NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – northern wheat belt - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/resources/soils/guides/soilpak/northern-wheat-belt

Updated versions of this document can also be found at the above web address.

B1 Trouble-shooting guide

Purpose of this chapter	To help you determine the cause of a soil problem and to direct you to chapters that will help.
Chapter contents	• some problems • possible causes of these problems • direction to chapters that may help.
Associated chapters	All chapters

B1 Trouble-shooting guide

Erosion control (keeping the soil in place) is the most important practice. After that, other problems may need solving, as they reduce productivity and often contribute to erosion risk.

Go to Chapter B9 or D-s1 for more information on controlling erosion.

Soil problems

As described in **Chapter A2**: Ideal soil for farming, the soil should supply plants with adequate water, oxygen, nutrients and support. When the soil does not supply these needs, we say that there is a soil problem. An example of a soil problem is a crusted surface which reduces infiltration and increases run-off. Less water is stored in the soil for plants to use.

A soil problem may be due to:

- recent management (for example, tillage when soil is too wet compacts, remoulds and smears the soil);
- a long history of a certain management (for example, continuous cropping for many years may deplete soil organic matter to the point where the surface sets hard when dry); or
- a property of the soil itself, and the problem may always have been there (for example, if a soil is sodic, it has probably been sodic for a very long time).

Consider the needs of plants, examine the soil, and then deduce the problem. You will then be able to choose a management strategy to deal with the problem. Economics will decide if the strategy is feasible.

Go to Chapter C1 for more information on examining soil.

Common problems

Common soil problems in the northern wheat-belt are:

- Loss of soil and plant nutrients by erosion;
- declining chemical fertility, particularly nitrogen;
- damaged topsoil structure caused by traffic, wet tillage or stock trampling;
- plough pan caused by wet tillage;
- poor surface structure causing crusting or hard-setting;
- compacted subsoil caused by traffic.

Other soil problems, less common but serious when they do occur, include salinity and soil acidity.

Figure B1-1 will help you determine the cause of a soil problem.

Figure B1-1 Some soil problems, their possible causes and where to get help

Problem:	Possible other signs:	Could be due to:	Go to Chapter:
poor seedling emergence	dispersion*	sodicity	B8
poor seedling emergence	hard surface, few cracks	crusting, hard-setting	B4 E3
poor seedling emergence	cloddy seedbed	topsoil compacted by machinery or stock	D-s2
poor crop growth	dispersion*	sodicity	B8
poor crop growth	plough pan	compacted subsoil	B5 D-s2
poor crop growth	unusual leaf colour	poor nutrition	B10 D-s3
poor crop growth	unusual leaf colour	waterlogging (nitrogen deficiency)	B10 D-s7
poor crop growth	unusual leaf colour	acidity	B6
poor crop growth	unusual leaf colour	herbicide damage, disease	**
poor crop growth	salt-tolerant species, rising levels in bores	salinity	B7 D-s9
ponding	flat or hollow ground	poor surface drainage	D-s7
ponding	dispersion*	sodicity	B8
ponding	cloddy surface or plough pan	compacted topsoil or subsoil	B5 D-s2

*Dispersion shows as a skin of dispersed clay, or light- coloured, separate sand grains. Check with dispersion test, Chapter C1.

**See an agronomist for help with herbicide damage or disease.

B2 Weed control

Purpose of this chapter

This chapter explains the options for weed control whilst minimising damage to soil structure and considering erosion control.

