two soils?

Fundamentally microbial activity is limited by the amount of water available for growth in the soil, and by the amount of readily available organic carbon and nutrients. Climate and the physical and chemical properties of a soil determine the amount of water available for microbes, but land management is often more important in determining the amount and type of organic carbon available.

Cellulose is the most abundant carbon resource on earth, with many bacteria and fungi adapted for using it as an energy source.

In this activity rectangular strips of unbleached calico will be used as a source of cellulose, to be buried in the soil for four weeks. In the absence of sufficient water, microbial activity will be very limited, and little decomposition of the strip will occur. However by removing soil cores from your 'best' and 'worst' country and by watering them regularly, differences in the extent of microbial activity within the two soils can be observed. The method used for extracting the soil cores from your country is the same as that used for the seedling growth comparison activity.

Extracting soil cores

What is needed

- Moist soil for the collection of soil cores.
  Use a hessian bag or old towel to pre-wet a small area for one week before sampling if Mother Nature is not cooperative.

- At least two milo or coffee tins (about 10-15cm diameter) with the basal end cut out and several holes punched downward into the lid.

  You could use similar diameter storm water pipe cut in 15cm sections with a bevelled lower edge.
- A lump of wood larger than the diameter of the tins to distribute the pressure when pushing the cylinders into the soil.
- A spade to dig the cylinders out of the soil.
- At least two ice-cream containers (or equivalent) to maintain a reservoir of water to sit each soil core in.

Completing the task

1. Use a spade and scrape across the surface of the soil to remove any pre-existing plants, large stones, twigs or other obstacles. Place the hessian bag or old towel on the surface of the soil and use a watering can or equivalent to soak the surface. Repeat the watering every day or so over the next week to ensure that the profile to a depth of about 20cm will be moist.

2. Assemble the tins with the lids on. This will provide a more substantial surface on which to apply pressure, and may reduce the likelihood of the tins distorting their shape. The lid will also make it easier to transport the soil core back to the shed or house without losing your sample.

3. Label each cylinder using a permanent marker pen (if necessary, this can be removed later using methylated spirits). Label each corresponding ice-cream container with the same identifying code.

4. Lift the wet hessian or towel and place the thin edge of a cylinder into the soil. Place the piece of timber over the lid and apply pressure. Hopefully the cylinder will slide into the soil, with air escaping through the holes punched into the lid. Keep pushing until the lid is close to the surface of the soil. Use a spade to ease the cylinder out of the soil. Once removed from the soil, use the edge of the spade to trim the soil extending out of the base of the cylinder flush with the lower edge.

5. Leaving the lid firmly in place, turn the cylinder upside down for transporting. Once at the house or shed, place the appropriately labelled ice-cream container over the end of the cylinder and invert it right side up. Remove the tin lid.

6. Repeat steps 1 to 6 for your other paddock, and for any replicate cores to be cut from each site. You may wish to record comments on the degree of difficulty encountered in removing the soil cores (cylinders) from each site. Was it easier to remove the cylinders from your 'best' country?

7. Wet each of the soil cores to field capacity by filling the base of each ice-cream container with water – up to, but not above, the surface of the soil within the cylinder. Let the soil sit in the water for a half to one hour (depending on whether your soil is sandy or clayey). Pour out the water without disturbing the base of the cylinder and allow the excess to drain. Now you are ready to bury the calico strips.

Burying the calico strips

What is needed

- At least two soil cores collected from each of your selected paddocks, watered to about field capacity (four soil cores in total for this test).

  Due to the variation that can exist in soils, it is suggested two soil cores are used from each location as this will give you a more meaningful result.

- At least 12 strips of unbleached calico.

  Calico can be purchase from most curtain, fabric, or upholstery supply shops. It should be rinsed and dried before using and cut into rectangles that are about 2cm by 6cm.

- Permanent marker pen for numbering each strip.
- Metric ruler and tweezers or slim-line tongs for placing the strips into the cores.

Completing the task

1. Number each calico strip. Three calico strips will be used for each soil core and the strips will be buried at 10cm.

2. Use the ruler to make a cut into the soil to a depth of 10cm, leaving the ruler in place. Move the ruler backwards and forwards to create a 10cm deep slot in the soil.

