



NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – southern dryland farmers - Readers' Note

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<http://www.dpi.nsw.gov.au/agriculture/resources/soils/guides/soilpak/south-dryland>

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PART D. PRACTICAL SOIL MANAGEMENT

Chapter D1. Acidity

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D1. Acidity

PURPOSE OF THIS CHAPTER

To explain the cause of acidity and how to manage acid soil

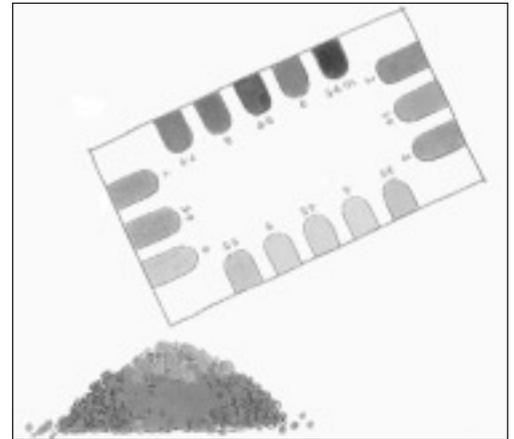
CHAPTER CONTENTS

- causes of acidity
- management
- using lime
- lime quality

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B2. Is my soil acid? Does it need lime?
- B14. Choosing the next crop
- B12. Does my soil need fertiliser?
- C4. Examining plant roots
- C5. Chemical soil tests
- D8. Improving soil chemical fertility



CAUSES OF ACIDITY

Soils acidify naturally as they weather over thousands of years. The acidity in any soil varies according to the type of rock it came from, the length of time it has weathered, and the local climate. As a result, some soils are naturally very acid (low pH) while others are much more alkaline (high pH). Agricultural practices have accelerated the natural acidifying process. (See Figure D1-1.)

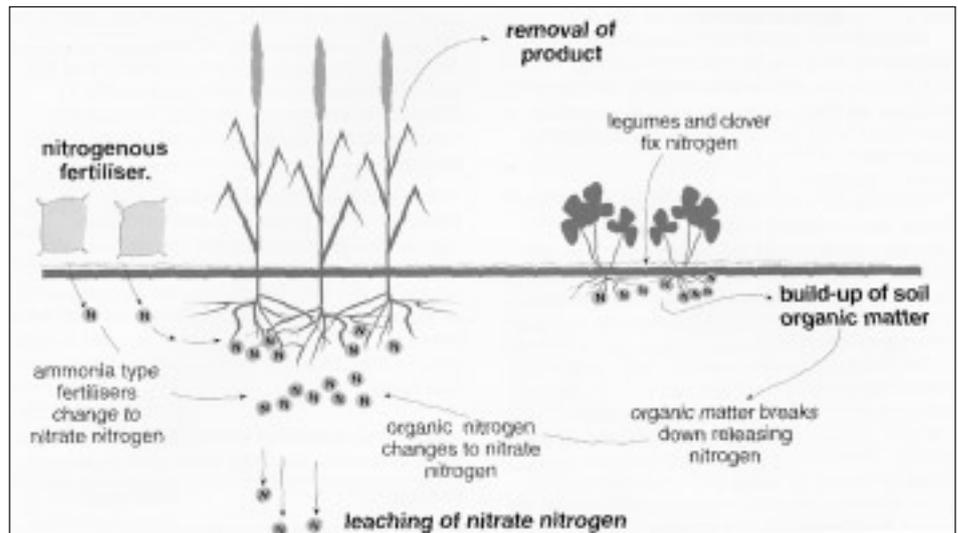


Figure D1-1. The process of acidification

D1-1.) Agricultural practices that have an effect are:

- removing products from the farm such as hay, grain and, to a smaller extent, animal products, which effectively remove alkali from the soil
- adding nitrogen fertiliser, which can add to the acidity problem if the fertiliser is ammonium based and if nitrate is leached before the plant has a chance to take it up
- using legumes. Legumes (for example, clover) produce nitrogen; if this nitrogen is not taken up or used by plants it can be leached (washed) from the soil, increasing acidification.

Table D1-1. Lime required to replace products removed

Produce removed	Lime required(kg/t of produce)
Milk	4
Wheat	9
Wool	14
Meat	17
Lupins	20
Grass hay	25
Clover hay	40
Maize silage	40
Lucerne hay	70

On dairy farms, continuous use of the same paddock as a night paddock causes acidification of other paddocks. The stock graze the whole property, but manure is concentrated on the night paddock. The remainder of the property needs about 25 kg of lime per hectare per year to neutralise this product removal. (See Table D1-1.) Similarly, grazing at a set stocking rate causes acidification because the whole paddock is grazed, but the manure is concentrated at stock camps. The remainder of the paddock needs about 25 kg of lime per hectare per year to neutralise this effect. (Source: Bill Slatery and Anna Ridley, Rutherglen Research Institute, Rutherglen, Victoria.)

MANAGEMENT

Ways to manage acidity include reducing nitrate leaching, choosing a less acidifying fertiliser, managing product removal, growing acid-tolerant species and adding lime.

Reducing leaching of nitrate nitrogen

Nitrate nitrogen is a form of nitrogen used by plants. It is either produced in the soil by the breakdown of organic matter, or supplied as nitrate fertiliser or produced biologically from ammonium-type fertilisers. The breakdown of organic matter and the chemical changes to the ammonium-type fertilisers leave the soil more acid. This effect is usually temporary, because the soil returns to its original pH after the nitrate nitrogen has been taken up by the plant roots. However, if there is more nitrate nitrogen than the plant can use, it drains away (leaches), leaving the soil permanently more acid.

The acidifying effects of leaching nitrate nitrogen can be reduced by adopting farming practices that:

- decrease the level of nitrate nitrogen or
- use water and nitrate nitrogen before they are lost below the root zone.

A particular concern is in the winter rainfall environment, where the mineralisation of organic matter over summer produces high levels of nitrate nitrogen. With the onset of

autumn rains, and with little plant growth or presence this nitrate is leached through the soil, leaving the soil more acid.

In pasture paddocks the accumulation of nitrate nitrogen is reduced by summer-growing perennial grasses that take up nitrate as it is formed and during the early autumn rains. Also, these perennial pastures are preferable to annual pastures because their roots extract water and nitrate nitrogen from deeper in the soil.

Avoiding strongly acidifying fertilisers

Acidification rates can be reduced by avoiding the use of strongly acidifying fertiliser such as ammonium sulfate (Figure D1-2).

Conversely, calcium and potassium nitrate fertiliser can reverse acidification if the nitrate is not leached. However, they are generally not used on a broad scale because of their high cost per unit of nitrogen, and their limited availability.

Splitting applications of nitrogen fertiliser to crops helps to minimise leaching. Any factor that increases crop or pasture growth (such as the use of acid-tolerant plants and correct fertiliser practices) increases the uptake of nitrogen.

Managing product removal

The acidifying effect of removing product, particularly hay and silage, is reduced if the hay or silage is fed in the paddock from which it came. If the hay is sold off-farm, regular liming is the only way to prevent the paddock becoming acidic, since removing hay is equivalent to the removal of alkali from the soil (Figure D1-3).

Use of acid-tolerant plant species

The use of acid-tolerant crops and pastures allows a paddock with acid soils to remain productive. When you are deciding whether to use an acid-tolerant species, check its tolerance to aluminium, as this closely reflects the acid-soil tolerance (Table D1-2). The tolerance does not in itself improve soil acidity; it only allows plants to be grown.

Acid-tolerant species can help farmers to manage soil acidity by:

- maintaining a cash flow if lime cannot be applied when required
- maintaining or increasing production on soils with acid subsurface layers that are too deep to be limed economically, or that are on non-arable land
- allowing more efficient use of nitrate nitrogen and soil moisture
- allowing crop and pasture rotation sequences that match the typical decline of soil pH during a 10 to 15 year liming cycle.

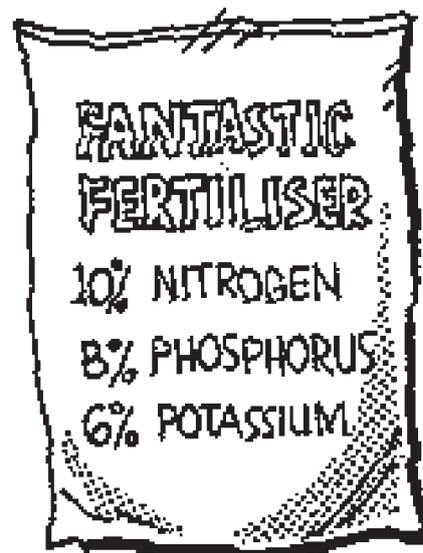


Figure D1-2. Avoid using strongly acidifying fertilisers



Figure D1-3. Removing nutrients from the farm in the form of produce, without replacing them in the soil, will acidify the soil.

Table D1-2. Aluminium-tolerant plants

Highly sensitive	barrel, stand and burr medics; lucerne; strawberry, berseem and Persian clover; tall wheat grass
Sensitive	canola; wheat (Sunstar, Rosella, Shrike, Glebe, Janz); barley (O'Connor, Yerong, Schooner, Lara); red grass (Wagga); wallaby grass (<i>D. linkii</i>); Kenya white clover; murex and snail medic
Tolerant	Brindabella barley; wheat (Swift, Sunstar, Currawong, Hartog, Dollarbird); white lupins; phalaris (Uneta and Australian); tall fescue, cocksfoot (Currie and Porto); white clover; subterranean clover (Seaton Park, Goulburn, Junee, Clare and Nungarin)
Highly tolerant	lupins; yellow and slender serradella; oats; triticale (Empat, Muir, Tahara); cereal rye; Wana cocksfoot; Consol lovegrass; paspalum; kikuyu; subterranean clover (Karidale, Trikkala, Woogenellup); Maku lotus

USING LIME

Applying lime is the only practical way to neutralise soil acidity.

Decisions on rate, frequency and timing need to be made for each paddock. Soil testing the surface and where possible the sub-surface soil ensures more reliable decisions.

For cropping country, the application is best made before a cultivation that fits into the crop and pasture rotation. Often, making an application before the crop or pasture is sown will give the best return from lime. For non-arable land, the availability of funds can often be the most limiting factor, but delaying liming for too long will increase the acidity in the sub-surface soil. Once acidity is in the subsurface soil it is hard to fix. The time of the year when the lime is applied is unimportant.

When you are liming to increase the pH, the amount of lime needed will depend on the texture of the soil and how much of a pH increase you need. See your local agronomist. Often, after liming, responses are small in the first year but increase in the following few years.

Lime has the following effects:

- less available aluminium in the soil
- less available manganese in the soil (sometimes in waterlogged or hot conditions this is not good enough to stop toxicity)
- increased availability of molybdenum
- decreased availability of boron, copper, iron and zinc
- increased exchangeable calcium levels
- improved nodulation of most crop and pasture legumes
- increased breakdown of organic matter, increasing nitrate nitrogen and available sulfur levels

- higher chance of take-all in wheat, causing up to 40% loss in yield
- less chance of other plant diseases found in the soil, including seedling diseases.

LIME QUALITY

The lime used in agriculture comes from naturally occurring limestone that is mined and crushed at several places in eastern Australia. The quality and usefulness of different lime products vary. The finer the lime, the more effective it is.

NEUTRALISING VALUE

The ability of a liming material to neutralise soil acidity is said to be its neutralising value (NV). The nearer the NV to 100% the more pure is the product.

CALCIUM AND MAGNESIUM CONTENT

Pure lime (CaCO_3) is made up of 40% calcium and no magnesium; dolomite has 22% calcium and 13% magnesium; pure magnesite has no calcium and 28.6% magnesium. (See Agfact AC.19, *Soil acidity and liming*, figure 8, for more details.)

When choosing whether to apply lime, dolomite or magnesite, you need to consider the crop type, what nutrients the crop needs to grow, your soil test results, whether the soil is low in an essential nutrient (such as magnesium) and the costs of applying the lime or dolomite.

CHECKLIST

- Take a soil sample and send it away to be tested:
 - Is the soil pH (CaCl_2) less than 5?
 - Is the Al% greater than 5%? Consider liming.
- What is your fertiliser program? Do you add ammonium sulfate and monoammonium phosphate (MAP)?
- Do you rotate your crops with pastures? If you do not, think about adding perennial pastures to your system to use up deep nitrate nitrogen.
- Do you cut silage or hay? Is this removed from the property? If you do cut it, try to keep it in the paddock where it was grown. If it is removed from the property, then replace it with lime.
- How much to apply? Between 1 and 5 tonne/ha – see your local agronomist.
- Do you incorporate the lime? Desirable but not always possible-see your local agronomist.
- Which plants are acid tolerant? See Table D1–2 – see your local agronomist.

D2. Salinity

PURPOSE OF THIS CHAPTER

To explain what salinity is and how to prevent further outbreaks

CHAPTER CONTENTS

- causes of salinity
- off-site effects
- prevention
- case study

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B3. Is my soil saline?
 - C5. Chemical soil tests
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SALINITY

Soil salinity refers to the concentration of salts in the soil solution; these salts are the positive and negative ions that are dissolved in the soil water. Any ions present in the soil water will add to soil salinity. Soil needs to have a low level of salinity, as a soil without salt would contain no plant-available (soluble) nutrients. So when we talk about salinity, we usually mean excessive salinity.

The degree of soil salinity is most conveniently assessed by measuring the electrical conductivity (EC) of the soil solution. The more salt dissolved in the soil water, the more readily it will conduct an electrical current. The current flow is measured with an electrical conductivity meter, and the result is usually expressed as deciSiemens per metre (dS/m). The effective EC is calculated according to the soil type and is referred to as the EC_e .

CAUSES OF SALINITY

Salt occurs naturally in many soils in Australia. Sea spray enters the atmosphere and can be carried long distances inland on the wind. Minerals in rocks contain elements that can form salt and, when those minerals decompose by weathering, the salts are released. Sedimentary rocks such as sandstone may contain high levels of salt if they were laid down when the sea or salt lakes covered that part of the land.

Normally, the salt is deep in the soil. Before European settlement, natural vegetation had evolved to use up most of the rainfall, and little was left to drain below the root zone. Since then, large-scale clearing of trees and replacement with shallow-rooted plants, as well as overgrazing, has allowed more rain to pass through the root zone and reach the ground water. Where this happens, the watertable can rise and bring dissolved

salts up with it. When the watertable is within 1 to 2 m of the soil surface, the water and salts rise to the surface by capillary action, causing the root zone to become saline. As the problem worsens, saline water may begin discharging into creeks and other low-lying areas.

PROBLEMS CAUSED BY SALINITY

Water is the principal agent of salt transport, and evaporation and transpiration by plants are the agents of concentration. Salinity works against plant water uptake. The greater the concentration of salts in the soil solution, the harder the plant has to work to take up water.

Excessive amounts of sodium chloride (common salt) also dilute and displace plant nutrients, reducing soil fertility. At high concentrations, chloride is toxic to plants.

Plants vary in their tolerances to salinity, but even low levels of salt leave fewer options for crop choice.

Salinity is also linked with:

- dispersion and soil structure decline following rainfall or reclamation. This causes cultivation problems.
- high levels of salt in livestock drinking water
- soil waterlogging
- increased erosion due to loss of ground cover
- clearness of water in streams and dams, because high salt levels settle the sediment.

PREVENTING DRYLAND SALINITY

Dryland salinity is a catchment-wide problem that does not stop at property boundaries. Some farming practices may be adding to the problem in a catchment (off-site), while the farm itself may not be directly affected (on-site), by salinity. If the problem is disregarded, the land resources degrade and the costs are handed on to another generation.

Salinity control involves all landholders in the catchment. Join your local Landcare group, or form a new one. Cooperate with your neighbours to tackle the problem with a Total Catchment Management approach. Find out where the main recharge areas are (often at the top of the catchment), and start remedial action there, working down. Contact your local Salt Action Officer (Department of Land and Water Conservation and NSW Agriculture) or Catchment Manager (Department of Land and Water Conservation) for help.

The first step in preventing salinity is to increase the productivity of the farm!

