Making More From Sheep

MODULE 6

Healthy Soils

A joint initiative of Australian Wool Innovation and **Meat & Livestock Australia**

CONTENTS

Procedures

		Page
6.1	Manage according to soil capability — develop a simple farm map that includes the main soil types and their potential productivity/management needs.	2
6.2	Maintain groundcover to protect soil and keep the soil 'bugs' healthy — with some tools to help assess groundcover and soil health.	4
6.3	Test soils for key indicators of soil health — how to take and interpret soil tests.	7
6.4	Implement solutions for problem soils — including soil acidity, salinity, sodicity, waterlogging, compaction and non-wetting sands.	9

Tools

		Page
6.1	A guide to classifying land capability	10
6.2	Measuring groundcover and litter levels	11
6.3	Assessing soil health	12
6.4	Taking a soil sample for laboratory testing	14
6.5	Soil health benchmarks and guidelines for managing problem soils	15

6

Healthy Soils

What does this module do for you?

Our thinking about soils and 'soil health' has come a long way in the past decade — soil is not there simply to support plants and their root systems; it's a dynamic, living environment and a vital farm resource in its own right. However, the 'science' of soil health is not very advanced and we don't have a broadly accepted definition of a healthy soil. But we can usually tell one when we see it — healthy soils take in and retain water, look alive and feel crumbly, recycle nutrients and water, and provide a healthy environment in which to grow plants.

This module will help you answer questions such as:

➜ How can I improve my soil to maximise pasture growth?

➜ What will a soil test tell me?

➜ How can I maintain healthy soil biology?

➜ Why is groundcover so important to a healthy soil?

More than any other farm resource, soil health is about protecting and building up the capital so that we, as well as future generations, can continue to live on the interest. No amount of technology, genetics or grazing management will protect a business in the longer term if that business is depleting the soil resources.

Nutrients and soil testing for maximising pasture growth are covered in Module 7.

Procedure 6.1

Manage according to soil capability

Background information

The key principle is to make the best possible use of the farm's resources by targeting areas which give the best return for effort (time and money) to maximise nutrient and water use. Sometimes this will involve building on the strengths in one area of the farm, and at others it will mean targeting weaknesses.

For example, fertiliser will give the greatest economic return if you apply it to paddocks with the most responsive pasture species (ie, legumes rather than grasses and introduced pasture species rather than natives) and responsive livestock enterprises (eg, ewes and lambs rather than wethers). On the other hand, if you are trying to increase groundcover (to reduce soil erosion, water movement and nutrient loss), start with those areas that have the lowest levels.

Key decisions, critical actions and benchmarks

Doing the right thing, in the right place at the right time means knowing where different soil types are, and managing them appropriately. For example, whether or not to fertilise (if so, how much and when - see procedure 7.1 in ***Grow More Pasture***); where and how to sow introduced pastures or plant crops (see procedure 7.3 in ***Grow More Pasture***); how to graze (crash grazing, rotational or set stocking - see procedure 7.2 and tool 7.5 in ***Grow More Pasture***); and such considerations as managing riparian zones, biodiversity, tree planting and groundcover levels (see procedure 5.3 in ***Protect Your Farm's Natural Assets***). Any difficult-to-manage areas such as drainage lines, areas prone to waterlogging, shallow soils and those where salinity, acidity or sodicity may be a problem, need to be identified.

The most practical way of bringing all this soil and paddock based information together is to construct a farm map (see tool 6.1 for one way to do this). Or, if a farm map exists already, a series of plastic overlays can be made to show soil capability information (eg, soil types, depth, slope, fertility, identified problems, current use and productive potential). Often, this is simply a matter of recording existing knowledge about the farm, but it helps build a picture of your resources, allowing you to prioritise actions and inputs.

Ideally, the mapping exercise will provide a picture of the current productivity and potential for each paddock or land class, enabling sheep producers to assess the possibilities and limitations that their soils pose for their farm business. Most critically, does current or anticipated land use match land capability on a paddock-by-paddock basis?

Farm maps can be supplemented with satellite images of your farm (available free from www.earth.google.com). These can add additional insights into farm planning and align production goals with farm capability and productive potential.

Sheep producers who want to take farm mapping and planning further than the relatively basic level outlined in tool 6.1, may find it useful to attend a farm planning workshop or to access soil and land classification surveys through their State Department of Primary Industries/ Agriculture or local CMA or NRM body.

AT A GLANCE

- Identify and understand the different soil types on your property and manage them appropriately
- Make a simple farm map to help build a picture of your resources so you can prioritise your efforts

Signposts

View

Grain and Graze 2 is a GRDC and Federal Government initiative to improve soil health in mixed farming regions of Australia. Visit: http://grainandgraze2.com.au.

Soil Health Knowledge Bank: provides an overview of current soil health knowledge and tools to assess soil condition. Visit: http//www.soilhealthknowledge.com.au/

Attend

PROfarm is the training program developed by NSW DPI to meet the needs of farmers, primary industries, agribusiness and the community. NSW DPI PROfarm short courses are available by contacting:

- 1800 025 520 in northern NSW
- 1800 628 422 in southern NSW
- www.profarm.com.au

The PROfarm course most relevant to this procedure is ***Landscan***®. This course will help you assess your natural resources to better match land use to land capability and to balance production, profit and sustainability.

Landcare on-line: outlines the benefits of farm planning and includes a range of national links to training providers. Visit: http://www.landcareonline.com/page.asp?pID=119

Technical Colleges (TAFE) across Australia offer a range of whole farm planning workshops. Find your local college at: http://www.australiantechnicalcolleges.gov.au/

Many ***catchment management authorities or regional NRM bodies*** sponsor whole-farm planning courses. Find your local organisation at: http://www.nrm.gov.au/about/nrm/regions/index.html

A farm plan including a soils map and land class information will greatly assist management decisions including fertiliser, grazing and fencing

Website link not working?