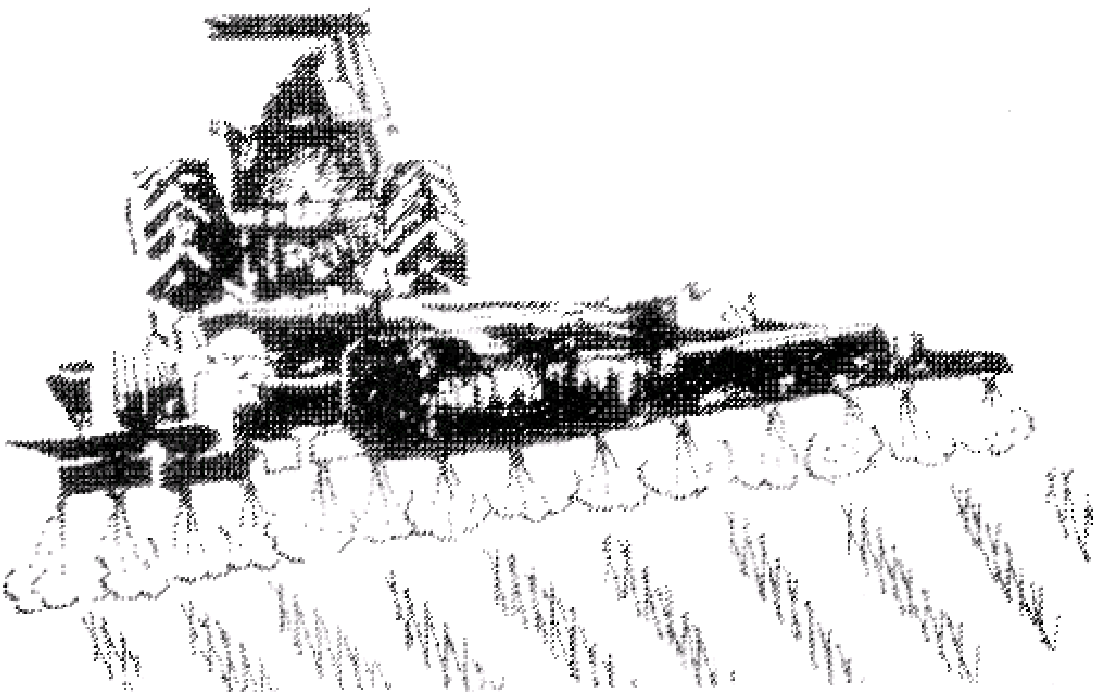
Chapter contents

- weed control on wet soil
- weed control on dry soil
- advantages and cautions of each method.

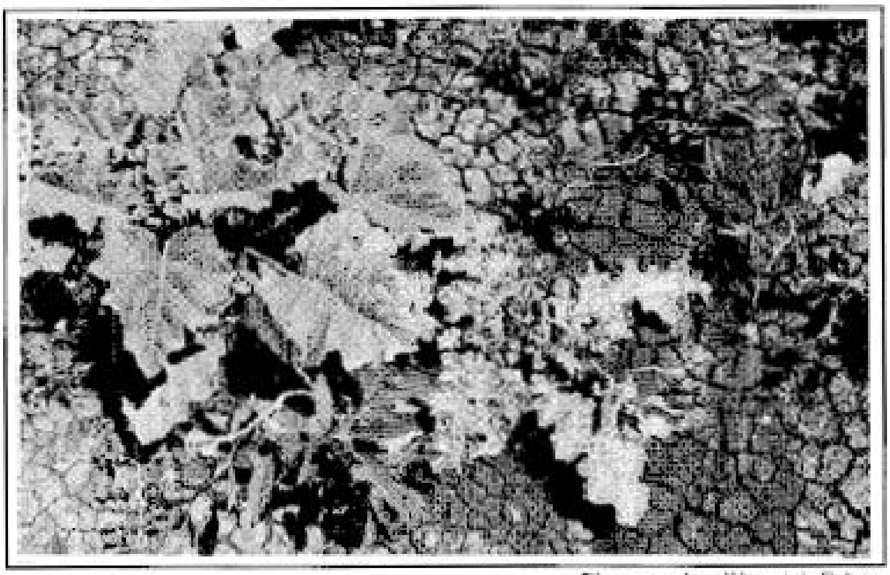
Associated chapters

You may need to refer to the following chapter:

- B9: How do I control erosion?
- D-s1: Erosion control
- D-s6: Soil moisture and tillage



B2 Weed control



Photograph: Warwick Felton

Weed control strategy

In controlling weeds between crops, consider the effect on soil erosion and soil compaction. Use herbicides rather than tillage when the soil is wet. Tillage on dry soil is permissible, but avoid creating finely-tilled, bare, dry soil; such a surface is very prone to erosion.