If crops and pastures are managed to ensure good, even plant populations and vigorous growth, there will be higher water use and a reduction in unproductive losses of water due to evaporation, drainage and run-off. High crop and pasture production and a decreased risk of salinity go hand in hand; high producing crops use more water and reduce the risk of deep drainage.

The basis for increasing farm productivity is to prepare a whole-farm plan. This enables you to assess the needs and production capability of each area of the property. The property can then be divided into the large areas to be managed for maximum production and the small areas that need rehabilitation. Give first priority to the good management of productive areas of the farm. Only when that is assured should resources be diverted to remediation of the salted areas. Two important tools in the fight against salinity are perennial pastures and farm trees.

PERENNIAL PASTURES

Perennial plants have longer growing seasons and deeper root systems. They are most effective in extracting water and thus preventing deep drainage, and should be included in the pasture phase of all farming systems.

Native perennial pastures have an important place in permanent pastures in the high rainfall (> 600 mm/y) areas. Wallaby grass (*Danthonia* spp.) and weeping grass (*Microlaena stipoides*) are two native grasses that will spread under suitable management and provide productive pastures while reducing recharge. Further information can be obtained from *Managing High Rainfall Native Pastures on a Whole Farm Basis*, by Peter Simpson and Col Langford (1996) (available from NSW Agriculture).

Where lucerne can be established, sow it into the pasture phase of the cropping rotation to dry out the subsoil.

Sow perennial pastures or annual–perennial mixes on all laneways and other uncropped areas. These pastures grow well into the spring, drying the soil to depth and so reducing the amount of water finding its way into the subsoil. At the same time, they contribute to farm productivity.

TREE PLANTING

Native trees are effective water users. They can take up more than the annual rainfall in the right situation, and also use ground water, thus lowering the watertable. Remnant native vegetation and tree lots can help to reduce recharge by intercepting ground water as it moves down-slope. Take into account the local rainfall, the soil type and the salinity of the ground water when choosing tree species for your farm. Planting trees on saline sites (that is, discharge areas) is risky, as they must withstand both the salt and waterlogging. Water samples collected from piezometers and tested for EC can be used as a guide to the degree of salt tolerance that trees will need. EC tests are cheap insurance when compared with the cost of tree planting. Local foresters and Greening Australia can help with species selection and the supply of seedlings or seed.

Trees should be planted in areas identified on the whole-farm plan. This ensures that the trees are planted where they will do the most good without disrupting farm operations. In hilly country the ‘break of slope’ where the hillsides merge with the valley floor is a zone where a tree line will provide maximum benefit in terms of water uptake.

Trees provide additional benefits such as shade for stock, windbreaks for stock and crops, increased biodiversity and an improved appearance (and thence value) of the property. While woodlots provide timber for fencing and firewood, they are limited in their contribution to farm profitability. Over large areas, deep-rooted perennial pastures should be the first option.

REMEDIATION OF SALT AFFECTED AREAS

Salinity control must be addressed on a whole catchment basis. Early recognition of salt-affected areas is vital. If there are high levels of salt on the surface of bare patches, a reduced range of plants will grow on that site. Your local catchment manager will help you install piezometers to monitor the level of the watertable. Management of recharge in the higher parts of the catchment aims to ensure that the watertable stays below the soil surface of the down-slope discharge areas for most of the year. Only then can vegetation be established.

If possible, establish salt-tolerant species before the area becomes bare. This will reduce the risk of soil erosion, minimise surface evaporation and lower the watertable.

Fence off the discharge area before stabilising it. Keep stock off revegetated areas for at least a year. Once salt-tolerant species have been established they can be grazed for short periods to maintain healthy growth.

SALTBUSH

Saltbush sown in hedge lines is a viable alternative on the more saline sites where the soil salinity (EC_e) is above 8 dS/m.

Mounding up the soil before planting provides a salt-reduced, drier environment for plants and is extremely important for saltbush if the site is waterlogged. Once the saltbush is well established, salt-tolerant pastures should establish between the mounds. Well-established saltbush will tolerate heavy grazing for short periods, but must be rested after grazing. Ensure that stock have access to plenty of fresh water and areas of dry grass or stubble. This will dilute the salt taken in when they are grazing salt-tolerant species such as saltbush or blue bush.

Rows of saltbush can provide a good windbreak. Saltbush can be substituted for trees in drier areas, and should be considered for the lower outside row in multi-row windbreaks in other areas.

WATER QUALITY LIMITS AND USES

Some water quality limits are listed in Table D2-1.

Table D2-1. Water quality limits

	Electrical conductivity (dS/m)	
	Absolute limit	Desirable limit
Humans	2.5	0.83
Poultry	5.8	3.20
Beef cattle	6.6	6.40
Adult sheep on dry feed	23.0	9.60

A SALINITY CASE STUDY

In 1995 Barbara Carmichael of the Downside Landcare group won the NSW NLP Independent Landcare Award, qualifying her for the national level in 1996.

Barbara and Noel Carmichael have been farming 455 ha on 'Fairfield' for 36 years. During this time they have been very conscious of the environmental concerns that have arisen in the catchment. On 'Fairfield' the watertable rose 6 m in 14 years, and by 1989 it was within 2 m of the surface. By 1995 the water table had reached ground level. The Carmichaels have been doing every thing they can to lower the rising watertable.

Major action began in 1990, when an area of 7 ha was fenced off and trees were planted, along with strawberry clover and phalaris. Since 1990 every year, except during the drought year of 1994, 1000 trees have been planted in the area. The site is prepared every February when machinery can get on to the site. Deep ripping occurs a year before each tree planting begins. In the wettest areas trees have been placed on mounds. Tree rows are 4 m apart to allow a four-wheel-drive motorbike to spray for weeds in spring. Plastic tree guards are used to protect the trees from frost and hares. In 1992 the surrounding paddocks were limed and sown to lucerne.

In 1993 salinity indicator species such as sea barley grass were discovered on another 7 ha area, which was too wet to drive on. In May of that year, tall wheat grass, strawberry clover, phalaris and puccinellia were direct-drilled into the site. This area was fenced off and not grazed until spring, 1994, during the drought.

In 1996 the watertable fell to 0.3 m below the surface and has continued to fall. In 1998 the watertable was 1.5 m below the surface. Barbara said:

Dryland salinity can be reversed with proper management. Our only regret is that we should have been liming, establishing lucerne and planting our trees in the 1970s. It's easy to be wise after the event.

SALINITY CHECK LIST

See Chapter B3 for more information on salinity indicator plants.

- Look for areas of poor growth, low yield, waterlogging, very clear dams, indicator plants, bare areas or dying trees.
- Have the electrical conductivity of your soil tested.
- For moderate- to high-salinity areas:
 - Fence off the site; remember that areas of salt can increase quickly, so allow extra space around the salt area
 - Exclude stock (until salt-tolerant species can be crash grazed).
 - Try to establish salt-tolerant plants to use water and help with leaching, to protect the ground from erosion and reduce waterlogging. You may need to till or deep-rip to assist with germination.

- Redirect run-off with diversion banks and other soil conservation works. See the Department of Land and Water Conservation for more information.
- Plant deep-rooted perennials and trees to use the water before it reaches the watertable.

D3. Sodicity

PURPOSE OF THIS CHAPTER

To explain how sodicity affects soils in southern New South Wales and define ways to manage affected areas

CHAPTER CONTENTS

- causes
- problems caused by sodicity
- management
- case study

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B4. Does my soil need gypsum?
- B5. Poor seedling emergence
- B6. Does my soil form a surface crust?
- C1. Examining the soil profile
- C3. Soil types and landscapes
- D4. Maintaining and improving soil structure
- D6. Conservation farming
- E1. Soil structure
- E2. Soil-structure rating system



SODIC SOILS

Sodic soils are commonly found in our area. In recognition of their importance, and of the special problems that they have, these soils have been grouped together in the latest soil classification and given the name sodosols. There are some other soil groups, such as cracking clays with sodic surface soils, that are also a problem.

Sodic soils contain clay that swells and disperses when wet. Dispersion shows up as a fine suspension of clay in the soil water. Soils with sandy topsoil and dense clay subsoils may have severe problems at depth without any surface signs.

The clay disperses because of an excessive proportion of sodium in the exchangeable cations attached to the surface of the clay.

Soils with 6% or more of sodium as a percentage of the total exchangeable cations are sodic.

Sodicity is a distinctly different problem to salinity. Sodic soils have excessive amounts of sodium attached to the clay, whereas saline soils have excessive amounts of salt (sodium chloride) loose in the soil water.

☞ See Chapter C3 for more information on problem soils.

CAUSES OF SODICITY

Soils can be naturally sodic because sodium salt has been left in the soil by geological processes. Soils can also become sodic due to management practices, for example, the use of high-sodium bore water. When such water is used for irrigation or watering stock, sodium is added to the soil. This may cause the soil to become sodic.

Animal manure from feedlots and waste products may contain sodium, the concentration depending on the animals' diet. Spreading these materials over paddocks will contribute to soil sodicity.

PROBLEMS CAUSED BY SODICITY

Surface soil crusting

Sodic clay soil at the surface disperses when wet. As it dries, the dispersed clay packs down tightly, leaving little pore space for water or air entry. A clay crust forms on the soil surface, causing problems with water and air entry and seedling emergence.

Subsoil waterlogging

The extreme swelling of the sodic clay closes off subsoil pores, reducing drainage and root entry. Rainwater rapidly percolating to the top of the subsoil causes dispersion, and the clay is carried into the subsoil, where it clogs soil pores, further reducing drainage. As a result, a shallow 'perched' watertable will develop at the bottom of the topsoil. This waterlogged area lacks oxygen, causing root death and the loss of soil nitrogen.

Erosion

Erosion is a serious problem on sloping sites if the sodic subsoil is exposed. Once the clay is exposed, rainwater running over the surface causes rapid dispersion, and the clay is carried off with overland flow. This results in steep-sided gullies where the gully walls fret away, undermining the more stable topsoil. Reclaiming these gullies means expensive mechanical reshaping and covering of the slopes with topsoil that can then be revegetated. Get advice from your local Department of Land and Water Conservation office.

Tunnel erosion can also occur on slopes when water flowing through natural soil cracks or pores (or holes left by decaying tree roots or rabbit holes) carries away clay, undermining the surface soil, which eventually collapses to form a new gully.

Prevent erosion on sodic soils by protecting the stable topsoil so that the subsoil is not exposed. Do not overgraze, and try to prevent sheep tracks deepening to expose the subsoil. Take care with roads and contour banks, so that the subsoil is not exposed to excessive water flows.

Farm dam failure

Farm dams constructed from sodic clays are very prone to failure. If the clay at a potential dam-site disperses in water, consult your local Department of Land and Water Conservation officer.

☞ See Chapter C1 for details on the dispersion test.

MANAGEMENT OF SODIC SOILS

Short- to medium-term improvement can be obtained by topdressing with gypsum (calcium sulfate). Gypsum is usually spread on the soil surface during summer or autumn, and is incorporated by rainfall. Deep ripping to incorporate gypsum into the subsoil is rarely cost effective, except if high-value horticultural crops are to be grown.

The rate applied will depend on the purity of the gypsum available and the degree of sodicity. Generally, 2.5 t/ha is an adequate rate for broadacre cropping. Due to its greater solubility, gypsum will need to be applied more frequently than lime (about every 2 or 3 years for gypsum).

Gypsum readily dissolves in any rainwater or irrigation water, preventing dispersion by increasing the salt content of the water. At the same time, calcium from the gypsum displaces some of the sodium from the surface of the soil, allowing it to be flushed away and thus reducing the exchangeable sodium percentage at the surface layer. This leads to a longer-term improvement in soil stability.

Lime (calcium carbonate) also supplies calcium and is preferable for the strongly acid soils (pH CaCl_2 less than 5) widespread in this area. Lime is not recommended for alkaline soils. Gypsum is more soluble than lime and is more commonly used; it acts quicker but leaches sooner. Lime has a slower acting but longer lasting effect. A combination of gypsum and lime may be a good compromise on soils with a pH CaCl_2 between 4.8 and 6.

PRECAUTIONS WITH GYPSUM

Caution 1. Gypsum application can, by improving infiltration and drainage, increase the leaching of nitrogen and so induce nitrogen deficiency. Monitor soil nitrogen status, and be prepared to use a little more nitrogen fertiliser.

Caution 2. Because of the increased infiltration, gypsum can increase groundwater recharge and worsen a salinity problem. This could be a problem where watertables are already dangerously high. Do not apply gypsum to areas that might be used to grow rice.

Caution 3. Once the gypsum has improved the physical condition of the soil, it is necessary to adopt better management practices such as reduced tillage and stubble retention; these will increase the organic matter content of the soil. Vigorous pastures are a good way to add organic matter to the soil and improve its structural stability. The organic matter binds the soil together, reducing dispersion, and greatly increases the soil's cation exchange capacity, diluting the effect of the sodium.

CASE STUDY

David and Nicole Chamberlain bought 'Inglebrae West' in 1995. The 380-ha property, near Coolamon, had been traditionally farmed with a one-way disc, lacked the benefit of fertiliser applications and was suffering from a weed problem.



Nathalie Brown

David Chamberlain

It didn't take long to discover that the red brown earths at 'Inglebrae West' had different characteristics to those of the red earths found at the family's Downside property. After David and Nicole found it difficult to scarify the area, soil tests were conducted in early 1996 to identify the available nutrients in the soil.

David used reduced tillage methods to help achieve weed control. In 1996, canola was planted, but the crop was not as good as they had hoped. Examining the canola at the end of the season, they discovered that the roots of the crop had been unable to penetrate a compacted layer in the soil.

David approached some of his neighbours, hoping to learn from their experiences. As a result, in early 1997, he applied gypsum across the property, at a rate of between 400 kg/ha and 1 t/ha. Because gypsum is highly soluble and works its way into the soil quickly, NSW Agriculture staff advised David not to go to the expense of deep ripping, so he spread the gypsum on to the surface of the paddock.

Rosella wheat was planted in autumn with minimum disturbance. Although it was a very dry year, it was much easier to get onto the paddock

'The gypsum turned cement into plasticine,' said David's father Max. 'That area has gone from the worst on the property to the best.'

By 1998 David could push a screwdriver straight into the soil, and there were no penetration problems.

He direct-drilled lupin into the paddock 1999. After 70 mm of rain in June, the property, which used to be a lake after heavy rain, had no water lying on the surface.

SODICITY CHECKLIST

- Look for indicators of soil crusting, dense soil, waterlogging and toad rush.
- Do a dispersion test. (See Chapter C1.)
- If your soil disperses it is best to get a lab test done. Collect a soil sample following the do's and don'ts of soil testing (Chapter C5). You will need to take a sample at 0 to 10 cm, then one at 10 to 20 cm or deeper.
- If your sample returns with an ESP > 6 then you will need to speak to your local agronomist about gypsum suitability and quality.
- Try test strips of 2.5 t/ha and 5 t/ha that cross over and have a section of 7.5 t/ha.
- Work out the cheapest and most effective gypsum by:

$$\frac{\text{delivery cost} \times 100}{\text{gypsum purity}} = \text{real cost to farmer}$$

Remember, it is very important after applying gypsum to grow a vigorous plant to increase organic matter and retain the soil's stability.

D4. Maintaining and improving soil structure

PURPOSE OF THIS CHAPTER

Soil structure is a major soil management problem. This chapter describes some soil management methods that will help you to avoid soil structural problems.

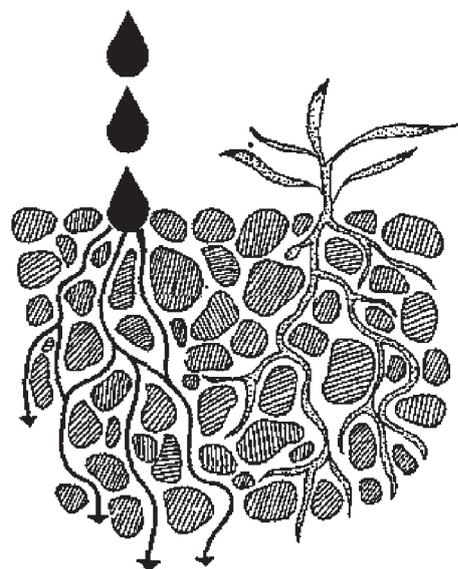
CHAPTER CONTENTS

- importance of soil structure
- the difference between structure and texture
- effects of tillage
- soil management

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- D6. Conservation farming
- E1. Soil structure
- E2. Soil-structure rating system



SOIL STRUCTURE IS IMPORTANT BECAUSE:

1. It is the plumbing system for the soil that controls:

- water flow into, and through, the soil (infiltration, drainage and surface ponding can affect runoff, erosion, soil tilth and trafficability)
- air flow (can affect soil aeration, waterlogging)
- water storage (affects the available water-holding capacity).