Go to the Making More From Sheep website:

www.makingmorefromsheep.com.au

and follow the links to updated signposts

Attend a farm planning workshop to add soil and land classification information to your farm plan

Photo source: Lachlan Catchment Management Authority

Procedure 6.2

Maintain groundcover to protect your soil and keep the soil 'bugs' healthy

Background information

In a pasture system, grazing animals account for only about 25% of the living animal tissue in the system. The rest is accounted for by bugs that live in the soil and litter (decomposing plant material that lies on the soil surface). The top 10cm of most soils is particularly rich and contains most of the soil's nutrients, plant roots and living organisms (bacteria, fungi, protozoa, nematodes, earthworms and other soil animals).

Soil organic matter and the activity of bugs and earthworms that feed on it help improve soil structure and water holding capacity, allowing rainfall to penetrate the soil and be available for plants. As a general rule, a one percentage point increase in soil organic matter increases soil water holding capacity by 12mm.

Groundcover (litter and plants), as well as being a forage source, minimises raindrop impact and loss of water by runoff, reducing soil erosion and nutrient loss. Litter on the soil surface can reduce evaporation by up to 1mm per day. High groundcover levels can also be important in weed control, particularly for thistles and Paterson's curse, and for reducing the impact of root feeding grubs such as cockchafers and scarabs.

Introduction

One mm of topsoil lost by erosion equals about 10 tonnes of soil per hectare. This soil can take thousands of years to be replaced through the weathering of parent material. Where topsoil has been lost through erosion, the only way to restore some of the productive capacity is by building up organic matter from plant and animal residues.

Nutrients are also removed in animal products (meat and wool). In a sustainable system, nutrients removed in animal products need to be replaced to maintain the productivity of the system.

AT A GLANCE

- ➜ Maintain groundcover to provide good soil bugs with close to ideal conditions, protect soil from erosion and mimimise water loss
- ➜ Assess groundcover and litter levels at key times and give your soils the 'look, feel and smell' test

Key decisions, critical actions and benchmarks

All of the biological 'action' in the soil relies on providing food together with suitable temperature and moisture conditions. By far the most critical management action which sheep producers can take to protect their soils and 'keep the soil bugs happy' is to maintain high levels of groundcover. This is provided by litter, as well as growing and dead plants. The standard benchmark is 70% groundcover (see figures 6.1 and 6.2, and tool 6.2).

Maintain groundcover

A minimum of 70% groundcover is the accepted benchmark for the high rainfall zone except for sloping country where close to 100% is needed. For the lower-rainfall wheat–sheep zone, where annual pastures dominate, equivalent benchmark values have not been established, but they may be lower than those for higher rainfall areas.

Ground cover protects soil, encourages microbial activity and increases water holding capacity in soils.

Soil organic matter levels are influenced by management, climate and soil type, making it almost impossible to set target levels, but for soil health, more is always better. Generally, woodland maintains higher organic matter than pastures and pastures are higher than land cultivated for crops. Procedure 8.2 in ***"Turn Pasture into Product"*** has tips for maintaining ground cover with grazing.

Attracting good soil bugs

➜ Litter (or mulch) not only helps protect the soil from wind, rain and temperature extremes, it is also the main food source for soil organisms. Litter quality is just as important for the bugs as pasture quality is for grazing animals. Highly digestible, high protein feed is readily consumed and the nutrients recycled but it takes much longer for dead, fibrous stems and leaves to break

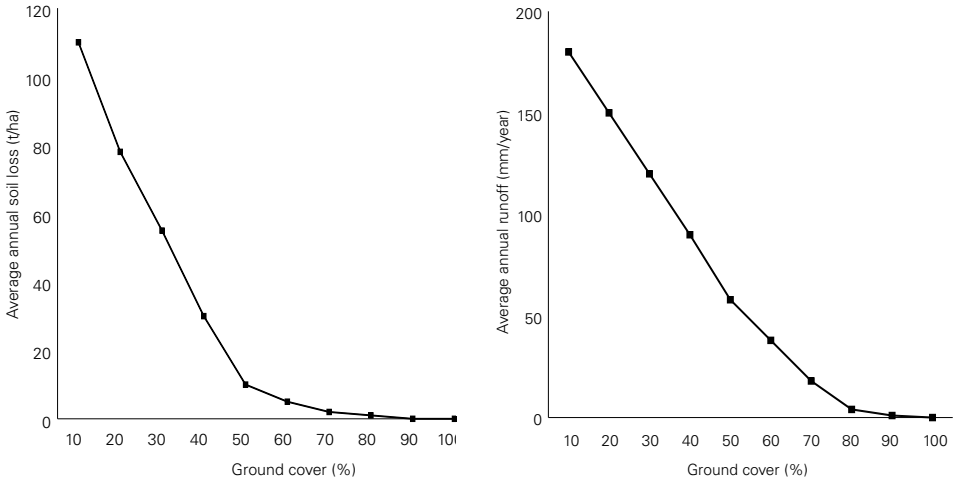

Figure 6.1: In the medium to high rainfall zones of eastern Australia, maintaining 70% groundcover can minimise both run-off and soil loss (Lang, RD (1998). Pasture management for both production and stability. Australian Society of Agronomy).

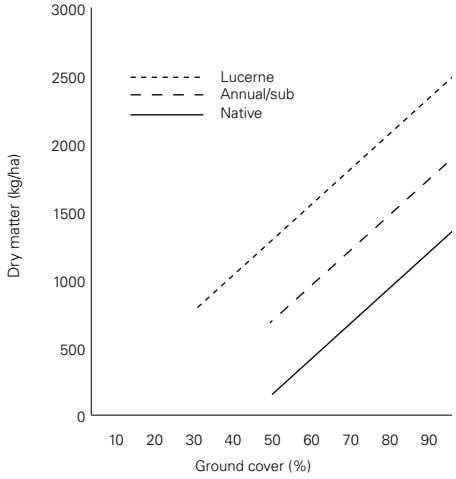

Figure 6.2: There is a strong relationship between available dry matter and groundcover (Lang, RD (1998). Pasture management for both production and stability. Australian Society of Agronomy).