Sheep are effective for weed control in certain cases. They will graze isolated weeds that may be present after harvest or that escape tillage or spraying. Isolated weed patches may be inconvenient or expensive to spot spray or cultivate, and sheep are useful. Sheep are good for controlling low density and scattered weed or volunteer crop plants. Volunteers often germinate at irregular intervals, not necessarily after rain.

Sheep do not replace tillage or herbicides for control of high density weeds.

The DetectSpray™ (formerly known as the WASP) can significantly reduce the amount of herbicide used when spraying scattered weeds.

Wet soil

Herbicides are more effective when weeds are growing vigorously, as they will in wet soil. The use of herbicides minimises the disturbance of wet soil, and consequent compaction and smearing.

However, when spraying on wet soil, you are likely to damage soil structure due to wheel pressure. Drive in wheel tracks you have already made. This limits soil compaction to a minimum area of the paddock.

Go to Chapter D-s7 for more information on minimising wheel compaction.

Weed control using **tillage** on wet soil:

Advantages:	**Cautions:**
• None! See **Chapter D-s6** for information on specific soils and moisture contents.	• Soil will smear or compact.

*Weed control using **livestock** on wet soil:*

Advantages:	**Cautions:**
• None! See **Chapter D-s2** for information on trampling damage.	• Any livestock will poach the soil. • Especially, do not use cattle.

*Weed control using **herbicide** on wet soil:*

Advantages:	**Cautions:**
• Herbicide most effective on actively growing plants.	• Wheels of spray vehicle can still smear or compact soil.

Dry soil

Herbicides are not very effective when the soil is dry, because the weeds are not growing vigorously. Timing of herbicide application is critical. Working the soil when it is dry is less likely to cause smearing or compaction.

Before tilling, check the moisture content of the soil well below the plough layer (say, 30 cm, even though the tillage may not be that deep). Soil can appear dry on the surface, while remaining wet underneath. If this is so, tillage can cause compaction at depth.

Go to Chapter C4 for information on determining soil moisture content.

*Weed control using **tillage** on dry soil:*

Advantages:	**Cautions:**
• Minimum danger of damaging soil structure.	• Not compatible with zero tillage.