2. It provides space, and a protected home for:

- roots (root growth and distribution)
- seed germination
- plant emergence
- soil fauna and flora
- plant establishment (coleoptile elongation and emergence).

3. It affects farming operations:

- trafficability for machinery (the time after rain before machinery can get back on the paddock)
- response of the soil to tillage (such as draught needed to pull machinery, tine penetration, friability/cloddiness, susceptibility to smearing).

4. It can affect the impact of land-use on the environment:

- amount of run-off and erosion (devaluation of soil quality on farms, and accumulation of sediment and nutrients in rivers and water storages)
- amounts of nutrients in drainage from the soil (especially nitrogen and phosphorus in ground water)

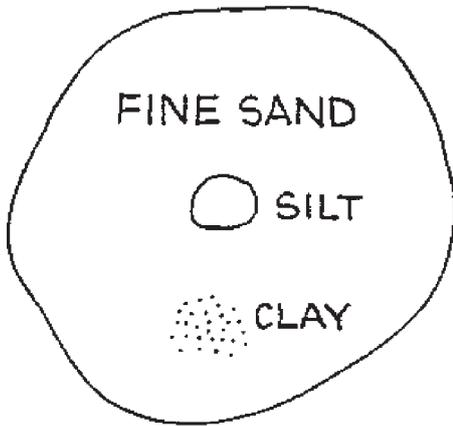


Figure D4-1. Soil particles are divided into three groups, depending on their size.

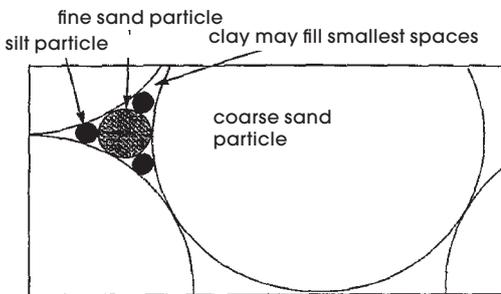


Figure D4-2. Soil structure is determined by soil texture.

Tom Green, CSIRO

- amounts of pollutants removed from farms in erosion, runoff or drainage (herbicides, heavy metals or biological hazards from effluent or waste materials added to soils).

Often if the soil structure is in a satisfactory condition, you don't notice any problems with these things and take them for granted. When they don't work well there is no doubt a soil structure problem, and this can cost you yield and money, or can cause problems with erosion, tillage or spraying operations. Alternatively, the problems can be seen by others in the sediment, nutrients or pollutants in rivers and water storages.

SOIL TEXTURE AND SOIL STRUCTURE — WHAT'S THE DIFFERENCE?

Soil texture and soil structure are different, although they are sometimes confused.

Soil texture describes the relative amounts of different sized building blocks in the soil. Soil structure is the way in which soil particles are arranged into larger units, and the nature of the spaces between the soil units.

These building blocks are the solid soil particles that make up the soil and they vary in size and in chemical composition. The particles in the soil are divided into three groups based largely on their size: sand, silt and clay (Figure D4-1). The size of the particles determines how the particles behave in the soil. When wet soil is squeezed, the large, inert sand particles give a grainy or gritty feel to the soil, the silt size particles give a smooth silky feel to the soil, while the clay particles are the most chemically active and give the soil a heavy, plasticine feel.

Texture determines how soil structure is formed in a soil and also the retention of nutrients and water (Figure D4-2). The more clay in the soil, the more surface area within the soil (see Table D4-1), and so the higher the chemical (nutrient retention) and physical activity (shrinking and swelling) in the soil.

The clay type is also critical. Soils formed from weathering basalt are rich in smectite and montmorillonite clays. These have a very high surface area and high chemical and swelling activity, and are the basis of these soils' high fertility. Soils forming on the shales, sandstones and granites typical of this area contain mainly kaolinite clay. This 'pipeclay' has a lower surface area and much lower chemical and physical activity.

Table D4-1. Soil particle sizes that make up soil texture

Soil particle	Particle size	Relative surface area (chemical activity)
Clay	< 0.002 mm (very small) (If shaken up in water clay particles settle less than 10 cm in 8 hours.)	1 000 000
Silt	0.002 to 0.02 (small)	10 000
Fine sand	0.02 to 0.2 (can see these)	100
Coarse sand	0.2 to 2 mm	1
Gravel	> 2 mm (small rocks)	

TEXTURE AND MANAGING SOIL STRUCTURE

Texture can be used to give simple grouping of soils that summarise the major aspects of managing soil structure. (See Table D4–2.)

Table D4–2. Relative importance of mechanisms of soil structure development based on soil texture (adapted from Murphy B. W. and Lawrie J. L. 1996, What surface soil is that? Extension brochure, NSW DLWC, Cowra)

Mechanism for the development of soil structure	Light-textured soils	Medium-textured soils	Clays		
	sands, loamy sands, sandy loams, fine sandy loams (< 15% clay)	loams, silty loams, sandy clay loams, clay loams (15% to 35 % clay)	light clays, medium clays, heavy clays (> 35 % clay)	low activity sodic	high activity non-sodic
Wetting and drying cycles resulting in shrinking and swelling activity	minimal	low to moderate	moderate to high	very high, maximum	
Biological processes such as plant growth, soil fauna activity, soil microbe activity	maximum	moderate to high	moderate	minimum	

The light- and medium-textured soils are fragile soils, because they have a low potential to develop soil structure through wetting and drying cycles. The development of soil structure depends on the amount of biological activity occurring in the soil. This biological activity includes plant growth, which provides surface cover, and also root growth, soil fauna activity and soil microbe activity. Managing the structure of these soils requires proper management of the biological activity within them, and so proper management of plant growth, surface cover, root growth, organic carbon levels, soil fauna activity and soil microbe activity. In clay soils, the relative amounts of exchangeable cations, especially sodium, are critical in determining soil structure. Managing these soils requires good management of the cation levels in the soil.

☞ See Chapter C5 for more information on cation levels in soils.

TILLAGE IN THE WINDOW OF OPPORTUNITY

How a soil responds to tillage, and whether it is in a condition to support machinery traffic, are strongly influenced by soil structure. Obviously the weather is the major influence, but a well-structured soil will have a wider window of opportunity. It will be in a friable condition over a wider range of moisture contents, and will be able to support the machinery sooner after a period of rainfall. This simplifies management at sowing time and ensures that more of your crops are sown at the best time for maximum yield.

Friability

Friability determines the response of soil to tillage. It is a measurable, physical property of the soil. It is actually a measure of how the strength of the aggregates (structural units of the soil) changes with size. In a friable soil, the smaller aggregates (about 2 mm in diameter), are much stronger than the larger aggregates (over 20 to 50 mm in diameter). This

means that when a friable soil is cultivated it readily breaks down into the smaller aggregates. In very friable soils, such as self-mulching soils, the soil will break down into the smaller aggregates naturally, without any tillage, because the smaller aggregates are strong, and the larger 'aggregates' (over 20 to 50 mm in diameter), which are weaker, fall apart. This should not be interpreted as aggregate instability, as tests for aggregate stability are carried out on aggregates of 5 to 10 mm diameter.

In a non-friable soil, the aggregate strength does not change with aggregate size: large aggregates have the same strength as small aggregates. The consequence of this is that the large aggregates do not break up or fracture with tillage, and large clods 100 to 200 mm are produced. This increases the draft on the tines tremendously, but also results in a poor seedbed with little seed-soil contact; it usually means that further tillage operations are required to break down the clods to form a suitable seedbed. Each one of these tillage operations can reduce the level of organic matter in the soil, losing soil moisture, killing soil fauna, and destroying any pores developed by roots or soil fauna. The sodic surface soils in the region, or other soils with very low organic carbon levels, are the most typical non-friable surface soils.

A soil tilled when too wet smears and packs down, whereas a soil that is too dry has weaknesses, so that it either breaks into large clods or shatters into dust. Most soils are friable at some moisture content, usually near the 'plastic limit'.

The 'plastic limit' is an engineering term; it is the lowest water content at which a particular soil will still bend rather than break when disturbed.

Just drier than the plastic limit, the soil is strong enough to resist plastic failure or smearing, but the soil strength is low enough for larger aggregates to be fractured by the tillage operation. The critical factor is the range of moisture contents at which the soil is in a friable condition. A well-structured soil remains in a friable condition over a wide range of moisture contents, whereas a poorly structured soil remains friable for only a narrow range of moisture content. For example, sodic surface soils are sometimes called 'Sunday soils' or even 'lunchtime soils', because they remain in a friable condition for such a short time after the soil dries out after rainfall. On the other hand, some of the red earth soils derived from parna, and the self-mulching clay soils, remain in a relatively friable condition, even when the soil is dry.

Trafficability

The timeliness of many farming operations is determined by the ability of the soil to carry traffic. If a soil remains saturated for a long time, trafficability will be a problem, and the timeliness of operations such as sowing or weed spraying can be severely affected. A soil with good structure should be sufficiently permeable for water at the surface to flow relatively rapidly deeper into the soil. A soil with soil structure problems is likely to pond water and hold the water at the soil surface for long periods, especially in late autumn and winter, when

evaporation is low. The soil will be in a non-trafficable condition for long periods.

A further factor influencing trafficability is soil strength. A tilled soil has a lower strength than a non-tilled soil, and usually the untilled soil will be in a trafficable condition and able to support the passage of machinery sooner after rainfall than a tilled soil. If a tillage operation has cut off the large pores taking water from the surface deeper into the soil, or has smeared or compacted the soil at the depth of tillage, the tilled soil will also remain wetter for longer than the untilled soil.

MANAGING SOIL STRUCTURE

Good management of soil structure means that the soil should be maintained in a condition that allows the functions controlled by the structure of the soil to continue in an effective manner. There are several basic principles that form the basis for the management of soil structure.

Basic principles

- Identify which kind of surface soil you have, so that you can identify the mechanisms that can be used to improve the structure of your soil. (See Table D4–2.)
- Maintain surface cover to protect the soil surface from raindrop impact (Figure D4–3), and provide surface roughness to reduce the speed of run-off. This also provides a more favourable environment that encourages the growth and development of soil fauna and microbes.
- Reduce the amount of tillage to maintain organic matter levels in the soil, especially in fragile surface soils where organic matter is critical to give aggregate stability; reducing tillage will also reduce the likelihood of destroying those large pores that link the surface to the subsurface and subsoil.
- Aggregate stability is critical for soil structure; it prevents surface sealing, increases the range of moisture contents through which the soil is friable, increases soil aeration, and generally improves the structural condition of the soil. To increase aggregate stability, maintain the organic matter levels at at least 2%, or increase the electrolyte concentration by adding gypsum and possibly lime, when soils are sodic or dispersible.
- When a soil is sodic (ESP greater than 6 %) or dispersible, you can consider the use of gypsum to improve soil structure. Gypsum works by increasing the electrolyte concentration in the soil. (See the sodic soil section in Chapter D3.) The use of lime on sodic or dispersible soils has given variable results, and more investigations are required before lime can be generally recommended for stabilising sodic-dispersible soils.
- Stock can cause damage to the surface soil by compacting it when it is wet. Therefore, on your better paddocks that are used for cropping, you should shift stock when the soil is wet.

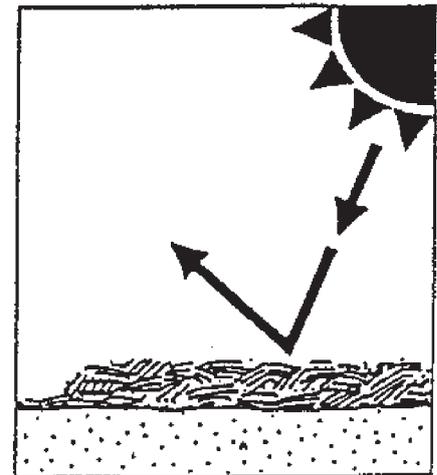
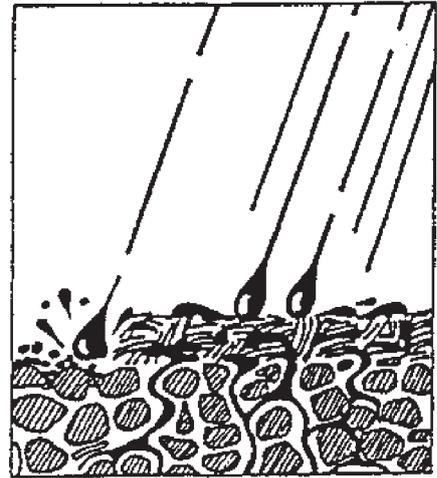


Figure D4-3. Good structure protects the soil from run-off and drying.

- Tillage should be done when the soil is in a friable condition, which is when it readily breaks apart into small 5 to 10 mm aggregates. If the soil is too wet, plastic failure will occur and the soil will be smeared adjacent to tines and wheels. If it is too dry, the soil will shatter (brittle failure) and stable soil aggregates will be smashed apart, making dust, and organic matter will be oxidised and lost from the soil. If the soil is in a friable condition over a very narrow range of moisture contents, look to improving the aggregate stability of your soil by increasing the organic matter levels, or by reducing dispersibility associated with high sodium levels. (For example, add gypsum.)
- Remember that, in fragile soils, biological activity is the major mechanism for improving soil structure; therefore, try to maximise plant growth and the associated root growth. This will, in turn, maximise the amount of soil fauna and soil microbe activity. In pastures, try to get maximum plant growth, and do not graze heavily all the time. After cropping, keep the stubble on the surface; if it is necessary to burn (it is only necessary if tines cannot otherwise get through the soil), burn as late as possible to maximise the time that stubble is on the surface. Plant growth is a good way, and often profitable way, to improve your soil structure.
- A brief summary of the factors to consider when managing soil structure and the mechanisms that can cause changes in soil structure is given in Table 4.3.

Table 4.3 Soil structure considerations

Factors that improve soil structure	Factors that degrade or damage soil structure
Reduced tillage	Frequent tillage
Increased organic matter levels	Low organic matter
Surface mulch to protect soil surface	Raindrop impact on bare soil
Decreased sodium levels	Increased sodium levels
Increased electrical conductivity	Reduced electrolyte concentration
Increased plant growth and surface cover	No/low vegetation cover
Wetting and drying cycles	Rapid wetting of the soil Traffic on a wet soil (stock or vehicles)

D5. Erosion

PURPOSE OF THIS CHAPTER

This chapter outlines the main types of erosion and the impacts of erosion. It also discusses methods of erosion control.

CHAPTER CONTENTS

- on-farm impacts
- off-farm impacts
- types of erosion
- principles of soil conservation
- management

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- D2. Salinity
 - D3. Sodidity
 - D4. Maintaining and improving soil structure
 - D6. Conservation farming
-

EROSION CONTROL

A productive farming system follows three main rules:

1. Control erosion to keep the soil in place.
2. Use rainfall effectively.
3. Manage soil chemical, physical and biological fertility.

Land degradation through soil erosion is of economic significance in soil management. Soil erosion is the movement of soil—often from a position where it is of value to a position where it represents a cost. In most practical circumstances it is uneconomic to move soil back to its original position. Therefore, in practice, soil erosion is irreversible. The emphasis must be placed on soil conservation, not remediation.

Land-use practices that reduce soil erosion generally also improve soil structure and plant-available water. So the good news is that soil-conserving farming is good for farm productivity.