Aim for at least 70% groundcover on flat land, and 100% on sloping country

down and be recycled. When the bugs die, nutrients (such as nitrogen, phosphorus, potassium, and sulphur) are released and become available again for plant growth

➜ Fertile soils: increasing soil fertility generally increases both pasture growth and quality, which leads to more and better quality litter and, therefore, more of the 'good soil bugs' with increased activity.

Earthworms are a good indicator that soil conditions are suitable for micro-organisms. Sample moist soil at the end of winter / early spring. In the high rainfall zone, more than 10 earthworms per spadeful (20cm by 20cm by 10cm deep) indicates an active biological system — that is a stocking rate of more than 2.5 million earthworms per hectare. An earthy smell is also a good indicator as this suggests active and healthy actinomycetes (beneficial soil bacteria).

Soil conditions to avoid

➜ Soil temperatures above 25°C or below 15°C: it is impossible to keep the soil temperature always in this range, but a good litter layer can help

➜ Dryness: most soil micro-organisms live permanently in the water film around soil particles and like their food moist

➜ Regular cultivation physically disturbs the soil and reduces soil microbe levels by decreasing aggregate stability and depleting organic matter

➜ Overgrazing and compaction reduce soil health and can starve the bugs of much needed food, reducing their activity and therefore the rate at which nutrients are recycled

➜ Burning destroys litter and reduces soil organic matter

➜ Waterlogging (as a result of compaction by grazing or cultivating wet soils or sodicity) can reduce the oxygen content of soil, slowing the rate of organic matter decomposition

➜ Acid soils: like plants, the preferred range for most micro-organisms is pH 6 to 7

➜ Some chemicals: herbicides generally have less impact on soil organisms than insecticides, which, in turn, are less harmful than fungicides and nematicides. Most microbes tolerate herbicides with few persistent effects. However, simazine, 2,4-D, paraquat, diquat and MCPA can be more harmful than glyphosate and sulphonyl ureas. Anti-parasitic drenches can have an adverse effect on organisms that first colonise affected dung, but over the entire year the overall effect should be small.

Signposts

Read

The MLA Pasture Health Kit: a field kit for producers to assess pasture health in the paddock. The kit can be ordered from MLA by:

➜ Calling: 1800 675 717

➜ Emailing: publications@mla.com.au

➜ Ordering on-line: www.mla.com.au/publications

Soil Biological Fertility: a Key to Sustainable Land Use in Agriculture (2003). L.K. Abbott and D.V. Murphy (Springer).

The Biology of Soil: a Community and Ecosystem Approach (2005). R.D. Bardgett (Oxford University Press: New York).

Soil Biology in Pasture Systems – Knowledge and Opportunity Audit: a summary of research into the types and function of soil organisms and their interactions in the soil food web under pasture systems. Get your free copy from MLA by:

➜ Calling: 1800 675 717

➜ Emailing: publications@mla.com.au

➜ Downloading from: www.mla.com.au/finalreports

View

MLA Tips & Tools: a large number of titles including: ***the MLA pasture ruler, earthworms, soil health*** and ***groundcover***. Get your free copies of these MLA Tips & Tools by:

➜ Calling: 1800 675 717

➜ Emailing: publications@mla.com.au

➜ Downloading from: http://www.mla.com.au/tipsandtools

Soil Biology Basics: individual fact sheets on soil biology and agriculture. Visit: www.dpi.nsw.gov.au/ and search for soil biology basics.

Living Soils: find out more about the living things in soil and what they do. Visit the University of New England website: www.une.edu.au/livingsoils

Life in the soil: an informative fact sheet detailing life in the soil. Download from CSIRO at: www.csiro.com.au/ and search for life in the soil.

Soil Health: provides background information relevant to soil health and the sustainable use of land for agriculture, horticulture and other practices, including forestry. Visit: www.soilhealth.com

Soil Quality: the USDA Natural Resources Conservation Service web site with a wide array of information about all aspects of soil health. Visit: www.soils.usda.gov/sqi/

Soil Quality: use the tools on this website to better understand soil health. Visit: www.soilquality.org.au

Soil Health Knowledge Bank: provides an overview of current soil health knowledge and tools to assess soil condition. Visit: http//www.soilhealthknowledge.com.au/

Dung Beetles: reports on dung beetles from producer-initiated R&D can be found by typing "dung beetles" into the search function on the MLA home page at: http://www.mla.com.au/

Attend

The MLA EDGE*network*® program is coordinated nationally and has a range of workshops to assist sheep producers. Contact can be made via:

➜ Phone: 1800 993 343

➜ Email: edgenetwork@mla.com.au

➜ Website: www.mla.com.au/edgenetwork

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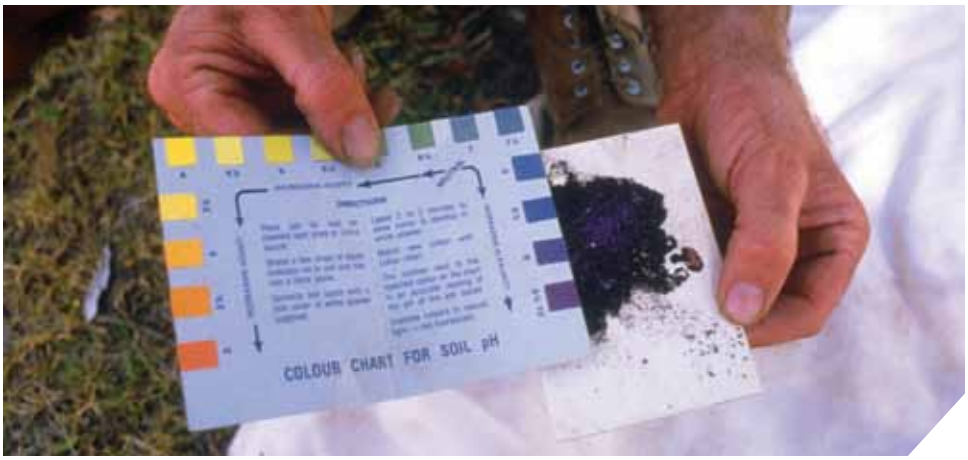
and follow the links to updated signposts

Photo source: Susan Orgill, NSW DPI

Procedure 6.3

Test soils for indicators of soil health



Background information

Standard soil fertility tests can provide a lot of information about your soils and differences between paddocks, no matter what your attitudes and preferences about using fertilisers. Soil nutrient deficiencies and imbalances can have a compounding impact — these soils are likely to have poor plant and root growth, low groundcover and litter levels and, therefore, a lower level of soil organic matter supporting fewer soil organisms such as bacteria, fungi and earthworms. Healthy biodiversity in soil organisms is also important to suppressing pathogenes which cause root disease.