3. Hold the lower end of one of the numbered calico strips firmly with the tweezers or tongs (the strip should now be supported within the arms of the tweezers or tongs). Slide the strip vertically down the ruler into the soil, hopefully down the full length of the 10cm slot. Remove the ruler before removing the tweezers or tongs. Open the tweezers or tongs as wide as possible to remove them from the soil, hopefully leaving the strip in place.

4. Record the number of the strip that you buried, the soil type that you buried it into, and the depth.

5. Repeat steps 1 to 3 until at least three strips of calico have been buried in each soil core (in each cylinder).

6. Cover the surface of the slots with loose soil from the surface of the core, and wet the core to field capacity as described previously. This should help to improve the contact between the soil and the calico, favouring microbial activity.

7. Put the soil cores in their ice-cream container 'saucers' in a warm, sheltered place. Once a week over the next four weeks, water each soil core to field capacity. This should ensure there is sufficient water available to favour microbial activity.

8. After 4 weeks, fill the ice-cream container 'saucers' to capacity to saturate each soil core. Leave for about an hour (more if your soil is a heavy clay) to soak completely. Up-end your soil core into a bucket full of water and wash the three calico strips free from the soil. Do this gently. Excessive force may result in your strips disintegrating!

9. Place the strips from each soil core onto a sheet of paper towel. Label the paper towel with the soil type (for example, Paddock A, Paddock B, or 'best' or 'worst'). Allow the strips time to dry.

10. Compare the extent of microbial decomposition of each strip. You may find that comparing the intactness of each rectangle, looking for holes or estimating the percentage missing, or indeed differences in the sharpness and completeness of the number written on each, could be useful indicators of the extent of microbial activity. Record your observations and comments.

11. Do you have any evidence of different rates of microbial activity in each soil? Could this relate to differences in the amount of organic matter present, the pH or texture of the soils? How different are your management practices – could this also explain any differences?

Exercise 4 – Your paddocks

Visualise two of your paddocks. Record some clues to the barriers to growth and soil health that you think are affecting the performance of your property.

Your information (Paddock A)

Paddock identification:				
Landscape as a factor limiting plant growth over time				
Slope, location in catchment	Depth to water table	Aspect	Pasture type (native, sown, annual, perennial)	Indicator species (weeds, native community)
Soil surface as a limiting factor for seedling germination				
Extent of Litter layer (ground cover)	Depth of organic carbon stain (% OC from soil test)	Extent of soil animal activity	Calico strip test (microbial activity)	Water infiltration test (drainage, aeration)
Soil profile as a limiting factor for root growth and plant yield				
Depth and colour of different soil layers Rooting depth	Strength of different layers	Texture of different layers Depth to hard pan	pH of different layers (pH from soil test)	Seedling growth comparison (fertility status from soil test)
Management and plant performance				
Grazing strategy (set stocking, rotational, % cover)	Pasture strategy (native, annual or perennial, seasonal spelling, hay cutting)	Cultivation, contour banks	Cropping or pasture rotation	Fertiliser strategy

Impact of management practices on my Paddock A

Farm management practice	Impact on soil health

Your information (Paddock B)

Paddock identification:				
Landscape as a factor limiting plant growth over time				
Slope, location in catchment	Depth to water table	Aspect	Pasture type (native, sown, annual, perennial)	Indicator species (weeds, native community)
Soil surface as a limiting factor for seedling germination				
Extent of Litter layer (ground cover)	Depth of organic carbon stain (% OC from soil test)	Extent of soil animal activity	Calico strip test (microbial activity)	Water infiltration test (drainage, aeration)
Soil profile as a limiting factor for root growth and plant yield				
Depth and colour of different soil layers Rooting depth	Strength of different layers	Texture of different layers Depth to hard pan	pH of different layers (pH from soil test)	Seedling growth comparison (fertility status from soil test)
Management and plant performance				
Grazing strategy (set stocking, rotational, % cover)	Pasture strategy (native, annual or perennial, seasonal spelling, hay cutting)	Cultivation, contour banks	Cropping or pasture rotation	Fertiliser strategy