Water or wind can erode soil if the soil surface is not protected by ground cover and plant roots. In southern New South Wales we have a winter-dominant rainfall, so erosion is mainly a problem in winter, although autumn-break rain can fall in storm events of high density. Wind erosion can be a problem on sandy soils, particularly on exposed hills and soil disturbed by livestock or tillage. We have experienced major dust storms throughout the eighties and nineties due to very dry conditions.

ON-FARM IMPACTS OF SOIL EROSION

Loss of soil

Soil forms at a very slow rate, typically one millimetre or so every 100 years. One millimetre of soil is about 14 t/ha, so this rate of soil formation produces new soil at (about) 0.14 t/ha per year.

It takes only a small amount of erosion to exceed this rate of soil formation. Typical losses can be 60 to 80 t/ha per year from bare fallow, 8 t/ha per year under a crop and 0.24 t/ha under pasture. Single, high-intensity storms can erode 70 to 300 t/ha. Erosion losses are particularly damaging on texture-contrast soils that have a shallow topsoil over clay subsoil. (See Chapter C3.) Such soils have little topsoil in their natural state.

Loss of nutrients

Most nutrients are attached to soil particles. Nutrients are commonly concentrated in the top few centimetres of the soil. Therefore, erosion of topsoil is particularly damaging in removing the most valuable part of the soil profile. Again, this is particularly the case in texture-contrast soils. To stop this topsoil loss, there needs to be a minimum of 70% groundcover.

Damage to plants

Much of the soil that erodes from the upper slopes on a farm is deposited on the lower slopes and/or in channels. Wind erosion can move soil from bare areas to planted areas. Deposited soil can bury plants and reduce yields. In addition, wind can damage plants by sandblasting them with fast-moving soil particles. Soil deposited by water must dry out before field operations can start again. Therefore, water erosion can adversely affect the timeliness of field operations.

Damage to on-farm structures

Erosion can bury fences or knock them down. Gullies interfere with farming operations in paddocks, and with access tracks.

There is a significant cost in clearing silt from on-farm structures such as farm dams, channels of erosion control earthworks and farm roads.

OFF-FARM IMPACTS OF SOIL EROSION

Environmental impacts

Some sediment and associated nutrients from water erosion will leave the farm and end up in streams and water storages. This can have a significant impact on the ecology of the streams. The presence of sediment and nutrients is related to the occurrence of algal blooms and other water-quality problems in our inland rivers and lakes. Another common effect may be reduced fish stocks or a change in predominant fish species.

Other costs to the community

Soil erosion often results in the siltation of off-farm roads, dams and drains. The costs of these impacts can be substantial, and are borne by the community as a whole, often via local government.

TYPES OF EROSION

Sheet

Sheet erosion is erosion from the entire surface of the soil. Sheet erosion by water is exacerbated by the impact of raindrops hitting the soil surface. Sheet erosion by wind occurs on dry, bare soil. Soil cover—both living (growing plants) and dead (stubble or straw)—is most effective in reducing sheet erosion.

Rill

Rill erosion occurs when water forms small channels (rills) in the surface of the soil. Rill erosion is exacerbated by excessive run-off, steep slopes, loose tilled soil, and tillage up and down the slope. The main methods of reducing this form of erosion are maintaining ground cover and minimising tillage to maintain the soil in a firm, more erosion-resistant condition.

No-till can, on some soils, greatly reduce rill erosion. Some tillage may be necessary to smooth the soil surface and reduce the concentration of run-off into rills. When necessary, cultivate across the slope and not up and down the slope (contour cultivation). Erosion-control banks stop rills becoming gullies.

Gully

Gully erosion forms large channels that cannot be levelled by cultivation. It is exacerbated by excessive run-off, concentration of water flow, long slopes and the presence of dispersive soils. The main techniques used to reduce this form of erosion are maintaining ground cover to reduce run-off, and building earthworks (including diversion banks, erosion control banks, grassed waterways and small dams).

Wind erosion

Wind erosion is the movement of soil particles by wind. To cause erosion, the wind has to have sufficient velocity, drag and turbulence. This, combined with the soil particle size, weight, aerodynamic shape and existing cohesive forces, can result in soil loss (Figure D5-1). Dry times, bare ground, lack of soil structure and low organic matter levels can make soil vulnerable to wind erosion.

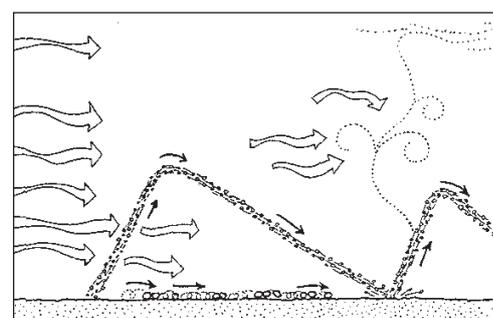


Figure D5-1. Wind erosion occurs when particles of soil are moved by the wind. Heavier particles roll along the ground and lighter particles bounce, or are blown up into the air in dust clouds. (Reproduced with permission from the Department of Primary Industries, Queensland.)

PRINCIPLES OF SOIL CONSERVATION

Reduce run-off

Run-off carries soil in suspension. The more run-off there is, the more soil that can be moved. Therefore, reducing run-off will reduce erosion.

Reduce run-off by:

- protecting the soil surface by maintaining good surface structure and adequate infiltration capacity. In practice this means minimising the number of tillage operations, and maintaining a good cover on the soil surface throughout the year using either growing plants or a crop residue cover. Particularly during times of peak erosion risk (summer storms and autumn break), ensure a firm (untilled) soil and adequate surface cover
- using stored soil water.

Slow the erosive agent

To reduce water erosion, slow the run-off. To reduce wind erosion, intercept the wind.

Some run-off will occur with all management practices, although it will be less frequent and of a smaller magnitude under conservation farming. The speed and depth with which water moves across the soil surface determines the amount of erosion. Practices that slow run-off include contour cultivation, maintenance of surface cover (retaining stubble) and the installation of erosion control banks and channels. Note that banks and channels are not always effective on their own, particularly during high intensity storms.

Windbreaks help to control wind erosion by reducing the velocity of the wind. Windbreaks are also effective only over a certain distance, and several may be required across large paddocks. Remember that windbreaks need varying levels of vegetation and at least three rows. Note that windbreaks are not effective on their own. Surface cover is also necessary to reduce wind erosion.

Keep the soil in place

The soils of southern New South Wales are generally highly erodible by water. However, soil management can influence the erodability of any soil. A finely cultivated seedbed of loose soil with no surface cover offers the least resistance to erosion. An undisturbed soil surface with a complete cover of growing plants offers the most resistance. Practices that increase soil resistance to erosion are: reduced tillage, stubble retention and the application of measures—specific to each soil type—that improve soil structure.

The impact of raindrops hitting bare soil breaks off soil particles, leading to crusting and erosion (Figure D5-2).

Water erosion occurs when raindrops smash soil into particles; this blocks soil pores and prevents water draining through the soil. Water then flows across the top of the soil, carrying eroded particles with it (Figure D5-3).

Different solutions for different slopes

Different slopes and slope lengths give run-off differing erosive powers. On flood plains with slight slopes (0.5% to 1% slope), emphasis should be placed on spreading and slowing flood flows. Techniques include road levelling and vegetation.

For slopes greater than 1%, emphasis is always on the use of erosion control earthworks and maintaining surface cover throughout the growing and fallow periods, but surface cover is particularly important during periods of high erosion risk. On slopes greater than 8% the soil should not be cultivated, but sod-seeding may be an option.

For more information contact your local Department of Land and Water Conservation.

☞ See Chapter D6 for more information on conservation farming.

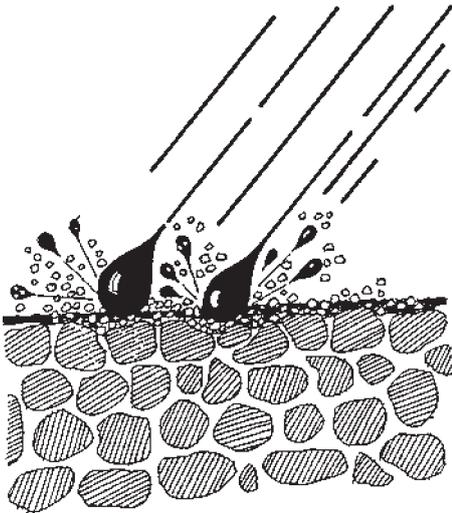


Figure D5-2. Raindrop impact

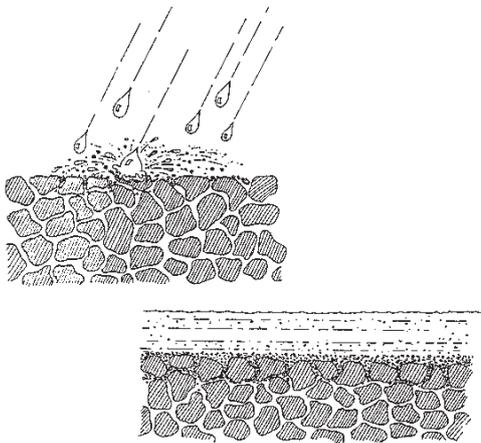


Figure D5-3. Raindrop impact causes surface crusting.

SOLUTIONS TO EROSION

Stubble retention

The retention of stubble and straw is the single most important soil-conserving step in farm management in the southern dryland area. Plant residues act to protect the soil surface from erosion in both the fallow and the period immediately following planting. Residues, by increasing infiltration, also increase the storage of water over the fallow, making more water available to the following crop.

Fallow management

Maintaining cover

A cover of 70% is desirable. Maintain a minimum of 30% surface cover. Crop residue breaks down over time, and cultivation buries standing stubble and straw.

What type of cover?

For cover to be effective in reducing run-off and erosion it must resist being moved by run-off. Therefore, anchored cover is better than loose cover. In practice, this means leaving some standing stubble during the fallow period to anchor the loose straw.

How much cover?

Figure D5–4 is a guide for the minimum level of residue cover for typical winter crops.

Burning

Residue burning is generally not desirable for erosion control. In the period following burning, the soil is exposed to increased run-off and erosion. If burning is absolutely essential, burn at the end of the fallow period with a ‘cool burn’.

Grazing

Grazing can be used to reduce heavy straw and stubble cover in the fallow period. However, this grazing should be managed to maintain surface cover at or above 30% (Figure D5–5). It is also very important not to graze your stubble when the soil is wet, as this causes compaction. To know when to remove stock from a paddock before this critical level is reached you will need to monitor the situation carefully.

Tillage

Tillage reduces the amount of residue available for surface cover. Table D5–1 lists the residue reduction caused by various implements.

Table D5–1. Effects of passes of different implements on residue cover levels

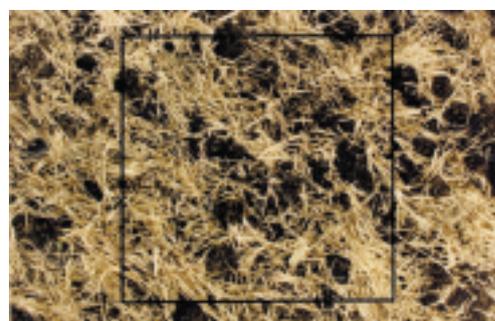
Implement	Percentage residue reduction per operation
One-way disc	40–60
Offset and tandem disc	35–40
Chisel plough-chisel points	0–25
Chisel plough-sweeps	15–20

Source: L D Ward, formerly QDPI

Tip: Set your target stubble level at harvest. Spread straw from the header on to standing stubble. The standing stubble anchors the straw to form an excellent cover; conserving moisture, reducing run-off and controlling erosion during the fallow and crop establishment periods.

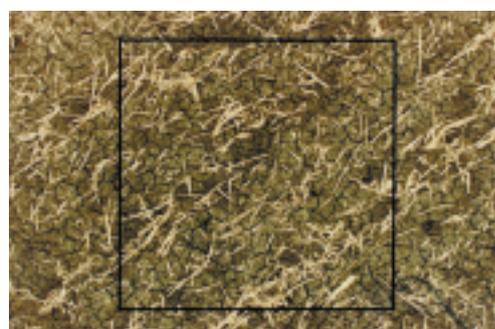
Tip: To estimate the amount of ground cover you have, stand in a representative part of the paddock with your feet half a metre apart. Visualise a square in front of your feet. Mentally divide the square into thirds and imagine that all the bare areas move into one third. If the bare areas fill less than one third, then the cover exceeds 70%. Repeat five times in a paddock, then average out the results.

Tip: See Chapter D4 for more information on maintaining and improving soil structure.



J.M. Molloy QDPI

Figure D5-4. 70% ground cover



J.M. Molloy QDPI

Figure D5-5. 30% ground cover

Minimise tillage to only what is essential; reducing the time that the soil is in a loose condition saves time and money.

Crop establishment

Disturb the soil as little as possible during sowing. Soil cover is just as crucial in the period immediately following planting as it is during the fallow. Seedlings provide little or no erosion protection.

By using equipment able to handle large amounts of trash, ground cover can be maintained until the new crop is established.

Contour cultivation

On slopes when tillage is necessary, till across the slope. Tillage on, or near, the contour provides additional control of run-off. Some run-off is held in the tillage marks, thus increasing water infiltration by delaying run-off. Contour cultivation also orientates plant residue across the slope; this is most effective in slowing run-off.

Earthworks (including waterways)

Erosion control earthworks are an integral part of conservation farming in the slopes of the southern dryland farming area. Erosion control banks effectively break the slope into segments, which are protected from the development of gullies. They also provide a means of diverting run-off safely from the paddock into a grassed waterway, generally to a farm dam.

Erosion control banks are not the entire solution to soil erosion problems. The effectiveness of the banks is greatly enhanced by surface-management practices between the banks. Stubble cover to control sheet and rill erosion prevents siltation of the channels above the banks. Using conservation farming can mean that fewer banks are required in some paddocks to control erosion.

Contact your local Department of Land and Water Conservation office for advice regarding the layout of erosion control banks, diversion banks and grassed waterways.

D6. Conservation farming

PURPOSE OF THIS CHAPTER

This chapter gives an overview of conservation farming and the benefits its use has for your soils.

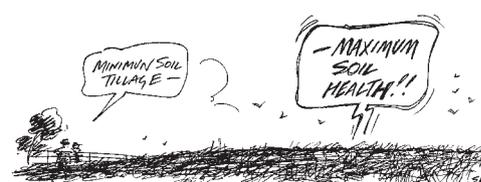
CHAPTER CONTENTS

- reducing tillage
- retaining stubble
- reducing traffic

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B9. Is my soil suitable for direct drilling?
- B14. Choosing the next crop
- B15. How wet can I cultivate?
- B16. What can I do about waterlogging?
- D4. Maintaining and improving soil structure
- D5. Erosion
- D7. Soil improvement through biological activity
- D10. Soil-borne diseases
- E1. Soil structure
- E2. Soil structure rating system



CONSERVATION FARMING

Too often the need to farm profitably and the need to farm well are seen as being in conflict. As cropping intensity increases and the time spent in pasture is reduced, the risks of soil damage and erosion increase. Conservation farming offers a way to increase cropping intensity safely and profitability without excessive soil damage.

Conservation farming is not just the use of narrow points to sow into crop stubble. It is an approach to farming that uses a whole raft of ideas for soil management that together can increase long-term profitability. Conservation farming is built around three 'R's:

- **Reduce cultivation** to maintain soil structure and soil water storage.
- **Retain stubble** to reduce erosion and increase soil organic matter.
- **Reduce traffic** across the paddock to avoid compaction.

All three 'R's need to be used together in successful farming.

REDUCING TILLAGE

All tillage damages soil structure and increases the risk of soil erosion. Reducing tillage is the key to increasing the length of the cropping phase. Tillage is used to control weeds, prepare a seedbed, and sow the crop.

With the increasing problem of herbicide resistance, producers can no longer simply ‘see weed and spray’. This applies particularly to the Group A (HoegrassTM, FusiladeTM, VerdictTM etc.) and Group B (GleanTM, LogranTM etc.) herbicides, which, before the advent of resistance, made stubble retention, reduced till seeding and continual cropping so viable.

Because of the resistance problems, producers have had to ‘revisit’ herbicides like trifluralin. While this seems to be working quite well under incorporation by sowing applications, stubble cover dramatically reduces its effectiveness.