This procedure deals with the issues of taking a soil test, interpreting the results, and identifying soil health problems such as soil acidity or sodicity. Fertiliser decisions, which are essentially about pasture growth and maximising profit, are dealt with in procedure 7.1 in ***Grow More Pasture***.

Key decisions, critical actions and benchmarks

Even without a laboratory test, the number of earthworms present, and/or the 'look, smell and feel' test can give an indication about soil health. Tool 6.3 explains how to do these tests.

Take soil samples for testing

Tool 6.4 provides the directions for taking a soil sample for analysis at an accredited laboratory.

Standard soil tests provide an analysis of:

- Texture, colour, pH (usually in water and in calcium chloride (CaC_2)) and electrical conductivity (EC)
- Phosphorus (P), Phosphorus Buffer Index (PBI), potassium (K), sulphur (S) Calcium (Ca), magnesium (Mg), aluminium (Al) and sodium (Na)
- Calculations of cation exchange capacity (and Na percent of cations), Ca/Mg ratio and Al saturation.

Sub-soils can also be sampled to monitor pH and aluminium. This is important to determine if sub-soil acidity will affect survival of sensitive species like lucerne or phalaris seedlings. For each soil type/paddock, take six subsoil samples from a depth of 30–40 cm or the top of the B horizon in duplex soils.

Interpreting soil tests

Interpreting soil tests as part of developing a fertiliser strategy is discussed in tool 7.3 in ***Grow More Pasture*** which considers the use of phosphorus, potassium, sulphur and nitrogen.

AT A GLANCE

- Use soil tests to help monitor nutrient levels and soil health on different areas of your property

Tool 6.5 is provided to help interpret soil tests for any soil health problems (acidity, sodicity, salinity and trace elements) on your farm.

Spreading lime on acid soils should be carefully evaluated to ensure it is profitable for your current enterprise mix

Photo source: NSW DPI

Signposts

Read

Soil Analysis, an Interpretation Manual: edited by K.J. Peverill, L.A. Sparrow and D.J. Reuter (CSIRO Publishing: Collingwood).

Towards Sustainable Grazing – the Professional Producer's Guide, Chapter 3, Soil Health and Nutrients: a collation of proven best practices for modern grazing enterprises in southern Australia. Order your copy from MLA by:

➜ Calling: 1800 675 717

➜ Emailing: publications@mla.com.au

➜ Ordering on-line: www.mla.com.au/publications

View

Making Better Fertiliser Decisions for Grazed Pastures in Australia: use the Farm Nutrient Loss Index tool (on CD) to create a farm map and assess the likelihood of fertiliser applications being lost from the site. Get your free copy of the booklet and software tool by:

➜ Calling MLA on: 1800 675 717

➜ Emailing MLA at: publications@mla.com.au

Five easy steps to ensure you are making money from super phosphate. This booklet is relevant for the management of temperate legume-based pastures grazed by sheep and beef cattle on acid soils in southern Australia. Download or order your free copy by searching for "Five Easy Steps" on the MLA website home page at: www.mla.com.au

Soil Acidity: a wide range of fact sheets covering soil health issues (not just acid soils). Visit the NSW DPI website: www.agric.nsw.gov.au/ and search for acid soils.

The DAFWA - Soil acidity Guide - google DAFWA soil acidity, it is the first link.

Identifying Gypsum-Responsive Soils: describes the action and benefits of gypsum in dispersive (erodible) clay soils. Visit the DAFWA website: http://www.agric.wa.gov.au/ and use the function on the home page to search for gypsum.

Simple soil tests can inform you of problems and opportunities to improve the productivity and sustainability of your soil resource

Earthworms form worm casts, create soil pores and mix organic matter with soil to increase the soil organic matter content

Photo source: Susan Orgill, NSW DPI

Procedure 6.4

Implement solutions for problem soils

Background information

Most farms have some areas of problem soils associated with soil acidity, salinity, sodicity, waterlogging, compaction, or non-wetting sands. Recognising them is always the first step. If you can correctly identify the problem and its extent, you are well on the way towards implementing solutions. Once a problem area is identified, mark it on your farm plan.

Often the presence of indicator plant species can help to identify the problem (see tool 5.1 for indicators of saline land in ***Protect Your Farm's Natural Assets***).

Key decisions, critical actions and benchmarks

Correct soil problems

Once a problem soil is identified, look for solutions that are feasible, practical and profitable. In some cases, there may be little or nothing that can be done for a problem soil, eg, shallow or stony soils and permanently waterlogged areas. In these cases, uses other than grazing (such as wetlands and biodiversity or conservation areas) may be a more practical option. Alternate uses need to be feasible and, if possible, profitable, and should be considered as part of your whole farm plan.

Use the questions below to work through the options in a generic sense.

1. Can the problem be fixed? If yes, go to 2. If no, go to 4.

2. Is fixing the problem likely to be profitable within your current enterprise mix and is the return on an investment in this soil likely to be comparable to other investments you might make on or off the farm? If yes, take action. If no, go to 3.

3. Is the area small enough that you may want to 'fix it up' even if it is not very economic to do so (you may be seeking aesthetic or other benefits)? If so, take action. If not, go to 4.

4. If it cannot be fixed, or it is not profitable to do so, are there alternative land uses that are practical and profitable? If so, take action. If not, go to 5.