*Weed control using **livestock** on dry soil:*

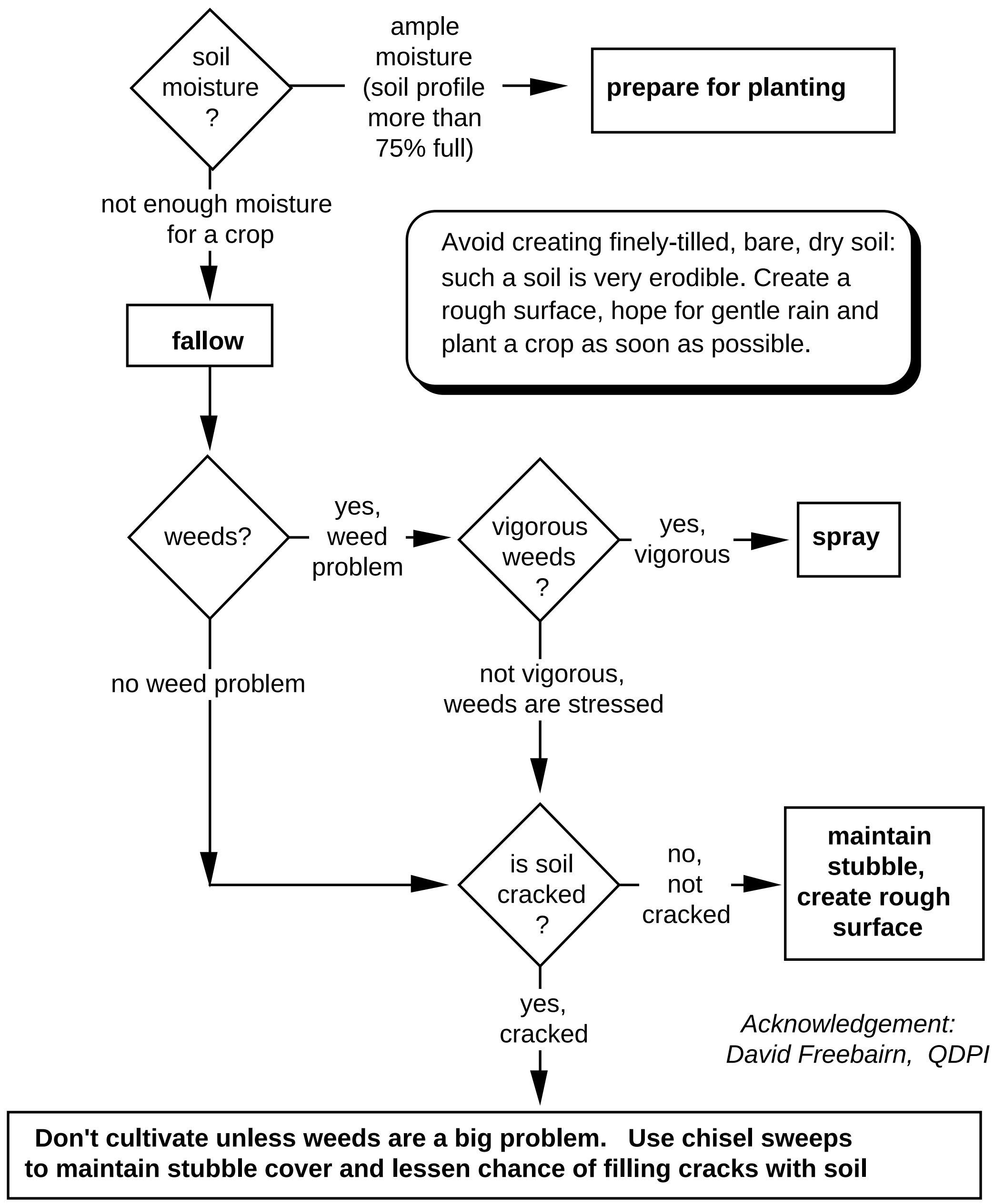
Advantages:	**Cautions:**
• Good for isolated weeds.	• Grazed grasses regrow with rain. • Stock prefer some weeds,

Weed control using ***herbicide*** *on dry soil:*

Advantages:	**Cautions:**
• Compatible with zero tillage.	• Not effective if weeds are stressed.

The tillage strategies in **Figure B2-1** aim to maximise the intake of rain while controlling weeds. Where the soil is cracked, keep the cracks open. Where the soil is not cracked, leave the soil surface rough and with as much stubble as possible.

Figure B2-1 Controlling weeds and erosion between crops



'The Law of the Land', taken trom the Stellerlander Newspaper, Vryburg, Cape Province, South Africa, author unknown. Adapted by Dr Brian Roberts and published in his book 'Soil Conservation', Darling Downs Institute of Advanced Education (now University of Southern Queensland) 1983.

The Law of the Land

Now this is the Law of the Land, son —
as old and as true as the hills.
And the farmer that keeps it may prosper,
but the farmer that breaks it, it kills.

Unlike the Law of Man, son,
this law it never runs slack;
What you take from the land for your own, son,
you've damn well got to put back.

Now we of the old generation
took land on the cheap and made good;
We stocked, we burnt and we reaped, son,
we took whatever we could.

But erosion came creeping slowly,
then hastened on with a rush,
Our bluegrass went to glory,
and we don't relish wiregrass much.

The good old days are gone, son,
when those slopes were white with lambs;
Now the lambs lie thin and starved, son
and the silt has choked our dams.

Did I say that those days were past, son?
For me they're as good as gone;
But to you they will come again son,
When the job I set you is done.

I have paid for this farm and fenced it
I have robbed it and now I unmask;
You've got to put it back son,
and yours is the harder task

Stock all your paddocks wisely,
rotate them all you can;
Block all the loose storm waters,
and spread 'em out like a fan.