Since the downturn in the livestock industries, many mixed farmers have moved to continuous cropping. However, herbicide resistance has pressured producers into reconsidering the role of pastures (short-term, one to three years), because pasture phases allow for potent weed control options to be used. Options such as silage production, winter cleaning and fallow spraying can be used to suppress weed numbers before the crop phase.

As an additional complication in these times of resistance, producers need to rotate herbicide groups, and this places restrictions on crop choice.

Some producers have such severe herbicide resistance problems that they need to use techniques such as burning header trails in order to kill some of the weed seed. This applies in areas of Western Australia, where soil types are too light to run stock, so the pasture phase is much less attractive.

With the above in mind, it is plain that long-term weed management in cropping needs forward planning. Producers need to be thinking two or three seasons ahead. In addition, less palatable options like short pasture phases and stubble burning need to be kept in focus.

Using cultivation to prepare a seedbed means spending money and time to break up soil that need not have been compacted in the first place. Use the third ‘R’—reducing traffic and compaction—to reduce the need for pre-sowing cultivations. Ensure good seed–soil contact by choosing suitable points and the correct sowing speed, and by choosing suitable seed-covering equipment, such as rotary harrows, press wheels and prickle chains.

Sowing the crop through stubble and into uncultivated soil has been made much easier by developments in no-till machinery. However, managing stubble and soil compaction are still the keys to successful crop establishment. Much has been achieved by improving tine and point design. In our area, tines should have a breakout force of at least 170 kg to handle hardsetting soils. Either a forward-sloping tine with a high ‘elbow’ or a C-shaped tine sheds straw best. Tines with rounded rather than square-section shanks are best, and a spacing of

600 mm between tines is needed. Consult your neighbours and experiment a bit to find the right points for your soil. One option is deep-banding points, which have the advantage of breaking up the soil below seeding depth, thus reducing the effects of any compaction and destroying root-disease hyphae. They also allow you to place high rates of N fertiliser away from the seed. Their disadvantages are a higher power requirement for the deeper working and an increased likelihood of the point smearing the soil when you are sowing in wet conditions.

Where root disease has been controlled by crop rotation and soil compaction is not a problem, working only to sowing depth will reduce power requirements and often leads to more even seed placement and emergence.

All sowing points need to be kept in the soil at the correct depth and at the design angle for good performance. The force on no-till points is usually much greater than that in cultivated soil, so a higher breakout force is required. When the tine is dragged back by excessively hard soil the angle of the point becomes more vertical. This increases the draught of the point and makes it more likely to cut through the soil. This cutting action increases compaction and reduces the fracturing of the soil needed to produce a seedbed. In uneven soil the extra expense and complexity of a floating parallelogram tine assembly may be justified.

RETAINING STUBBLE

Begin by ensuring that your header has an effective chaff spreader that spreads the chaff and straw across the full width of the header cut. All stubble should be retained over the summer to protect the soil. Don't incorporate stubble. The extra working adds cost and damages the soil. Large amounts of incorporated stubble may tie up nitrogen and slow seedling growth. Light stubble is best left standing. No-till equipment works well through standing stubble.

Don't graze stubble unless you have to. Stock flatten some stubble, and the mixture of standing and randomly knocked down stubble is most difficult to sow through. Use coolamon harrows to flatten stubble after grazing. Always bash around the paddock so that the stubble lies in the direction of sowing. Where stubble treatment is necessary the aim should be to reduce the length of the straw to one-third the distance between the tines on any one bar of the combine for crops of 3 to 5 tonnes per hectare, and half the tine spacing for crops of less than 3 tonnes per hectare.

Whether you burn stubble or not is a very important management decision.

- If your machinery can sow through the residue and not leave heaps behind in the paddock, and if there are no known stubble-borne diseases present, then there is no reason to burn.
- 'Cool burn' if you are burning close to sowing, or burn the stubble when it is damp. This is subject to local shire fire rules. Retaining stubble through the summer months helps

prevent wind and water erosion, retains moisture, prevents evaporation and encourages the activity of soil organisms for organic matter improvement. A 'cool' burn in late autumn may be needed when the stubble has been grazed. The ideal is to leave some stubble to protect the soil while removing dense stubble that may impede sowing. It is more practical to establish crops accurately and thence add more organic matter in the next crop than to retain large amounts of stubble.

- A cool burn would be ideal before using trifluralin incorporated by sowing.

REDUCING TRAFFIC

This third 'R' is a very important part of any conservation farming system. Soil compaction is caused by vehicle traffic and by stock grazing over wet soil. Compaction reduces yield in any farming system but assumes major importance when soil-loosening tillage is minimised.

Organic matter levels and soil structure improve under pasture, but stock grazing over damp soil cause considerable surface compaction. During cropping, keep traffic over the soil to a minimum. Consider adopting a controlled traffic system as outlined below.

Severe compaction can occur during harvest. Headers, bins and grain trucks are all heavy vehicles that cause severe compaction if the soil is moist at harvest time. Plan harvesting to reduce the area covered by trucks and other vehicles.

Controlled traffic farming

In a controlled traffic-farming system all equipment wheel-widths are standardised and all paddock operations follow exactly the same wheel tracks (often called tramlines). This means that soil compaction is restricted to a narrow zone under the tractor wheels. This has a number of advantages. The wheel marks are not cultivated or sown, so they provide a firm bearing surface that allows earlier sowing or spraying after rain. Significant fuel and power savings are made because the tractor does not have to push through loose soil, nor is it required to re-loosen the soil compacted by the tractor wheels. Crops yield much better when grown in uncompacted soil. This increased yield more than compensates for the lost sowing area in the wheel marks. Much better performance can be obtained from minimum-till combines when they are used in uniform friable soil. Machinery overlap is controlled, so input costs are reduced.

Disadvantages include the expense of standardising machinery widths and wheel tracks. Controlled traffic is particularly useful in continuous cropping systems where there is no soil compaction by stock.

Raised beds

The best controlled traffic system is the raised bed system of 1.5- to 3-metre-wide beds separated by drainage furrows in which the machinery wheels are run. Once installed, these beds

can be kept in place indefinitely with occasional reforming. Raised beds come into their own in heavy, flat country, where they also show improved seedling emergence and less waterlogging.

PRECISION AGRICULTURE

This is a new approach to farming. A global positioning satellite system coupled to a computer is used to fix the position of each farming operation accurately. In the first instance this enables 'yield maps' of each paddock to be made. Soon it will be possible to match the seeding and fertiliser application rates to the expected yield from each part of the paddock. This will hopefully optimise yield while reducing input costs.

The value of precision agriculture lies in the fact that the yield maps made after a particular set of seasonal conditions will predict the yield achieved in following seasons, when rainfall patterns may be quite different.

CASE STUDY

The Scholz family has been farming in the Henty district since 1973 on their 700-ha property, 'Earls Ridge', located south of Henty off the Olympic Way.

Barry Scholz and his son, Murray, were among the first in the area to abandon conventional cultivation methods, adopting a no-till system by accident.

Barry explains:

In 1975 we were disc ploughing a paddock, but it was too wet, so we direct drilled instead. After a few years of trying a new, no-till system, we decided our chemical costs were too high and we converted back to conventional cropping.

However, the Scholzes soon found conventional methods to be less cost-effective. Cultivating with a triple disc was pinning the straw, overall chemical costs were just as high, and the farm's diesel costs were higher.

They adopted a no-till system again, and 19 years later they are still continuously cropping.

Barry and Murray have a rotation of lupin (which is windrowed), wheat, canola and a cereal (wheat or triticale).

They direct drill into stubble, and burn their wheat and triticale only when there is a resistant weed problem.

Their set-up consists of a John Deere 7800 (175 hp), pulling a 30-row John Shearer trash-seeder fitted with Superseeder™ points and rotary harrows. Their header has been fitted with a second cutter bar and chaff spreader.

The chaff spreader spreads straw across the header tracks, and has provided the Scholz family with an extra source of income, through contract work around the district.

The Scholzes have noticed real benefits in the no-till system. These include:

- increased trafficability (they no longer need a motorbike for spraying)



Nathalie Brown

Murray and Barry Scholz

- improved soil structure and less water run-off, especially in crops
- a 75% cut in their fuel bill, and reduced tractor hours
- a bigger earthworm population.

The farm chemical bill is 5% higher, but with Roundup™ prices decreasing and fuel bills increasing, the Scholzes believe they are better off.

An infra-red survey on 'Earls Ridge' showed areas of overlapping treatments. By placing the sprayer and urea spreader on the same wheel tracks the Scholzes have reduced costs by 5% in a 40-ha paddock.

Barry and Murray have recently sold all their sheep, and their 150 head of cattle are generally grazed in rocky country or on stubble in summer. If it is wet, they are moved back up the slope and kept off the cropping paddocks.

'When we first bought 'Earls Ridge' in 1973, we were yielding 3.5 t/ha of wheat,' says Barry. 'In drought conditions in 1997 we got 4 t/ha, and in an average year we yield 5 t/ha.'

Murray, at 30, was proud to say he had never cultivated in his life.

The Scholzes' final message is simple. Barry says:

With direct drilling and stubble retention, producers need to change their thinking. For example, with this system you can have rough beds and you don't need to go out straight after rain.

Australians need to work out their own farming systems. While monitoring successful systems overseas is vital, Australia is a unique country and we need to develop methods which work best here.

D7. Using biological activity to improve soil

PURPOSE OF THIS CHAPTER

To show the importance of soil organisms to the soil's physical, biological and chemical health

CHAPTER CONTENTS

- factors that influence biological activity
- earthworms
- termites and ants
- other soil animals
- bacteria
- fungi

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B11. Do I have enough organic matter?
- C1. Examining the soil profile
- D1. Acidity
- D4. Maintaining and improving soil structure
- D6. Conservation farming
- D10. Soil-borne diseases



SOIL IMPROVEMENT THROUGH BIOLOGICAL ACTIVITY

Soil organisms can modify the soil chemically and physically to improve soil structure and nutrient status. Some can improve drainage, while others can help increase water-holding. Some that are associated with plants can add nitrogen to soil by fixing it from the air.

The following factors may increase biological activity:

- retaining crop residues, rather than removing or burning them
- minimum or no tillage and mulching of crop residues
- correcting soil pH with lime if necessary
- having well-managed, not overgrazed, pasture
- having good soil chemical fertility to promote plant growth, and adding organic matter such as manures to the soil
- opportunity cropping to avoid long, bare fallows.

EARTHWORMS

Earthworms benefit the soil. Contrary to what many people from cooler temperate climates have thought in the past, Australian cropping soils are not too hot and dry

for earthworms. Earthworms can inhabit cropping soils in relatively large numbers, but populations are often limited if there is soil disturbance or if the soil is low in organic matter.

Tillage

Tillage often reduces earthworm numbers, because it destroys their burrows and hastens the decomposition of plant residues, which are their food supply. Tillage that incorporates plant residues into the soil removes the protective mulch that keeps the soil moist near the surface.

The amount and type of tillage may also affect the number of earthworms present. Earthworm numbers under direct drilling have been reported to be up to four times higher than under conventional cultivation. Under reduced cultivation, a single pass with narrow sowing points does not appear to reduce earthworm numbers significantly. However, the use of traditional broad points in a single pass with reduced cultivation may reduce earthworm numbers to the same extent as multiple passes with conventional cultivation.

Earthworms can be expected to respond rapidly to changes in management. It appears that some earthworms do not complete their development in a single season and may not mature until the following year. Therefore, increases in earthworm populations may not be obvious in the first year of direct drilling.

Stubble removal

Stubble removal has been shown to reduce earthworm numbers by two-thirds. With stubble retention, numbers are doubled. Crop residue handling may also affect the size of earthworms; for example, smaller earthworms have been recorded from stubble-burnt paddocks.

Crop rotations

Crop rotations that include a pasture phase will usually result in higher earthworm populations, compared with continuous cropping. Rotations that conserve soil moisture may also encourage earthworms. The amount of food available, which may depend on the previous crop, will also influence earthworm populations.

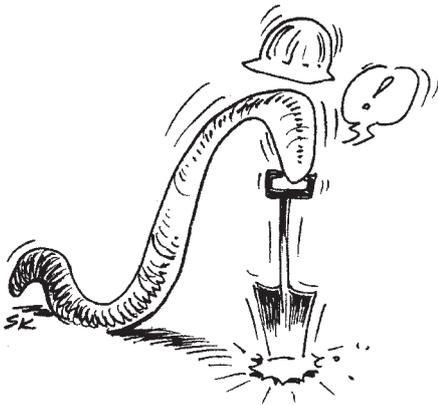
Soil acidity

Soil acidity can reduce earthworm numbers; they will not thrive in a soil with a pH (CaCl_2) below 4. Any soil with such a low pH is too acid for good plant growth, and you should lime it regardless of your feelings about earthworms! Lime raises the soil pH and adds calcium, which also appears to be beneficial to earthworms.

Benefits of earthworms

Earthworm burrowing:

- improves soil porosity and structure
- increases infiltration
- increases aeration of the root zone
- provides channels for root growth.



Earthworm feeding:

- increases the rate of organic matter turnover
- breaks up root mats and leaf litter
- increases microbial activity in the soil
- breaks up and mixes organic and inorganic materials.

Earthworm casts:

- produce a zone of nutrient enrichment for plant growth
- concentrate microbial activity and nutrient release
- contain nitrogen, phosphorus and potassium in forms available to plants.

Table D7–1 provides a comparison of earthworm activity in a red earth soil from Wagga Wagga under different crop-management practices.



Table D7–1. Density of active earthworms (per m²) under different stubble and tillage practices

Stubble management method	Direct drilled	Reduced tillage	Conventional tillage
Stubble retained	17	14.1	4.2
Stubble burnt	18.4	7.1	4.2

Source: Heenan DP and Chan KY 1993, 'Surface hydraulic properties of a red earth under continuous cropping with different management practices'. Australian Journal of Soil Research 31:13–24

TERMITES AND ANTS

Termite and ant burrows provide channels for water movement in the soil and may be important in drier areas where earthworms are less active. The feeding of termites on dead wood and grasses can help the breakdown of organic matter and the return of nutrients to the soil. It may be beneficial if ants collect seeds and carry them underground, but ants can also be pests if they deplete seed supplies in pastures.

OTHER SOIL ANIMALS

Healthy soils support a diverse variety of other soil animals, ranging from centipedes to springtails. Many, such as the spiders that sometimes cover tilled paddocks with their webs, occur in immense numbers. All have their places in the conversion of stubble and animal manures into plant nutrients. Many of these tiny animals ingest soil with their food, and their droppings form much of the fine structure of good soils.

BACTERIA

Bacteria are single-celled organisms, generally with rigid cell walls. Although bacteria are single-celled, colonies of cells may exist as chains or filaments. Bacteria are responsible for many of the chemical reactions in soil, including decomposition of organic matter and transformation of the various forms of soil nitrogen. Long-chain sugars produced by bacteria act as gums that bind soil particles together.

Soil bacteria feed on organic matter, and, in the process, convert nutrients from organic forms that are unavailable to

plants to inorganic forms that are available. This process is known as mineralisation. Nitrogen in organic matter, for instance, is converted first to ammonium and then to nitrites and nitrates.

Bacteria are small enough to live in the water that clings to the surface of the soil particles. When the water film dries out, many survive by forming spores. Some spores, such as those of anthrax, have been known to survive for more than 20 years. When moisture becomes available, the spores germinate and the bacteria multiply. In ideal conditions, each bacterial cell can subdivide in as little as eight hours. Because the bacteria respond to rain much more quickly than plants, the mineral nitrogen they liberate early in the season may exceed the seedlings' ability to take it up. This may lead to additional nitrate leaching in wet years.

FUNGI

Fungi are organisms that germinate from spores, but their cells cling together in long strands called hyphae. The mat these strands form is called the mycelium. When conditions are unfavourable for growth, the mycelium produces spores, either within the cell or on special fruiting bodies, such as mushroom caps.

Most fungi live on dead plant residues. Only a few fungi infect living plant tissues to cause plant diseases. Fungi decompose plant residues, and so release nutrients for plant uptake. Fungi are particularly effective in decomposing lignin, a plant material found in straw and wood. Fungi are most abundant in the surface layers of woodlands and grasslands.