AT A GLANCE

- Problem soils are likely to be associated with soil acidity, salinity, sodicity, waterlogging, compaction and hard pans, non-wetting sands or shallow soils
- Know which of the soils on your farm have these problems and work towards implementing solutions
- Ensure that solutions for problem soils make good economic sense

5. If it cannot be fixed, and there are no alternative land uses that seem profitable, are there alternative uses that can assist in meeting other farm objectives such as conservation or biodiversity enhancement?

Tool 6.5 contains detailed information, assistance with diagnoses and management suggestions for a range of soil problems – acidity, sodicity, salinity, waterlogging, compaction and non-wetting sands.

Tool 6.1
A guide to classifying land capability

There are a number of methods for classifying land capability. These methods attempt to rank the capability of the natural resource using land class as the basis to sustaining production over time. Use the key features and options for the various land classes shown in the following table (adapted from NSW DPI) to identify the pasture and cropping zones on your farm.

Land Class (LC)	Key features	Options
1-2 Arable land suited to intensive (LC 1) and regular (LC 2) cultivation	• Arable • Higher fertility • Minimal erosion risk • Non-acid (pH above 5)*	• For pasture and crop production when rainfall is adequate • High input / high output systems work well
3 Grazing land suited to cultivation for pasture improvement and/or occasional cropping	• Lower to middle slopes • Semi-arable • Lower natural fertility • Moderate acidity (pH 4.5-5)* • Moderate erosion risk	• Groundcover and pasture persistence is important • Maintain pasture base through direct drill options • Occasional cropping
4 Land suited to grazing but not for cultivation	• Middle to upper slopes • Non-arable • Low fertility, shallow soils • Acidic (pH below 4.5)* • Moderate to high erosion risk	• Only suited to permanent pasture • Manage to maintain pasture stability and groundcover • Best suited to lower input management systems • Generally not suited to introduced perennial grasses
5 Land suited to lighter grazing only	• Steep upper slopes • Non-arable • Low fertility, shallow soils • Acidic (pH below 4.5)* • Subject to erosion	• Leave natural or revegetate • Lightly graze to maintain existing pasture / groundcover • Potential conservation areas

* All pH measured by $CaCl_2$

Tool 6.2

Measuring groundcover and litter levels

Measuring groundcover is easy. Either visualise a 50 cm by 50 cm square or make one out of wire. Stand over this area, look directly down onto the pasture and estimate the amount of ground that is covered by plants, litter and dung. Even without any training you will be reasonably close to the right number and photos may help improve your estimate. For each paddock, record groundcover at about 30 random locations, look at the variation (highest and lowest values) and calculate the average.

You can also look for more visual signs of erosion and soil loss such as gullies, rills and tunnelling, washing of soil, dung and litter along fence lines and around plants, muddy and silted dams and muddy streams with high sediment loads. Monitor groundcover and grazing activity regularly to assess progress. You will be amazed how quickly you can make an impact. Be particularly careful in dry or drought periods . Select 'sacrifice' paddocks or construct containment areas for hand feeding, to retain groundcover or build it up in the rested paddocks over time.

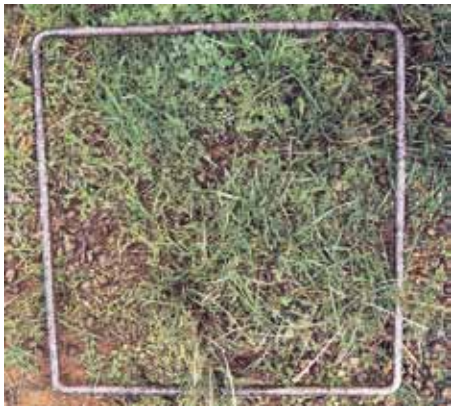
Source: Greg Lodge, NSW DPI

At 20% groundcover

- Run-off water loss = 160mm per year
- Soil loss = 8.5mm per year
- Poor plant production and sustainability
- Low green leaf and plant vigour
- Low water infiltration
- Plants exposed to temperature extremes
- Low litter
- Low microbial activity
- Poor organic matter content
- Poor soil structure and surface sealing of soil

At 40% groundcover

- Still too low
- Run-off water loss = 90mm per year
- Soil loss = 4mm per year
- Poor pasture and soil health



At 70% groundcover

- Run-off water loss = 10mm per year
- Soil loss = 0.3mm per year
- Good plant production and sustainability
- High green leaf and plant vigour
- High water infiltration
- Plant bases protected from temperature extremes
- High litter levels
- Good microbial activity
- High organic matter content
- Good soil structure and soil surface

At 90% groundcover

- Reduced run-off water and soil loss
- On slopes, groundcover should target 100% to retain top soil, nutrients and to promote stable pasture conditions
- Weed colonisation will be reduced when bare ground is removed

Tool 6.3
Assessing soil health

Earthworm sampling tool

1. Using a spade, dig a square of soil to a depth of 10cm. For earthworms it is best to sample in late winter or early spring when it is not too cold or hot and after about 20–25 mm of rain.
2. Sample different areas of the paddock (creek flats, stony ridges etc), taking 8-10 samples in a typical paddock. If the paddock is very variable more samples will need to be taken.
3. Dig up the soil and break the clods and roots by hand. Count the number of earthworms. In high rainfall permanent pastures, more than 10 in a square (spade width about 20cm) indicates high numbers. If the paddock has been recently cropped or cultivated, numbers will be less. Expect lower numbers in drier areas and years.
4. Record the earthworm numbers and sampling location. Sample again in approximately the same place the following year at the same time of the year to monitor any changes. After sampling, replace the earthworms and soil.
5. If you want to identify the types of earthworms that you have, a useful pictorial guide (Worm Wise II) can be found on the Victorian DPI website at www.dpi.vic.gov.au by searching for Worm Wise II from the home page.