Impact of management practices on my Paddock B

Farm management practice	Impact on soil health

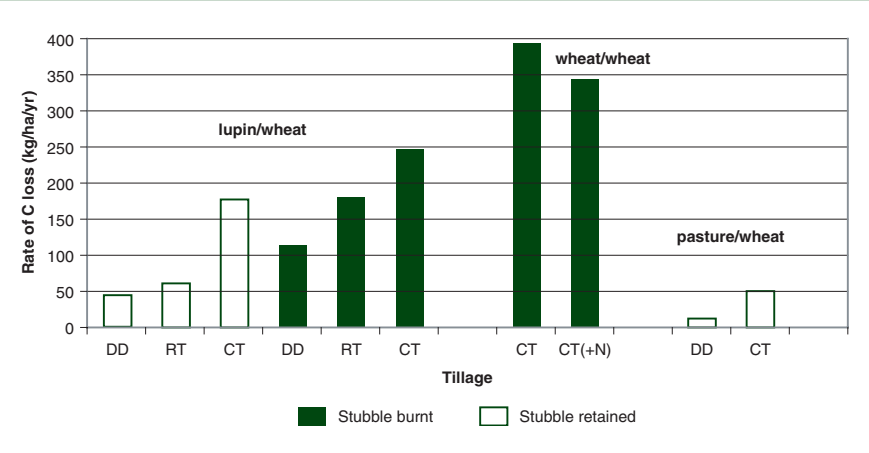
Management practices (as discussed in the *Better Soils* book section on How Does Agriculture Influence Soil Biota Activity, page 39) rarely fall into the 'all bad' or 'all good' categories. Choose a different soil type, a different cropping or pasture regime, a different climate, and the impacts may vary. However, hindsight has proven that some management practices have had a more negative impact on our agricultural soils than others.

Often the impact is related to the frequency of the practice, reducing the ability of the soil ecosystem to recover over time. These negative impacts are most obvious in soils that may naturally have a lower buffering capacity. In the wider context, buffering refers to the ability of a soil ecosystem to function within the physical, chemical and biological range that favours the growth and survival of preferred microbes, plants and animals. The technical term used to describe this greater buffering capacity is the Cation Exchange Capacity (CEC). This property of soils is discussed in the *Better Soils* book on page 29.

Figure 2 shows how different farm management practices affect the reserves of organic carbon in the soil. Organic carbon is the fuel used by most organisms to drive the metabolic processes essential for growth. Parasitic species such as bacteria, fungi and all soil animals utilise organic carbon either directly (herbivores) or indirectly (carnivores preying on herbivores). The actual concentration of organic carbon present in the soil at any one time depends on the amount being consumed by soil organisms, and the amount being replenished in plant residues. Burning is the fastest way to reduce organic carbon reserves, with conventional cultivation and mechanical fallow next. Pasture rotations have been acknowledged as soil building phases for a very long time. In part this is because pastures retain ground cover and replenish organic carbon reserves for a longer period than crops, and are minimally cultivated. The other reason is that pasture species often include nitrogen-fixing legumes, and plant species known to be good hosts for endomycorrhizae.

Figure 2 – Farm management practices

This graph indicates the effect of different farm management practices on the rate at which organic carbon is lost from soils.



The vertical bars show the loss of organic carbon associated with different crop rotations, tillage and stubble management practices. The black bars are where stubble is burnt, the white bars are stubble retained. The rotations are wheat after wheat, wheat after lupins, or wheat after pasture. The tillage practices are direct drilling (DD), reduced cultivation (RT), or conventional cultivation (CT).

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Different management practices can also interact with different stages of crop growth and development in unexpected ways. For example inorganic nitrogen applied at sowing to meet the expected demand of high protein wheat yields will stimulate vigorous tillering and leaf production. However if the moisture runs out towards the end of the growing season, the demands of the increased biomass restricts the ability of the crop to fight off root diseases. As a consequence, crops in this situation are very prone to crown rot. If the supply of nitrogen is in part organic, and part inorganic, the plant can adjust the biomass according to the season. In a wet season, more of the organic nitrogen will become available over time, in synchrony with increasing plant requirements. This slow release of nitrogen may also explain why the lupin-wheat rotation in the figure above reduces organic carbon to a lesser extent than wheat-wheat. Wheat stubble returns more carbon to the soil than lupins. However less nitrogen fertiliser will be added to wheat after lupins, due to the higher organic nitrogen content provided by the legume nodules!