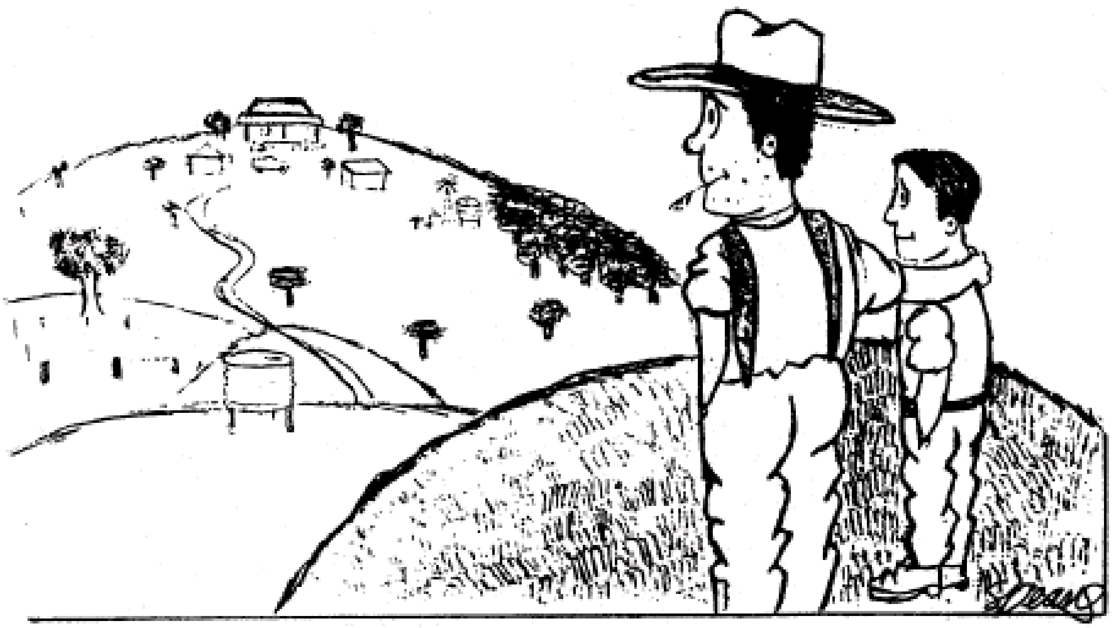
Tramp all your straw to compost,
and feed it to the soil;
Contour your lands where they need it,
there's virtue in sweat and toil.

We don't really own the land son,
we hold it and pass away;
The land belongs to the nation,
till the dawn of Judgment Day.

Now the nation holds you worthy,
and you'll see, if you're straight and just;
That to rob the soil you hold son,
is forsaking a nation's trust.

Don't ask of your farm a fortune,
true pride ranks higher than gold;
To farm is a way of living;
learn it before you grow old.

Now this is the Law of the Land, son,
to take out you've got to put back;
And you'll find that your life was full son,
when it's time to shoulder your pack.



B3 Harvesting on wet soil

Purpose of this chapter	To explain the options for harvesting on wet soil, with minimum compaction damage to the soil.

Chapter contents

- the dilemma
- increasing mobility
- minimising compaction

Associated chapters

You may need to refer to the following chapters:

- C1: Examining the soil profile
- D-s2: Maintaining and improving soil structure
- D-s7: Bed farming

B3 Harvesting on wet soil

The dilemma

A mature crop loses yield and quality in wet weather, and there is urgency in the harvest. Wet soil at harvest poses a dilemma. While it is important to harvest the current crop, the harvesting operation will damage the soil for the next crop. Soil preparation for the next crop includes what you do during this harvest!

Harvesting on wet soil is costly for three reasons:

- it takes more energy to drive on soft soil than on hard soil; (creating compaction costs you money through higher fuel use!)
- repairing damaged soil is costly;
- lower yield in the following crop is a cost.