'Look, smell, feel' tool

This can be done in conjunction with the earthworm tool or as a separate exercise. Use a spade and dig a square (about 20cm by 20cm) to a depth of 10cm and take 8–10 samples from different areas in the paddock. Record your observations in the table:

Action	Yes	No
The 'Look' Test: Does the soil surface have the right amount of groundcover, ie, >70% in high rainfall areas) and litter (>1,500 kg/ha) Are the plant crowns at or below the soil surface (elevated crowns indicate soil loss)? Any evidence of earthworm castings, worm holes (to aid water infiltration) or spider activity? Is the soil a dark, chocolatey colour (generally, the darker the soil, the higher the organic matter)? Are there lots of plant roots? Would you want to live here if you were a small animal?		
The "Feel" Test – rub the soil between your fingers: Does the soil feel soft and crumbly (coarse, gritty or gravely and stony would indicate a sandy texture and/or low water holding capacity)? Does the soil break easily into particles the size of bread crumbs (indicates good structure and high levels of organic matter)? Is the soil moist, soft and easy to dig up (hard, dry soil indicates low water-holding capacity)? Is the soil surface soft and friable (easily penetrated by the point of a pencil)?		
The 'Smell' Test – pick up a handful of soil: Does a handful of soil smell fresh and earthy?		

The more "Yes" boxes you ticked in the table, the healthier the soil in the sampled paddocks.

While you can't change your soil type, you can influence soil quality by increasing groundcover and organic matter levels (see procedure 6.2).

Use this simple table to record your observations for each of the samples taken in a paddock. Repeat the sampling at the same time next year in similar locations in a paddock. Track the trends over time to see if your management practices are also improving the health of your soil.

Other tests

For sandy soils, earthworm numbers may not be an ideal measure of soil biological health. A range of other methods are available, particularly cotton strip assays, which can provide a measure of how rapid stubble like material may break down in soil. Many labs offer tests to measure soil bacterial and fungal numbers and their activity. However, there is little evidence that the numbers mean anything from site to site or year to year and interpretation of these numbers and ratios is completely subjective.

For more general information on soil quality visit: http://soils.usda.gov/sqi/concepts/soil_biology/biology.html

Tool 6.4

Taking a soil sample for laboratory testing

Sample each soil type/management unit separately, according to these simple rules.

1. Identify a 5 x 5 square metre area and ensure you can locate it each year using GPS or fenceline markers. Make sure that the area is reasonably representative of the typical pasture growth for that soil type. Avoid sheep camps, areas near water points and waterlogged areas.
2. For each soil type take 25–30 soil cores to a depth of 10cm (7.5 cm in Tasmania) from within the 5 x 5 square metre area. The depth is critical as the interpretation of the soil test results is based on a sample of this depth.
3. Air-dry the samples and send them to an accredited laboratory straightaway.
4. Sampling. You may need to wait until at least 10mm of rain has fallen if sampling through normally dry periods. However, avoid sampling immediately following the break of a drought as available nutrients spike to abnormally high levels.
5. Avoid wet conditions when sampling.
6. When comparing soil test results over time, sample at about the same time each year. Soil tests should be taken regularly over time to track results. Use the same lab each time to ensure consistent results.
7. Test before fertiliser is applied or at least 6-9 months after the last application. Adjust application rates accordingly (see procedure 7.1 in ***Grow More Pasture***).

Soil testing

Sample each soil type/management unit separately. Having information on every paddock would be ideal, but if several paddocks are on a similar soil type and have been managed in a similar way, a test from one paddock can be used as a guide for the other paddocks. Take separate samples from within the same paddock if there are vastly different soil types in a paddock or one area of the paddock has noticeably poorer pasture growth.

Send the samples to an Australian Soil and Plant Analysis Council (ASPAC) accredited laboratory as soon as they are taken. Check the ASPAC website for a list of laboratories: www.aspac-australasia.com. To find a lab, go to the section on the ASPAC website titled Certified ASPAC Labs. Make sure the tests being conducted on your soil samples are ASPAC accredited.

Sub-soils can also be sampled to monitor pH and aluminium if problems are suspected. This is important in order to determine if sub-soil acidity will affect survival of sensitive species such as lucerne or phalaris. For each soil type/paddock, take six soil samples from a depth of 30–40 cm or the top of B horizon in duplex soils. Use a shovel to dig down to this depth and take a handful of soil to test.

Many fertiliser companies and rural merchandisers can make soil sampling easier for you, and help interpret the results of the analyses.

Tool 6.5

Soil health benchmarks and guidelines for managing problem soils

Soil pH (acid soils)

A pH of 7.0 is neutral (above 7 is alkaline) so, strictly speaking, any soil with a pH below 7 is acidic. However, many plants prefer slightly acid conditions so the definition of acid soils is those with a pH in calcium chloride of less than 4.6 or less than 5.5 in water. Plant roots are often affected by aluminium (Al) and manganese (Mn) toxicities as these elements are more soluble in acid soils. Waterlogging of soils high in iron (Fe) can also cause toxicity (eg, in the Dundas Tablelands, western Victoria) and, over time, the formation of insoluble oxides can reduce drainage (eg, in the Adelaide Hills, South Australia) and cause a breakdown in soil structure (eg, the tablelands of New South Wales).

The table below shows the preferred soil pH ranges for common pasture species, while the table on page 16 shows the aluminium concentrations at which growth is affected for common introduced pasture species.

Native species, such as wallaby grass/white top (*Austrodanthonia* spp), weeping grass (*Microlaena stipoides*), kangaroo grass (*Themeda triandra*), redgrass (*Bothriochloa macra*), and windmill grasses (*Chloris* spp) are not included as they are rarely sown and limits are not as well defined. Weeping grass is able to tolerate soils with low pH. The many sub-species of wallaby grass have different preferred pH ranges. Kangaroo grass and redgrass grow on low to neutral pH soils, while windmill grasses prefer heavier neutral to alkaline soils.

Most plants and micro-organisms have defined ranges of pH for optimal growth. The optimal range for plants is generally between 5.5 and 8.0 (pH in $CaCl_2$) whereas most soil organisms function best between pH 6.0 and 7.0. All species will grow outside their pH limits, but productivity and persistence may be less than their potential.