Fungi help improve soil structure by binding soil particles into aggregates. However, in sandy soils, they may cause water-repellence (non-wetting), which interferes with infiltration of rain.

Earthworms, fungi and bacteria and many other organisms make up the soil biota, the 'guts' of the soil in which all of the digestion of plant residues takes place.

D8. Improving soil chemical fertility

PURPOSE OF THIS CHAPTER

To define chemical limitations that affect cereal crops and pasture crops.

CHAPTER CONTENTS

- fertilising cereal crops
- fertilising pastures

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B2. Is my soil acid? Does it need lime?
 - B12. Does my soil need fertiliser?
 - C5. Chemical soil tests
 - D1. Acidity
-

IMPROVING SOIL CHEMICAL FERTILITY

Farm profitability and the sustainability of grazing and cropping lands are directly linked to soil fertility. Good management practice is concerned with providing the most suitable chemical, biological and physical soil conditions for plant growth. This includes determining and correcting nutrient deficiencies.

Specialist information on canola and pulses can be found in current Agfacts from NSW Agriculture.

FERTILISING CEREAL CROPS

The two major limitations to cereal growth, and probably to the growth of other crops, have historically been phosphorus and nitrogen deficiencies. Soil acidity is a recent concern.

Phosphorus

Most soils have received many applications of phosphorus (P) over the last 50 to 70 years. Of course, we do not fertilise for the sake of the soil, but for the sake of the plant. The aim of managing soil P is to make sure that the amount of soil P + fertiliser P is adequate for the growth of the crop. The 'critical' level of soil P is a form of insurance policy, to make sure that there is sufficient P 'in the bank'. The later a crop is sown, the more reliant plants are on fertiliser P, as the roots have less time to explore relatively warm moist soil before the cold sets in. Conversely, with an early sowing, plant roots can exploit soil P very successfully and are less reliant on fertiliser P.

The higher the yield potential, the greater the demand for P. Therefore, the need for fertiliser P has to be considered in terms of the grain produced. The rule of thumb for maintaining P fertility under cereal cropping is:

$$\text{Maintenance rate (kg P/ha)} = 10 + (\text{grain yield in tonne/ha} - 3) \times 3.5$$

for grain yields greater than 3 t/ha.

For example, to maintain P supply in a soil producing about 4 t/ha of grain requires:

$$10 + (4-3) \times 3.5 = 10 + 3.5 = 13.5 \text{ kg P/ha.}$$

For grain yields of less than 3 t/ha, a maintenance rate of 10 kg P/ha is required.

Such fertiliser rates will ensure that the fertiliser + soil P pool will meet the average long-term needs of the cereal crops. Although the P content of canola and lupin grain is different to that of cereals, a similar P requirement can be used as an estimate.

Nitrogen

The available forms of nitrogen are ammonium (NH_4) and nitrate (NO_3).

Nitrogen fertiliser is applied to non-legume crops such as cereals and canola. In the case of cereals, nitrogen may increase yield, grain protein, or both. When the soil has a low level of available nitrogen, applied fertiliser nitrogen tends to increase yield rather than protein. At higher levels of available nitrogen, grain yield increases less steeply, but grain protein starts to increase more steeply.

The amount of N required depends on the following:

1. The N in the soil at the start of the season (before sowing with starter fertiliser). This can be measured with the deep soil nitrate test (to 60 cm). For this example, let's say we have 20 mg N/kg in the soil test result, which is the equivalent of 26 kg N/ha.
2. The amount of N that mineralises during the growing season. Obviously this can never be known in advance, because it depends on temperature and rainfall patterns during the growing season. The average situation is given by a rule of thumb:

$$\text{N mineralised (kg N/ha)} = (\text{organic matter \%}) \times (\text{April to October rain in mm}) \times 0.15.$$

For example, on a soil with 1% organic matter that receives about 300 mm of rainfall in an average growing season:

$$\text{N mineralised (kg N/ha)} = 1\% \times (300) \times 0.15 = 45 \text{ kg N/ha.}$$

3. The total potential demand for N. This too, depends on rainfall. Again, we can make an estimate based on an average season, using the following rule of thumb:

$$\text{Yield (kg/ha)} = 15 \times (\text{April to October rain in mm}) - 1000$$

That is, 67 mm of rain (or $1000/15 = 67$) are lost in some way and do not contribute to grain yield. This rule of thumb assumes that we have little water stored in the soil at the start of the season. Using our example above, with 300 mm rainfall in the growing season, we can expect to produce:

$$15 \times (300) - 1000 = 3500 \text{ kg grain/ha.}$$

If we aim to produce this grain at 12% protein (2.1% N), then 73.5 kg N/ha (3500×0.021) are needed for the grain alone. About 0.5% N, or about 20 kg N/ha, are left in the stubble. Therefore, we need a total of about 95 kg N/ha for our crop (73.5 + 20 rounded off). Of course, you can try this calculation for any target yield and protein that local experience suggests is possible.

4. The difference between the soil supply (points 1 and 2) and the demand (point 3) is the amount of fertiliser N needed. In our example:

soil supply = $26 + 45$ kg/ha = 71 kg/ha, and

crop demand = 95 kg/ha,

so we need to supply 24 kg N/ha. In practice the uptake of N is only about 70% efficient, so we need to apply about 35 kg N/ha to give the crop its required 24 kg N/ha. To add 35 kg N/ha in the form of urea (46% N) we need 76 kg of urea/ha.

Since points 2 and 3 cannot be known in advance, and since N fertiliser costs about \$1 per kg, it is probably wisest to check point 1 (by the deep soil N test), to use a 'starter' rate of N, and then to monitor rainfall during the season. You can make a decision in early spring as to the likelihood of there being sufficient moisture to achieve some target yield and protein. These targets may be based on your average experience rather than on a rainfall model. The crop can be topdressed in early spring according to your best bet for that season's yield. For those interested in refining their N requirement predictions, the major fertiliser companies are testing computer-based models that use the principles outlined here.

SOIL ACIDITY

To remove toxic concentrations of aluminium we need to lime to a pH(CaCl₂) of about 5. However, we have found that cereal crops, and probably other crops, are sensitive to the presence of acidity in the subsurface soil. If your soil is acidic enough to need liming, it is worth checking the pH of the 10 to 20 cm layer of soil. If this layer has a pH(CaCl₂) less than about 4.8 (or has more than 5% exchangeable Al) then it can inhibit yield. We have found that by liming the surface soil to pH(CaCl₂) 5.5 we can, over several years, increase the pH(CaCl₂) of this subsurface layer. When we only lime the surface soil to a pH (CaCl₂) of about 5, there is little or no movement of lime below the plough layer (top 10 cm).

FERTILISING PASTURE

Choose a paddock that is likely to give the greatest response to fertiliser. The relatively high cost of fertiliser makes it necessary to produce a reasonable return on the investment. Your priority paddock for fertiliser would ideally have a good component of legume (lucerne, clover or medic) and be large enough to contribute significantly to farm profitability.

Soil testing can help you decide which paddock will give the best response for the least cost.

Soil testing for pH, N, P, K, possibly S and also exchangeable cations will give a good guide to fertiliser requirements. Plant tissue analysis should be used where trace element problems are suspected.

Test strips are an effective way of testing response to applied nutrients. On average, a visible difference in growth represents at least a 20% increase in yield.

☞ See Chapter C5 for more information on chemical soil tests.

The treatments or nutrients most likely to be needed for pastures are limestone, molybdenum (moly), potassium (potash), sulfur and phosphorus.

LIMESTONE

When soil pH(CaCl₂) falls to less than 4.3 to 4.5, even the acid-tolerant species that we have in our pastures benefit from liming. Species such as subclover, cocksfoot, annual and perennial ryegrasses are all tolerant of acidity. Phalaris seedlings are sensitive to acidity but increase in tolerance as the stand matures. The response of annual pastures to limestone is relatively small—typically 30% and less. The main benefit from liming is therefore that it opens the door to the introduction of perennials such as phalaris and, most importantly, lucerne.

Where possible, limestone should be applied before pasture establishment so that the limestone can be incorporated into the soil. In permanent pastures or on sloping ground where cultivation is undesirable, you have to accept that the benefits from topdressed limestone will take years to accrue.

MOLYBDENUM

‘Moly’ can be applied as Mo-super or as a spray of sodium molybdate. The sodium molybdate can be sprayed out in the same water solution as some herbicides, saving time and fuel. Check with your local agronomist as to which current sprays are compatible with sodium molybdate. Whether as a spray or with superphosphate, moly needs to be applied every five to seven years. This will ensure that legumes (clover, lucerne and medics) are able to provide sufficient N for the pasture (and any following crop). Pale legume leaves and greenness inside the root nodules are associated with Mo deficiency.

POTASSIUM

Potassium (K) has not been commonly used in our region, because the soils have naturally high reserves of K. However, in recent years soils in the higher rainfall areas have shown an increasing tendency toward lower K levels. Muriate of potash (potassium chloride) is the cheapest form of K fertiliser. In areas prone to grass tetany, take care that lactating stock receive magnesium (Mg) supplements. The addition of K fertiliser sometimes increases the risk of grass tetany.

SULFUR (S) AND PHOSPHORUS (P)

Sulfur (S) and phosphorus (P) are both supplied by single superphosphate, making it an ideal fertiliser for pastures. Our experience with soil tests for S is limited, since, historically, the need for P has always met the demand for S. Work is currently underway on soil testing for S.

The average maintenance requirement for fertiliser P is approximately 1 kg P/ha for each dry sheep equivalent carried on the pasture. For example, a pasture carrying 15 wethers at about 45 kg body weight would require, on average 15 kg P/ha each year to maintain the soil's current P reserve.

Finally, there is increasing concern about excessive nutrients producing algal blooms in waterways. Take care when applying fertiliser around waterways and water storage areas, especially when topdressing by aeroplane. Try to keep a buffer zone around waterways.

D9. Grazing and pasture management

PURPOSE OF THIS CHAPTER

To explain how different pasture and grazing management systems can affect soils.

CHAPTER CONTENTS

- pasture considerations
- advantages to the soil of maintaining a productive pasture
- grazing
- what happens under grazing
- managing grazing

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B2. Is my soil acid? Does it need lime?
- B3. Is my soil saline?
- B6. Does my soil form a surface crust?
- B11. Do I have enough organic matter?
- B12. Does my soil need fertiliser?
- C1. Examining the soil profile
- C4. Examining plant roots
- D1. Acidity
- D2. Salinity
- D3. Sodicity
- D4. Maintaining and improving soil structure
- D5. Erosion
- D8. Improving soil chemical fertility

GRAZING AND PASTURE MANAGEMENT

Productive pastures are the key to sustainable and profitable farming throughout the southern tablelands and the south-west slopes and plains. This section will show how pastures and grazing influence the health of the soil. This section will focus on Soil management and does not cover pasture agronomy. For further information on pastures and grazing, contact your local agronomist or livestock officer at NSW Agriculture or attend a Prograze course conducted by NSW Agriculture, which provides detailed information on pastures and grazing management.

PASTURES

Sown pastures need a well-adapted and persistent legume component.

The ideal legume content is greater than 30% of clover in a pasture on a dry weight basis. Without the legume component,

persistence and production of desirable perennial grasses is likely to decline unless fertiliser nitrogen is added.

Perennial grasses are an important component of a pasture. They are deep rooted and provide year-round ground cover.

In establishing an ideal pasture it is important to consider the following:

- Use those species and varieties that are best adapted for your climate, paddock aspect, soil fertility and grazing system.
- Have a range of pasture types on the property so that all pastures do not have to be managed in the same way at the same time. This allows flexibility, ensuring feed is available at critical times.
- Ensure that there are enough soil nutrients-especially phosphorus, sulfur and molybdenum.
- Introduce grazing at the appropriate time. Grazing pastures too early jeopardises plant establishment and growth. Grazing too late will jeopardise pasture quality.
- During the establishment year, grazing management should aim to ensure that perennials establish good root systems and that annual legumes flower for seed production. Provided that plants cannot be pulled out and there is good soil moisture, new pastures can be grazed for short periods when greater than 15 cm tall. Do not leave stock on for extended periods or they will overgraze new plants. Grazing stimulates tillering and root development when growing conditions are favourable.
- Where perennial grasses are sown under less favourable conditions (for example, using surface sowing, sowing late in the season, sowing into low fertility soils, or if there are dry conditions during establishment) and the root system is not developed, the grasses will benefit more if they are not grazed in the first year.
- Encourage desirable annuals to set as much seed as possible.
- Under extended dry conditions, consider concentrating stock into a few paddocks in order to save the better paddocks for rapid recovery following the break of drought. Native pastures will often recover better from intensive grazing during drought. You can help perennial grasses survive in dry conditions by leaving a reasonable amount of pasture.
- The chance of erosion will be reduced if ground cover is maintained at greater than 70%. Continuous grazing will deplete energy reserves in the plant and progressively weaken the pasture.

SOIL ADVANTAGES OF MAINTAINING A PRODUCTIVE PASTURE

There is a direct relationship between plants and soils. You cannot have a healthy pasture and soil system when only one component is in a productive state.

There are many advantages of a healthy plant and soil system. These include:

- **Acidity.** Legumes are an important source of nitrogen to the pasture system, but they have the potential to acidify the soil if nitrogen is leached through the profile. Deep-rooted perennial plants are beneficial to the system, as they have the ability to capture nitrogen before it is lost from the soil profile.
- **Nutrients.** Other nutrients that are easily leached through the soil profile can also be captured by deep-rooted perennials.
- **Salinity.** If a pasture is dominated by annual species, considerable amounts of rainfall and nitrogen escape through the surface soil into underlying subsoil during summer and early autumn. This results in surplus water entering the watertable, and has the potential to cause dryland salinity. Because of their perennial nature and deep-rooting capacity, perennials help to use this water more efficiently by drying the profile out.
- **Structure.** A healthy pasture results in a productive root system; this leads to improved soil structure. An improved soil structure leads to increased infiltration and therefore less run-off (and reduced erosion).
- **Ground cover.** A healthy pasture provides good ground cover, reducing run-off and the loss of soil and nutrients to waterways.
- **Organic matter, infiltration, erosion.** A healthy pasture system increases levels of organic matter in the soil; this nourishes the livestock below the surface. Soil organisms like worms and microbes are a vital component, as they help to convert organic substances into plant-available forms. Soil organisms produce gums and waxes that bind the soil, improving soil structure, increasing soil fertility and infiltration, and reducing erosion.

GRAZING

Now that you have your pastures under control, take a look at your stock.

- Do you destock during dry or drought times?
- Do you rotate your stock so that paddocks are rested?
- Do you move stock when there is less than 70% ground cover?
- When it's wet, do you move stock to sacrifice paddocks? Paddocks that are well drained have lighter soils (less clay).

If you answered No to any of these questions, read on to find out why you should be able to answer Yes. Poor stock management can degrade soils.

WHAT HAPPENS UNDER GRAZING?

The pressure exerted by grazing animals on the soil surface is comparable to that of agricultural machinery. For example, the pressure under the foot of a sheep is about 50 to 80 kPa,

compared with 60 to 80 kPa under an unloaded tractor or tracked vehicle. These pressures under grazing animals would be even higher when the animal is moving, because the weight is then supported by fewer feet. Also, we know that sheep walk about 2.5 km/day, so at a stocking rate of 12 sheep/hectare they would cover about 800 km within that hectare during a month of grazing. It is no wonder stock can be a problem in degrading the soil structure by compaction and soil pulverisation. Figure D9–1 shows the effects of grazing on the soil.

Compaction

The amount of compaction will depend on the pressure applied to the soil and the soil's resistance to this pressure. Grazing can be a major problem if the soil is wet. It is very noticeable around dams; where stock have trampled on wet soil the soil becomes compacted (pugged). The lack of air supply to plant roots kills the plant, leaving the soil surface bare. Bare soil can erode.

Moisture content

This is a major factor in the resistance of a soil to compaction. The wetter the soil, the less the resistance and the higher the compaction. Using perennial pastures is an excellent way of drying out the soils. This allows water stored in the soil to be used by plants to give greater ground cover.