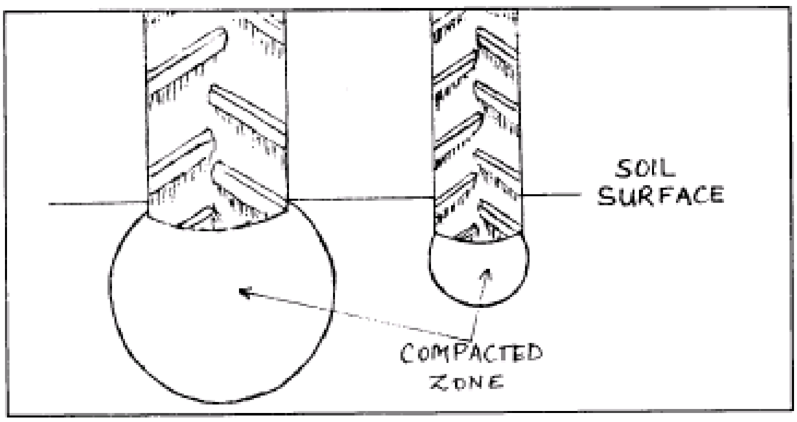
A mature crop uses virtually no soil water. The soil can dry only by evaporation from the soil surface, which is sheltered from drying winds by the crop canopy. It takes a long time for the soil to dry and there is always the possibility of further rain.

There are two distinct problems with a wet harvest, and you must weigh one up against the other. These are: the mobility of the harvester, and soil compaction.

Machinery mobility

One way to decrease wheel sinkage is to put wider tyres on the harvester. Wide tyres (or lower tyre pressures) extend the advisable limits of running machinery on moist soil without creating serious compaction. However, there will still be times when tyre ground pressure exceeds the strength of the soil, resulting in a broader zone of compaction (wide tyres compact a wide, deep zone of soil - see **Figure B3-1**).

Figure B3-1: Compaction under wide and narrow tyres.



Tracked vehicles have greater mobility than wheeled vehicles, and allow entry into a paddock when the soil is wetter. This comes at a price because damage to the soil is great.
Hydraulic drives on the rear wheels of harvest equipment helps improve mobility on wet soil.

Using wide tyres or tracks:

Advantages:	**Cautions:**
● You may be able to save a crop from rain damage by harvesting earlier.	● You are trading off the current harvest against soil damage and consequently future yields.

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Minimising compaction

Plan your harvesting pattern. Limit the number of wheel tracks across a paddock by running over previous wheel tracks where possible. This will confine wheel compaction to a reduced area. The wheel tracks of different vehicles are unlikely to match exactly, but the damage is confined to strips. When repairing the damage, you can concentrate on those strips, rather than the whole paddock.

Spreading the compaction by using different wheel tracks for each operation does **not** reduce the damage. The first pass of a vehicle over wet soil causes 90% of the damage. Subsequent passes on the same wheel tracks are running over already-compacted soil and do little further damage. In fact, subsequent passes get better traction by driving on compacted soil!

Tramlining is a system of controlled traffic where all implements have the same axle width, and run on the same wheel tracks. Different operations may use different multiples of that width. Broadacre farming in Australia is a long way from such a system because rarely do any two implements match axles.

Go to Chapter D-s7 for more information on minimising wheel compaction by bed farming.