Preferred pH range for some common pasture species

Plant species	Soil pH (water)[A]	Soil pH ($CaCl_2$) [B]
White clover	6.0–7.0	5.3–6.3
Sub clover	5.2–7.0	4.5–6.3
Perennial ryegrass	5.3–7.0	4.6–6.3
Annual ryegrass	5.3–7.0	4.6–6.3
Phalaris	5.7–7.5	5.0–7.8
Cocksfoot	5.0–7.5	4.3–6.8
Lucerne	6.0–8.0	5.3–7.3

[A] Acid Soil Action (NSW DPI).

[B] pH ($CaCl_2$), in most soils, pHCa is normally about 0.7 (0.6 in severe acid soils to 1.0 in alkaline soils) units lower than pHw, eg, 5.0 pHw (-0.8) = 4.2 pHCa

Critical aluminium concentrations for growth

Species	Soil test level above which yields are reduced		Sensitivity
	Al (% of Cation Exchange Capacity)	0.01M $CaCl_2$ (mg/kg)	
Lucerne Barley Medics Canola	5	2	highly sensitive
Red clover Phalaris Sub clover Wheat	10	4	sensitive
Woolly pod vetch Ryegrass Some oats Tall fescue Cocksfoot	20	8	moderately tolerant
Oats Triticale Cereal rye Lupins	30	13	highly tolerant

Modified from Acid Soil Action, NSW DPI

Managing acid soils

For soils classified as acidic (pH in calcium chloride of less than 4.6 or less than 5.5 in water), about 1.5–2.5 tonnes of lime per hectare will be required to raise the pH in the top 10 cm by 0.5 of a pH unit. Soils with a lower cation exchange capacity (CEC), such as sands, will respond more quickly to lime than soils with higher CECs, such as clay soils. If your soil test gives exchangeable aluminium values, another rough guide is to multiply the value (cmol/kg) by 1.5 and that is the amount of lime required in tonnes/ha to limit AI toxicity issues, (e.g. 0.5 cmol AI/kg requires 0.75 t/ha lime).

Liming is expensive and before considering it, ask the following questions:

- ➜ Is my pH above 5 (pasture growth response less likely)?
- ➜ Is my subsoil acid (not usually practical or economic to overcome)?
- ➜ Is the pasture aluminium tolerant (if yes, a lime response is unlikely)?
- ➜ Is there something else (eg, phosphorus) that is the most limiting factor (again, if yes, then a lime response is unlikely)?

Because of the need for incorporation, lime application is generally not recommended for native pastures. Some native pastures are very acid tolerant. However, when sowing paddocks with high aluminium levels to phalaris or lucerne, to ensure good establishment, liming should be given higher priority than topdressing other established pastures. From an economic perspective, building soil phosphorus levels should come before liming.

Liming works best when the product is finely ground, the lime is incorporated into the soil (since it is relatively insoluble and so moves slowly down the profile) and where the soil surface is acidic, but the subsoil is not. Soils are best limed six months before sowing a new pasture or during a cropping phase when acid intolerant crops are grown, as these will give a quick return on the investment.

Liming to raise pH also increases the activity of soil organisms, which in turn benefits soil health.

The ***MASTER (Managing Acid Soils Through Efficient Rotations) project*** demonstrated economically viable and environmentally effective practices for managing highly acid soils in the 550-800mm rainfall region of south-eastern Australia. Visit: www.dpi.nsw.gov.au and use the function on the home page to search for MASTER for a series of fact sheets on managing acid soils.

Other state Primary Industry departments also have good acid soil resources.

Soil salinity

Soil salinity is usually assessed by measuring the electrical conductivity (EC) of the soil because conductivity is closely related to the level of salt in the soil solution. Most commonly, the EC is measured in a 1:5 soil/water solution (ECw). The interpretation of this test varies with soil type. Another method is to measure the EC in a denser, soil/water paste (ECe). With this method, the results are independent of soil type and, while it is less commercially available, it is sometimes calculated and reported in soil tests.

Salinity ratings of soils measured by the two methods ECe and ECw

Salinity rating	ECe (dS/m)	ECw (dS/m)			
		Sand	Sandy loam	Loam	Clay
Low	0–2	0–0.15	0–0.18	0–0.2	0–0.3
Moderately saline	2–6	0.15–0.46	0.18–0.55	0.2–0.60	0.3–0.86
Highly saline	6–15	0.46–1.15	0.55–1.36	0.6–1.5	0.86–2.14
Extremely saline	Over 15	>1.15	>1.36	>1.5	>2.14

Responsiveness of a range of pasture species to soil salinity

	ECe (dS/m)		ECw (dS/m)							
	No effect	30% red*	No effect level				30% reduction in growth			
Species			Sand	Sandy Loam	Loam	Clay	Sand	Sandy Loam	Loam	Clay
White clover	1.5	4.0	0.12	0.14	0.15	0.19	0.31	0.36	0.40	0.50
Sub clover	1.5	4.0	0.12	0.14	0.15	0.19	0.31	0.36	0.40	0.50
Perennial ryegrass	5.6	9.5	0.43	0.51	0.56	0.70	0.73	0.87	0.95	1.19
Annual ryegrass	5.6	9.5	0.43	0.51	0.56	0.70	0.73	0.87	0.95	1.19
Phalaris	4.6	8.5	0.35	0.42	0.46	0.58	0.66	0.78	0.85	1.07
Cocksfoot	1.5	6.3	0.12	0.14	0.15	0.19	0.49	0.58	0.63	0.79
Tall fescue	3.9	9.6	0.30	0.35	0.39	0.49	0.74	0.87	0.96	1.20
Lucerne	2.0	6.1	0.15	0.18	0.20	0.25	0.47	0.56	0.61	0.76

*red = reduction

Managing saline soils

Plants growing in saline soils may face the combined challenge of high salt levels, waterlogging that exacerbates the salinity impact, and extreme grazing pressure (because sheep have a strong preference for grazing salty areas). However, a range of pasture species is available (including saltbushes, tall wheat grass, puccinellia and, to a lesser extent, balansa clover and burr medic) that will grow well in saline land, and because the saline sites are usually wetter for longer, these pastures can be highly productive if the salinity levels are not too high. Out-of-season pasture production can be another advantage.