Soil texture

Clay soils compact and pug more readily than sandy soils when wet, and stay wet longer. However, even sandy soils will have their infiltration rate reduced by heavy stocking during wet weather.

☞ See Chapter D5 for more information on erosion.

☞ See Chapter B1 for more information on trouble-shooting soil structure problems.

Soil density

The density of soil is a measure of the soil and its air pores. The denser the soil, the less air and water can be stored; plant roots find it hard to grow under these conditions. The lower the soil density (for example, as found in freshly cultivated soil) the greater the opportunity for compaction.

Soil organic matter

Organic matter is very important for soil and plant health. It helps to bind the soil and protects it from degradation. The higher the organic matter level the smaller the maximum compaction will be.

Soil structure

The arrangement of the soil particles, air and water can be altered by stock. The stock can directly affect the structure by compacting wet soils, walking constantly with hard hooves. Stock walking on dry soils create dust, and erosion often follows. Wind can blow soil away, and where the soil settles, it forms a crust or sets hard.

Rainfall infiltration

If the surface of the soil is compacted by stock, then often there are few pores through which water can drain. The water is unable to soak into the ground and runs off, often taking with it valuable nutrients.

Soil fauna

Overgrazing of pastures can have a major effect on the soil organisms. Bare ground leaves the soil unprotected from the impact of rain and stock. The compacted surface restricts infiltration of water. The lack of pasture means that there is less plant material to be broken down. This leaves the organisms with a low level of organic matter (food supply).

MANAGING GRAZING

For grazing to have a minimal effect on your soils you will need to:

- rotate stock
- maintain more than 70% ground cover
- have a sacrifice paddock (for wet times)
- maintain good pasture composition: 70% grass, 30% legume (ideally perennials).

For further information on carrying capacities on pastures and meeting livestock targets, refer to the Prograze manual produced by NSW Agriculture. There is also a Prograze course teaching more about the pasture and grazing management system.

If pastures are used as part of a cropping rotation they can act as a disease break, help with weed control and add nitrogen to soils for the cropping phase.

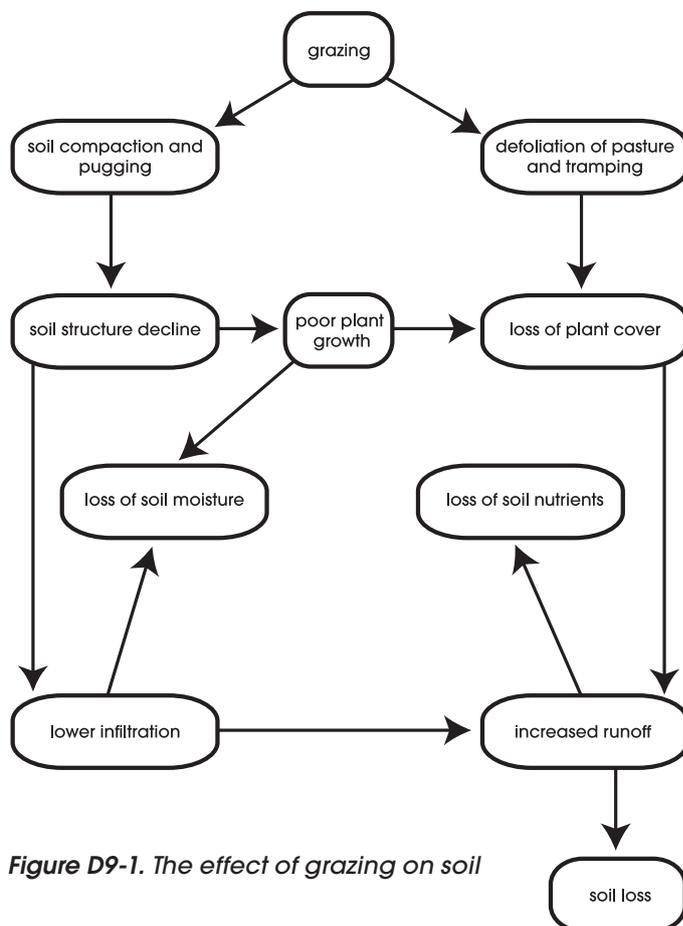


Figure D9-1. The effect of grazing on soil

D10. Soil-borne diseases

PURPOSE OF THIS CHAPTER

To show how the soil can influence soil-borne plant diseases

CHAPTER CONTENTS

- introduction to soil-borne diseases
- rhizoctonia
- brown leaf spot of lupins
- sudden death of lupins

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B14. Choosing the next crop
 - B16. What can I do about waterlogging?
 - C4. Examining plant roots
 - D4. Maintaining and improving soil structure
 - D6. Conservation farming
 - D7. Soil improvement through biological activity
-

INTRODUCTION

The soil harbours a large number of plant pathogens (micro-organisms that cause plant diseases). Frequently, management practices determine whether these pathogens can infect a crop, and the extent to which they affect yield.

Management practices that affect disease development can be as simple as tillage, timing of operations, and the amount of surface cover remaining after the crop is sown. Management is second after seasonal conditions in affecting the extent of disease development.

The effect of tillage on the development of rhizoctonia root rot is perhaps the best known. Several other diseases are also affected by tillage, including two major diseases of lupin, brown leaf spot and sudden death.

RHIZOCTONIA

Cause. Rhizoctonia root rot or bare patch is caused by the fungus *Rhizoctonia solani*, which in its various forms can infect cereals, pulses, oilseeds and pastures. This fungus survives on organic residues in the soil, such as old crop stubble, and following autumn rains grows out of these residues and attacks seedling roots.

Identification. Infected plants in the field are stunted, spindly and often brightly coloured. These plants often appear in patches that can be easily seen, varying in diameter from 30 cm to several metres. When pulled up, infected roots have brown points coming to a sharp point or ‘spear tip’.

Management. Rhizoctonia root rot is favoured by direct drilling, especially where soil is not disturbed below the seed. Therefore cultivation within two weeks of sowing, or use of modified sowing points that disturb the soil below the sowing depth, can help alleviate the problem. It is important to use adequate fertiliser; good soil nutrition can also reduce potential losses from Rhizoctonia.

BROWN LEAF SPOT OF LUPIN



Kurt Lindbeck

Cause. This disease is caused by the rain splash of fungal spores of the fungus *Pleiochaeta setosa* on to leaves and stems of lupin seedlings. These spores remain viable in the soil for several years, allowing infection of subsequent lupin crops to occur. Spread of spores between paddocks is via lupin stubble blown from nearby paddocks or carried on soil. This can infect paddocks where lupin has been sown for the first time.

Identification. Infected leaves develop dark irregular spots and fall to the ground (Figure D10–1). Often the disease occurs soon after seedling emergence, when conditions are cool and wet. Under these conditions there is potential for seedlings to be killed over large areas.

Management. Other than crop rotation, retention of cereal stubble on the soil surface is the most effective means of reducing the incidence of brown leaf spot. The stubble acts to reduce rain splash and protects seedlings from infection. Avoid sowing practices that allow a bare soil surface with little cover.

Figure D10-1. Brown leaf spot of lupin



Kurt Lindbeck

SUDDEN DEATH OF LUPIN

Cause. There is growing evidence to suggest that this condition is caused by an interaction between soil hardpans and fungal pathogens.

Early field observations have shown that areas where sudden death of lupin plants is occurring have suffered waterlogging earlier in the growing season, most likely in winter, when rainfall is high and evaporation is low. These excessively wet conditions are ideal for attack from fungal pathogens. Pathogens attack when plants are stressed and soil conditions are favourable. The effect of hardpans during extended wet periods is that waterlogging of the upper soil profiles can occur due to poor water infiltration of the hardpan layer.

Identification. Lupin plants are highly susceptible to waterlogging, but plants affected by sudden death will not necessarily display symptoms of waterlogging during the growing season. Typical indicators of sudden death are seemingly healthy plants in the field suddenly wilting and dying within days with no apparent cause (Figure D10–2). Sudden-death-affected plants can die in patches of a few plants or in areas a few metres wide. These symptoms are usually seen later in the growing season during late pod fill.

Management. Cultivation practices that improve soil structure, as well as breaking up soil hardpan layers, will allow free movement of water down the soil profile and decrease the incidence of this condition. Simple steps, such as timing cultivation correctly (see Chapter B15) and using narrow points may remedy the situation.

Figure D10-2. Sudden death of lupin

D11. Managing gilgais

PURPOSE OF THIS CHAPTER

To explain why gilgais form and options for gilgai management

CHAPTER CONTENTS

- cause of gilgais
- properties of gilgais
- should I landplane?
- case study

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B7. Do I have gilgais?
- C1. Examining the soil profile
- C3. Soil types and landscapes
- C5. Chemical soil tests
- D3. Sodicity
- D4. Maintaining and improving soil structure
- D6. Conservation farming
- D8. Improving soil chemical fertility

GILGAIS

Do you have areas on heavy clays that are undulating and that fill with water?

This landform is called gilgai, meaning ‘melon hole’ or ‘crab’. The term gilgai comes from an aboriginal word for small waterhole, and it is now used for all forms of undulations where there are mounds (‘puffs’) and hollows. There are many different forms, depending on climate and clay content. The central west has crab holes up to 2 m deep (from top of mound to bottom of hollow). So gilgais are not just a characteristic of southern New South Wales, but a feature of Australian heavy, self-mulching clays.

Gilgai are found where there are regular or intermittent periods of drought and in areas of high summer temperature. Climatic conditions need to be dramatic—wet and then very dry—so that the soil swells and cracks.

Causes

Gilgais are formed by the forcing upwards of large blocks of soil that have been released (pushed) through horizontal features in the subsoil. This is possibly caused by the swelling, in a wet period, of topsoil that fell down cracks earlier when the soil dried out (Figure D11-1).

These soils are best thought of as being in a state of slow continuous movement, a dynamic system in which the deeper layers are brought to the surface on the mounds and soil from the surface mulch slips down to lower levels in the holes and cracks of the depression.

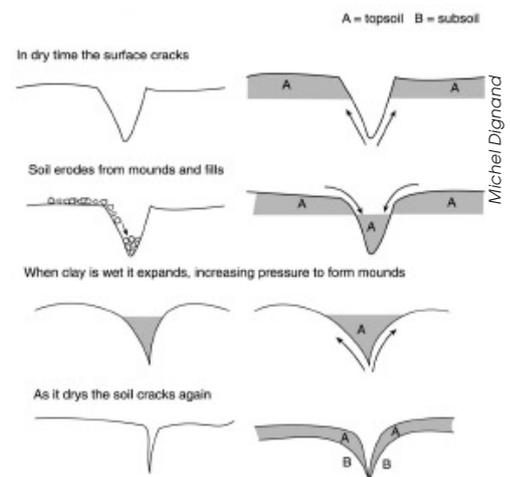


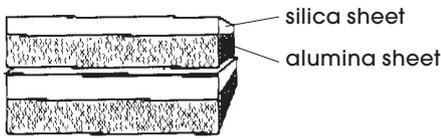
Figure D11-1. How gilgais are formed

CLAY

Clay is the smallest sized of all soil mineral particles. Clay is made from the weathering products of various minerals. The particles are composed of sheets of aluminate (aluminium oxides) and silicate (silicon oxides) (Figure D11-2).

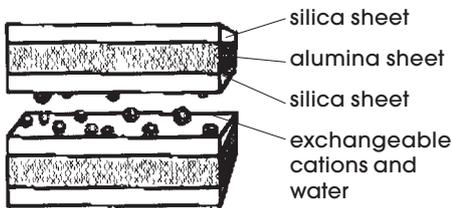
The characteristics of the clays change with their chemical compositions. Cracking clay soils contain a large proportion of smectite (montmorillonite) clay mineral. This mineral swells markedly when it absorbs water.

Clay particles are less than 0.002 mm in diameter, but their size gives a small volume of clay particles a large surface area. This surface area makes available many reactive sites for exchange of ions in a small volume of soil. The clay therefore acts as a colloid.



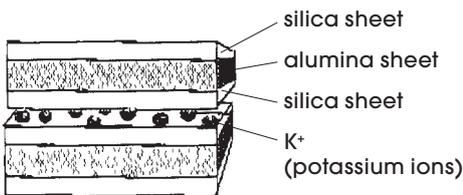
Kaolinite

- Little expansion on absorption of water.
- Used for ceramics.



Smectite (montmorillonite)

- Large expansion on absorption of water.
- This clay mineral has a major effect on the behavior of cracking clays.
- Used in agriculture as 'bentonite' for sealing dams.



Illite

- Little expansion on absorption of water.

Figure D11-2. The structures of some common types of clay minerals found in the soil

Why is clay negatively charged?

The basic building blocks of the clay minerals are silicon atoms surrounded by four oxygen atoms (silicate) or aluminium atoms surrounded by 6 oxygen atoms (aluminate). These groups of atoms are arranged in sheets. The atoms in these sheets are tightly bound and are not exchangeable with other ions in the solution.

Within sheets, negative oxygen atoms closely surround the positive silicon or aluminium atoms and the positive and negative charges cancel out. However, oxygen atoms that are exposed on the surface of the clay crystal are not wholly balanced by positively charged atoms. A net negative charge results.

Also, aluminium (only three positive charges, Al³⁺) can replace some of the silicon (four positive charges, Si⁴⁺) in the crystal structure and the negative charge increases.

The negative charge on the surface of clay particles attracts positive ions (cations). This is important for the storage of cations that can be used by plants as nutrients. It also allows us to alter soil structural characteristics chemically by changing the cations that are absorbed on to the clay surface.

The surface of a clay particle, being negatively charged, attracts positive ions. When the clay is too wet, the exchangeable positive ions on the surface of the clay move into the soil solution surrounding the clay particle. They are, however, still attracted to the clay surface and consequently swarm close to the clay surface.

HIGH ESP AND DISPERSIVE SOILS

In a dispersive soil with a high exchangeable sodium percentage (ESP) and low salinity, the weak bonding of the clay particles by sodium ions can be broken. As water enters between the clay particles it hydrates the sodium ions. This, in turn, forces the plates away from the ions and lowers the attractive forces between the particles and the ions. The plates may move far enough apart for attraction forces to be overcome. The result is dispersion.

The depth of cracking is strongly influenced by the type of crop or vegetation that is present. Water movement is very

slow in these soils, so drying out is usually the result of roots depleting the soil water.

PROPERTIES OF GILGAIS

Gilgais contain medium to heavy clay, the amount of clay increasing with depth. The hollows are coarser textured. In the Riverina, montmorillonite and kaolinite are the clays commonly found in the soil, along with quartz particle fragments. Other gilgais are more uniform in texture with depth (with shrink-swell clays). Calcium carbonate is found in the mounds, but not in the hollows. This is seen around the Temora area.

A difference is found between the surface soil of the mound and the soil in the hollow; this difference follows the difference in carbonate distribution and range of pH values. (See the following case study for soil test information.) Since mounds and hollows have different pH values and varying amounts of carbonate, they need to be managed as separate units.

In the hollow, the CEC (cation exchange capacity) of the clay fraction increases with depth. The carbonate content is stable below the hollow. The proportion of montmorillonite shrink and swell clay, and the proportion of sodium on exchange complexes, increase with depth.

Table D11–1 shows some typical laboratory test results for gilgai soil.

SHOULD I LANDPLANE GILGAIS?

The management of gilgais is very difficult. It depends on climatic conditions within a year, as well as over 10 years. There are three considerations. These are:

1. One way to manage gilgais is to put them under pasture. This is not as costly as land planning, and the roots are able to use moisture and stabilise the soil.