Management practices summary

Pastures and grazing

Management practice	Advantages	Disadvantages
Fertilising pastures	Increases pasture growth and forage quality, increasing livestock productivity. Increases the nutrient availability for plants and soil organisms, increasing the groundcover and soil organic carbon reserves.	Excess phosphorus reduces root colonisation by beneficial fungi (mycorrhizae). Repeated use of acidifying nitrogenous fertilisers can increase soil acidity, reducing legume nodulation and the growth of sensitive pasture species. High rates of fertiliser will destabilise native grass pasture, encouraging weeds and annual species.
Perennial versus annual pastures	Groundcover protection is greater, improving weed and erosion control. Perennial species have deeper roots, reducing deep drainage and lowering water tables.	Perennial pastures cannot match the productivity of annual species over a short time period (annual pastures can supply seasonal feed demands and are better for silage production).
Resting pastures	Allows pasture species to set seed and regenerate. Increases the litter layer and organic carbon reserves of the soil, increasing the biological diversity and activity in the soil.	Reduces legume germination if grass growth is excessive in autumn. Rank pastures are less palatable and less productive for grazing.
Cell or rotational grazing	More even grazing pressure regulates the impact on palatable pasture species and the removal of groundcover. Reduces soil compaction and patchy pasture growth associated with stock camps.	Higher density grazing on wet clay soils can increase soil compaction.
Hay and silage production for off-site use	Provides feed for seasonally demanding times and utilises excess pasture growth.	Removes nutrients from the system, particularly potassium and phosphorus. Soil testing and fertilisers may be required to sustain the productivity of the pasture in the longer term.

Cropping

Farm management practice	Advantages	Disadvantages
Burning stubble or pasture	Reduces pathogen survival in crop residues, kills white snails, a renovation technique for some pasture species.	Loss of organic carbon and soil cover leading to a decline in soil structure and a proneness to erosion.
Mechanical cultivation	Alternative weed control for herbicide resistant species, controls rhizoctonia disease, breaks up plough pans.	Destroys the structure of sodic soils, increases the loss of soil organic carbon, breaks up mycorrhizal filaments.
No or reduced tillage farming	Improves organic carbon and soil biota activity, increases soil cover, improves water infiltration and storage.	Increases the risk of herbicide resistance, and of rhizoctonia and other diseases harboured in stubble.
Monoculture cropping	Returns are better on highest value crops, soil suppressiveness may kick in over time.	Reduced diversity of soil biota, increased risk of pest and disease attack. Reduced diversity of organic carbon reserves in the soil (humus).
Use of inorganic fertilisers	Provides plants with nutrients in the form most immediately available for root uptake, and improves the accuracy of nutrient budgeting.	Increased loss of organic carbon, acidic increase the risk of soil acidification, reduced mycorrhizal infection if applied in excess.
Irrigation	Provides crops with the water needed over the growing season.	Increased leaching via deep drainage, increases the height of the water table inducing water logging and salinity.
Pasture phase	Improves soil physical, chemical and biological condition, alternative weed control for herbicide resistant species.	Requires fencing for stock, returns are comparatively low relative to cropping, heavy stocking on wet soils can destroy soil structure.
Fallow management	Conserves stored soil moisture, reduces the carry-over of some diseases, controls weeds.	Reduced mycorrhizal populations, increased risk of erosion and soil structural decline, reduced organic carbon.
Use of pesticides	Provides immediate control of weeds, pest and disease populations.	Survival and activity of soil biota affected, pesticide persistence can severely limit crop growth.

Exercise 5 – Impact of your management practices

Use the table below to consider and record how you farm management practices could be impacting the health of soils on your property.

Farm management practice	Positive impact on soil health	Negative impact on soil health

Farm management practice	Positive impact on soil health	Negative impact on soil health

Exercise 6 – Management options (host property 2)

This exercise looks at the management options to improve the soil health status of the Day 2 host farm's paddocks and to keep them healthy and productive.

Management options to improve and maintain soil health	Method and frequency of monitoring to determine if strategy is successful

Exercise 7 – Action plan

The information covered in this workshop will apply differently to each business. Take a few minutes now to commit yourself to three actions (steps if you like) that you will take as a result of having completed this workshop.

Your action may be as simple as identifying someone to seek further information from, or it could be to set up a white paint infiltration test or, it could be identifying a change in management you are ready to implement.

What are your priorities for managing the soil health on your property?

The first action I will take as a result of completing this workshop is:

The second action I will take as a result of completing this workshop is:

The third action I will take as a result of completing this workshop is:

List any other actions you wish to note or refer to later.

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