The science and technology for establishing and managing saltland pastures has advanced rapidly in recent years but, because saline sites are very variable, it is a good idea to seek local advice from experienced sheep producers or professionals before implementing a program to establish saltland pastures. Tool 5.9 in ***Protect Your Farm's Natural Assets*** contains the current best practice guidelines for productive management of saline land, including some lower cost options for less affected areas.

Areas that are only moderately salt-effected are more financially viable to rehabilitate than areas that are severely effected. Highly saline soils are relatively unproductive even after rehabilitation.

For more information on saline soils see:

Managing Pastures in Saline Areas: read chapter 10 in the second edition of Greener Pastures for South-West Victoria edited by Z. Nie and G. Saul.

Saltland Genie: a website dedicated to the latest knowledge and tools for saltland management. Visit: www.saltlandgenie.org.au.

Soil sodicity

In technical terms, sodicity is a measure of the exchangeable sodium percentage (ESP), which indicates how much (percentage) of the cation exchange capacity is contributed by sodium. Sodic soils are unstable because the clays contain an excess of sodium, and soils with an ESP above 6% are classified as sodic. Gypsum (calcium sulphate) can reduce the dispersion of clay in soils by replacing some of the sodium with calcium. This can prevent surface crusting and so improve seedling emergence.

If your soil test indicates a high ESP (>6%), you can further test if your soil is likely to respond to gypsum by placing a soil aggregate (about 5mm in diameter) in water and leaving it for 24 hours. If the aggregate disperses and the water is cloudy then a gypsum response is possible. (Accurate prediction of effective rates for gypsum application to overcome sodicity is not yet possible.) Generally, rates of more than 5 tonnes/ha, incorporated into the soil, are used, which would almost never be economical in broadscale pasture situations.

Maintaining and increasing groundcover and organic matter levels are the keys to cost effective, long-term management of sodic soils. Gypsum is useful if you are going to cultivate the soil, but effectiveness is generally less than five years.

For more information on sodic soils see:

Sodic Soils: a range of information sources and management guides for sodic soils. Visit: www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/sodic_soils

Waterlogged soils

Waterlogging occurs when water fills the soil pores and does not drain away, thereby reducing oxygen availability, and reducing plant growth. Waterlogging can be caused by rising groundwater, or an impermeable layer, eg, where two soil horizons meet or a 'hard pan' from excessive cultivation. These are most prevalent on lower slope areas, on duplex and heavy clay soils.

There are no objective tests for impermeable soil layers other than digging a pit and looking:

1. For a bleached layer. This will indicate that the soil is likely to be waterlogged in winter. It is likely that this part of the soil will be poor in nutrients and most likely quite acid
2. At the clay layer and following the guidelines (below):

- A good rule of thumb is that uniform colour down the profile indicates uniform drainage characteristics
- Red soils are well drained, but if they are waterlogged for a period of time, the iron oxide (which is one of the components that gives soils their red colour) is converted to iron hydroxide which is yellow
- Mottling indicates fluctuating/changing drainage characteristics
- The progression (increasing waterlogging) is from red with yellow mottling to yellow with red mottling to yellow with grey/white mottling to grey/white with yellow mottling.

Plant production losses in waterlogged soils may also result from nitrate deficiency (lack of oxygen leads to soil nitrates being converted into a form plants cannot use) and fungal diseases (caused by plant roots in waterlogged soils being more susceptible to fungal attack). Waterlogging effects can be reduced by improving surface and subsurface drainage but you will need to carefully consider the feasibility and economics. Avoid grazing wet areas as pugging and further compaction will occur. Sowing waterlogging-tolerant species such as balansa and strawberry clovers can be a solution in some situations.

For more information on waterlogged soils see:

Managing Wet Soils (online consultant). Go to www.new.dpi.vic.gov.au and click on Agriculture > Dairy > Managing Wet Soils for a range of information sheets on wet soil management.

Drainage: the WA DAF has a collection of publications on the costs, benefits and design of drainage systems for waterlogged areas. Visit: http://www.agric.wa.gov.au/ Click on D from the alphabetical index and scroll down to find drainage systems.

Compacted soils

Soil compaction (an increase in bulk density) can occur as a result of grazing or cultivating wet soils. Routine grazing pressure often increases compaction in the surface 10-15cm. Hard pans can also occur as a result of repeated disc ploughing. To determine if a compaction layer exists, use a spade to examine the soil to about 30cm depth or use a backhoe to dig a deeper soil pit. Check for 'j-rooting' in tap-rooted species (where root growth is impeded by a hard layer) and if there is a mottled blue/grey layer, which indicates waterlogging.

Deep ripping is often proposed as a solution, but it is expensive, time consuming, can have variable results (particularly in sodic subsoils) and is unlikely to be economical for pasture production.

Well managed pastures (especially those with a perennial grass or legume content) will ameliorate compacted soils over time.

For more information on compacted soils: Visit: www.dpi.nsw.gov.au and select Agriculture > National Resources and Climate > Soil Health and Fertility > Soil types, Structure and Condition and look for Protect Your Soil from Compaction.

Non-wetting sands

Water repellence in non-wetting sands is caused by plant waxes that coat the sand particles and prevent water from infiltrating the soil, particularly when it is dry. The result is poor germination and plant growth and, with large bare areas, it can greatly increase susceptibility to wind erosion. Techniques to combat the problem include direct drilling, sowing on the contour and sowing into the bottom of furrows with press wheels to improve soil–seed contact and establishment. Adding clay or cultivating to bring subsoil clay to the surface (delving) has been used successfully, but cost effectiveness depends on clay type and its incorporation into the soil, and on the distance that clay has to be carted from a pit to the paddock. If you think you have non-wetting sand you can approach a lab and ask for the MED (Molarity of Ethenal Dilution) test to assess severity.

Search the internet for more information on non wetting sands.

Notes

For the most up-to-date Making More from Sheep information, including web signposts, products, publications and events, visit **www.makingmorefromsheep.com.au**

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