Table D11–1. Typical soil test results for gilgais

Test	Gilgai mound (0–10 cm)	Gilgai mound (10–20 cm)	Gilgai hollow (0–10 cm)
pH	7.87	8.27	6.73
EC (dS/m)	0.37	0.47	0.17
Carbon %	0.79	0.36	1.05
Nitrogen %	0.10	0.04	0.10
Phosphorus mg/kg	3	< 1	4
Aluminium (cmol/kg)	0	0	0
Manganese (cmol/kg)	0	0	0.2
Sodium (cmol/kg)	2.84	8.27	3.95
Potassium (cmol/kg)	1.26	0.99	0.98
Calcium (cmol/kg)	17.73	11.8	9.43
Magnesium (cmol/kg)	12.83	15.59	13.11
Total CEC (cation exchange capacity)	34.7	36.7	27.5
Exchangeable sodium percentage (ESP)	8.2	22.5	14.4

2. Cropping these soils is very difficult, as there are two separate soil types (puffs and hollows) requiring different management. Crops are very difficult to harvest because of the undulations and different growth stages of the crop. Soils in the hollows can become waterlogged, and small ponds can appear.
3. Land planning removes topsoil from the mounds and places it in the hollows (Figure D11-3). This leaves only subsoil on the puffs, which have lower organic matter levels, higher amounts of clay and higher sodium levels, therefore making it harder for the plants to get a good start to life.

Because of the shrink and swell nature of the clay, gilgais will come back in two to 10 years, so you need to think very carefully about the costs of laser levelling compared with the benefits. The costs of levelling may be covered by profit in the first five years of cropping: if the gilgais come back in 10 years there will have been five years of extra profit, but if the gilgais come back in three years you will have lost money.

When looking at the costs of land planning, remember the labour, fuel and time costs. For further information contact your local agronomist.

Try your own management trials with detailed monitoring of economic costs and benefits.

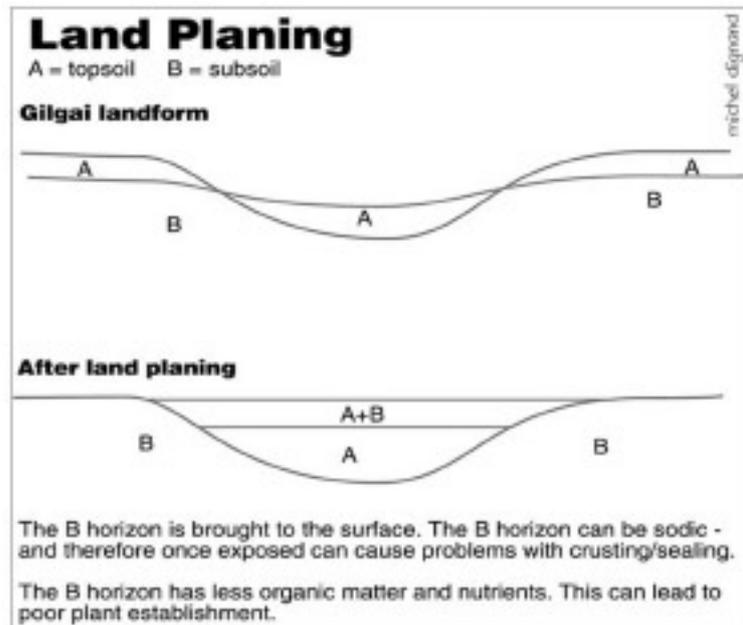


Figure D11-3. Land planing

CASE STUDY ON MANAGING GILGAI COUNTRY: LES BERGMIEIER, 'DALRIADO'

The 1400-ha property, 'Dalriado', near Lockhart, has large areas of gilgai country. Twenty-five years ago, owners Les and Margaret Bergmeier began thinking of different ways to overcome the problems associated with gilgais. According to Les, most of the water ran off the banks and filled

the hollows, making them waterlogged and unworkable. The smaller tractors of the time made it difficult to achieve large-scale levelling, so the Bergmeiers began with small areas, improving their property section by section. Today, Les is successfully producing many different crops, including wheat and canola.

The levelling process continues on 'Dalriado'. Starting in January or February every year, Les deep-rips the affected sections of a paddock with an Agroplow™, then levels the country with a grader. Today's larger machinery and hydraulics have made it easier to level larger areas, creating less stress on the equipment.

In April, gypsum is applied at 2 t/ha. Les has found that gypsum is the key to success when working gilgai country. Once the gypsum has washed in, the paddock is scarified and the crop is sown in late April or May. After the gypsum application, Les says the banks become the best areas of the paddock. The moisture content in the soil is also improved, and this helps to increase yields. The gypsum has made the system workable. Les can now direct drill his crops, allowing the soil to regain its structure.

Les believes his property looks much better today than it did a quarter of a century ago. It is worth more money, and it's easier, quicker and more timely to spray. There is less wear and tear on machinery and implements, saving dollars on replacement and repairs.

Although in some areas of 'Dalriado' the banks of the gilgais are starting to rise again, Les knows that they will not rise to the same extent and that they will be easier to level again.

Les's success in managing gilgais has provided him with the expertise to purchase other gilgai-affected properties, at a low cost, knowing that they can still be productive.

Les believes, 'If you know how to manage gilgais then you can still make the dollars'.

D12. Managing soil for efficient water use

PURPOSE OF THIS CHAPTER

To describe how to store water efficiently in the soil

CHAPTER CONTENTS

- seasonal background
- uses for surplus water
- soil water storage for crops and pastures
- how to improve your soil water storage

ASSOCIATED CHAPTERS

You may need to refer to the following chapters:

- B4. Does my soil need gypsum?
- B5. Poor seedling emergence
- B16. What can I do about waterlogging?
- C1. Examining the soil profile
- C4. Examining plant roots
- D4. Maintaining and improving soil structure
- D5. Erosion
- D6. Conservation farming
- D7. Soil improvement through biological activity
- E1. Soil structure

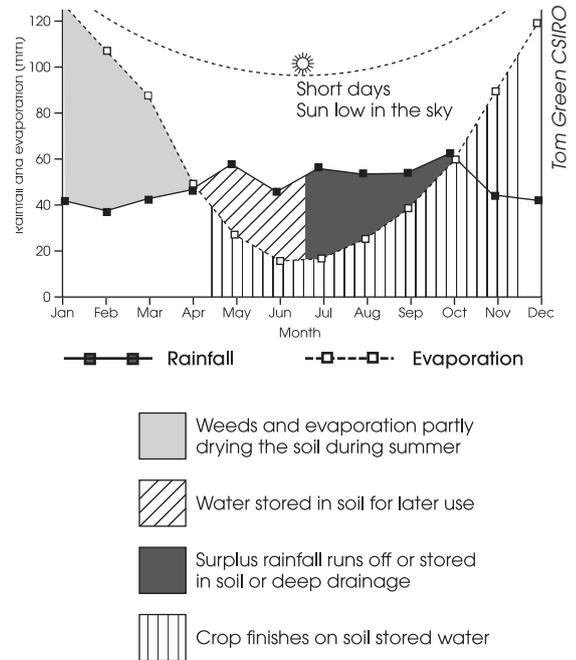


Figure D12-1. Wagga Wagga rainfall and evaporation

- ☞ See Chapter B10 for more information on erosion.
- ☞ See Chapter D2 for more information on salinity.
- ☞ See Chapter D1 for more information on acidity.

SOIL MANAGEMENT FOR INCREASING WATER-USE EFFICIENCY

Higher rainfall increases yield most years in most places. There is an advantage in making the best use of water.

Unwanted water movement can cause land degradation in several ways:

- Uncontrolled run-off will result in soil erosion.
- Drainage to the subsoil raises watertables and moves salt stored in the soil.
- Drainage below the root zone carries down nitrate, causing surface acidification.

Figure D12–1 shows the seasonal differences between rainfall and the potential demand for water through transpiration from plants and evaporation from the soil. Growing plants actively give off water in a process called transpiration. When plants are short of water they seal off their leaves to prevent water escaping. When this happens the plant stops growing and producing food. Energy from the sun drives the growth process, so the potential for growth is high

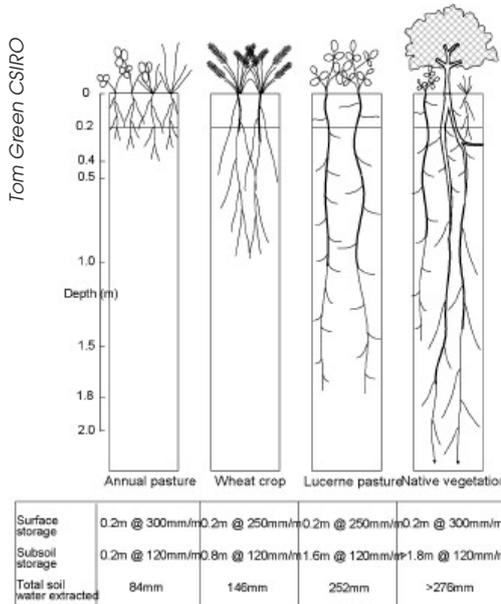


Figure D12-2. Effects of different vegetation at different soil depths on the amount of water that can be extracted from a sodosol soil typical of the heavier soils in this district

in summer and lowest in winter when the sun is low in the sky and the days are short. In the Wagga Wagga region, rainfall is low during the summer but higher in winter—higher than the potential combined evaporation from the soil and transpiration from plants. (This combined water consumption is called evapo-transpiration.) No matter what crops or native vegetation are grown, there will be a surplus of water during an average winter.

The fate of this surplus water determines the long-term viability of agriculture in this region.

Figure D12–2 shows how the differing land uses and rooting depths of vegetation affect the amount of water that can be extracted from a sodosol typical of many of the heavier soils in the region.

From Figure D12–1 we can calculate that winter rainfall exceeds evaporation by about 146 mm in an average year. If all this water soaks in, it will wet the soil down to about one metre (if the soil was completely dried out at the break of the season).

EFFECTS OF DIFFERENT TYPES OF VEGETATION ON SOIL WATER

Deep-rooted pastures like lucerne and native vegetation can dry out the soil to much greater depths than annual pastures, so soils growing this type of vegetation store all of the excess rainfall for later use.

An average wheat crop roots to about one metre, so its root zone can access the stored surplus winter rainfall in an average year. In the example shown we assume less water will be stored in the topsoil under wheat due to soil structure decline. In every wetter year there is the potential for deep drainage from a crop like this.

Annual pasture, with its shallow root system, can extract only 84 mm of the 146 mm of excess rainfall, so there is a potential for damaging amounts of deep drainage to build up in most years.

WHAT HAPPENS TO SURPLUS WATER?

Some is stored in the soil. Much of this water can be stored in the soil for use by plants in the spring when the sun shines more strongly and crops and pastures are growing rapidly.

Some runs off. Clean run-off is a valuable commodity if it can be stored in farm dams or community storages. Uncontrolled runoff causes erosion and costly siltation of streams and dams. Water that runs off a paddock is no longer available for crop or pasture growth.

Some seeps below the root zone. Water seeping below the root zone takes dissolved nitrates and sometimes herbicides along with it. The level of nitrate in well water is already too high for long-term human consumption over much of Australia.

Leached nitrogen from clover to below crop roots is a major factor in soil acidification. Re-using the stored soil water and its entrained nitrate by growing good deep-rooted crops is the best way to protect your soil.

The way to increase yield and at the same time reduce land degradation is to store more water in the soil and use it for plant production. Water draining away will sooner or later reach the watertable. In this region the watertable water is usually too salty for use in irrigation, so it accumulates in the soil. As a result, watertables rise until the water begins to leak out along drainage lines. This is the cause of dryland salinity.

HOW DOES THE SOIL STORE WATER FOR CROPS AND PASTURES?

Both the amount of water that can flow into the soil in a given time (its infiltration rate) and the amount that the soil can hold (its storage capacity) are important.

Infiltration rate

After rain saturates the soil surface, water flows into the soil through large holes such as wormholes and the holes left by decayed plant roots. These large holes are known as macropores and they are important in moving water away from the soil surface (Figure D12-3).

The bulk of the soil adsorbs water through small holes from these large pores by capillary suction. These small holes, called micropores, are less than 0.05 mm across, but there are huge numbers of them in a healthy soil and they spread the water throughout the soil.

From this you can see that the ideal soil needs a wide range of pore sizes to conduct water efficiently.

Soil storage capacity

The soil must hold the water for later use by plants. The less dense the soil (that is, the lower its 'bulk density'), the more air space it has between the solid particles. Water is stored in this airspace as layers of moisture around the soil particles and by capillary force in the small pores of the soil. Because so much of the soil water is stored as a thin layer coating the soil particles, soils with a large surface area (that is, clay-rich soils) store more water than sandy soils. Water held in the larger pores usually drains away by gravity within 24 hours.

The ease with which plants can suck water out of the soil is also very important. Water flowing into the soil is sucked into the small crevices of the soil by capillary attraction. The smaller the crevice the stronger its attraction for water. In this way the soil can be seen as competing with plant roots for water in the soil.

At some point the suction exerted on the remaining soil water by the very fine soil capillaries will exceed the maximum suction that the plant roots can exert. At this point the plant wilts permanently.

There is still a lot of water left in a clay soil after the plants wilt permanently—it is just unavailable to plants.

Plant-available water in different soil types

The difference between the just-drained state and the water content at the permanent wilting point is the maximum amount of water that the soil can store for crop use. This is called the 'plant-available water'.

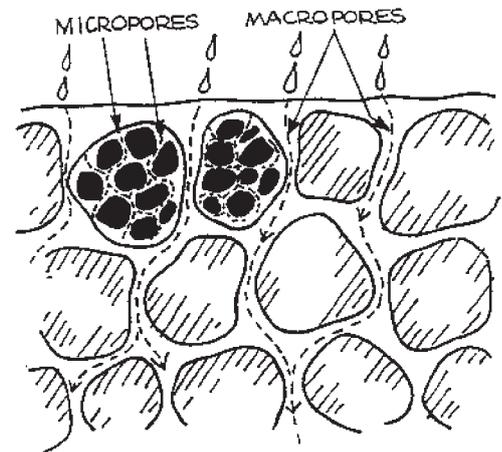


Figure D12-3. Infiltration of water into soil

Clay soils contain many fine particles with small gaps between them, so they hold a lot of water very tightly. Crops must work very hard to suck water from clay soils.

Loosening clay soils increases water penetration and storage by increasing the number of large soil pores.

Sandy soils have large gaps between the grains. Water drains through sand by gravity, leaving little behind for later use by the crop. Loosening sandy soils won't improve water intake and may reduce water storage by increasing drainage.

Loamy soils are ideal. They have a good range of pore sizes, so they hold good supplies of water, which plants can easily extract.

HOW CAN YOU IMPROVE YOUR SOIL'S WATER STORAGE?

For rain to be effective it must flow into the soil for storage, and to the roots for crop growth. Water that runs off is no longer available for plant growth, while water that lies on the surface will restrict air entry into the soil, thus slowing plant growth.

There are two parts to improving your soil's water storage or 'plant-available water':

1. storage capacity improvement by structural improvement
2. rooting depth improvement.

Storage capacity improvement by structural improvement

A good surface structure with no surface crust will ensure the rain gets in. The topsoil structure is improved by increasing soil organic matter levels and reducing tillage. Organic matter binds the soil together, and reduced tillage encourages earthworms to burrow up to the surface. Soils with low organic matter levels rapidly crust over when rain falls. Much of this crusting is due to raindrops battering the soil surface. Crop and pasture residues shelter the soil, thus maintaining the initial high infiltration rate. Retaining stubble will not help much if the topsoil is compacted and degraded to depth.

To ensure that water soaks through to wet all of the root zone, you need plenty of old root channels and worm holes. You also need to avoid subsoil compaction by not cultivating when the soil is too wet.

If your subsoil is dispersive you may need to add gypsum. Gypsum stops dispersion, thereby stopping clay from blocking the small crevices in the soil.

Rooting depth improvement

Annual pastures and crops often have very shallow roots. This limits the amount of soil from which they can extract water. Dense subsoils can be too hard for roots to penetrate; air entry is slow so roots have trouble breathing, making the soil a hostile place for roots.

☞ See Chapter D3 for more information on using gypsum.

This situation can be improved by:

- growing deep-rooted perennial grasses and lucerne in rotations. These plants are better able to grow deep roots, and their roots create channels that later crops can exploit. These roots dry out and crack the subsoil, letting in more air and leaving organic matter to stabilise the soil when they die.
- growing healthy, disease-free crops and pastures with strong root systems that can use the soil water. Break crops such as canola can greatly improve wheat root growth.

☞ See Chapter B14 for more information on crop rotations.