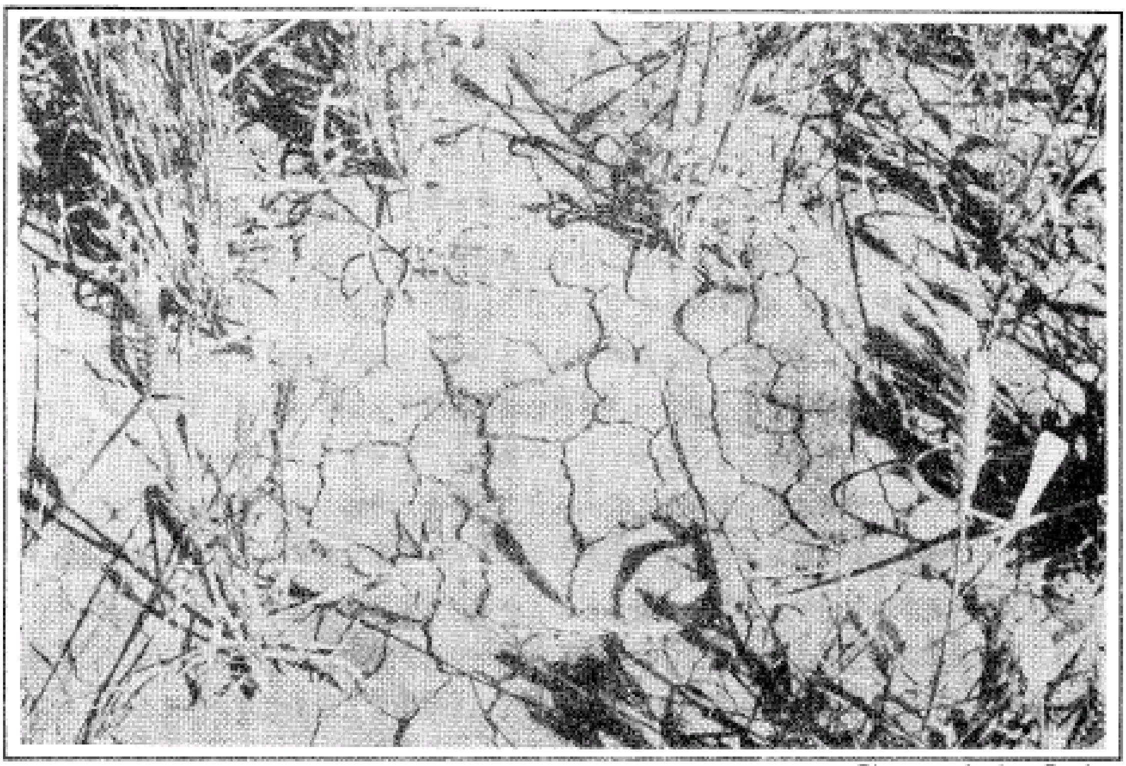
Repairing the damage

Should it be necessary to harvest on wet soil, wait until the soil dries out before you try to repair the compaction damage.

Go to Chapter D-s2 for more information on improving soil structure.

B4 Poor seedling emergence

Purpose of this chapter	To explain the causes of poor seedling emergence, particularly under no-tillage.
Chapter contents	• causes of poor seedling emergence • surface crusting
Associated chapters	You may need to refer to the following chapters: • D-s2: Maintaining and improving soil structure • D-s5: No-tillage • E3: Crusting and hard setting • E4: Organic matter



Photograph: Len Banks.

B4 Poor seedling emergence

Patchy crops reduce yield and profit. Poor seedling emergence is more of a problem under minimum tillage with reduced soil disturbance and more stubble retention. Emergence of only 30% to 60% of seedlings is common, particularly in winter crops. Seedling emergence is less of a problem under conventional tillage with finely worked seedbeds and bare ground. However, rather than reject minimum tillage because of its problems, it is preferable to address those problems.

Possible causes

Poor seedling emergence may be due to:

- poor seed-soil contact;
- inaccurate seed placement;
- too low or too high soil temperature;
- soil insects or soil-borne disease;
- surface crusting after sowing; or
- poor quality seed.

Poor seedling vigour and establishment **after** emergence may be due to compacted soil beneath the seedling. The soil may have been already compacted before sowing, or the planting tine may have smeared the bottom and sides of the seed trench.

Figure B4-1 Soil smeared when sowing with worn points in wet soil

Photograph: Warwick Felton

Planting machinery

If poor seedling emergence is due to poor seed-soil contact or inaccurate seed placement, then attention to sowing machinery will help to improve emergence.

Go to Chapter D-s5 for more information on no-till or minimum till planters.

Moisture-seeking implements may improve seedling emergence on soils with a dry surface, although moist at depth. See Agfact P1.E.1 'Moisture seeking for sowing winter crops'.

Surface crusting

Rain after sowing and before seedling emergence may form a surface crust that reduces emergence. Once seedlings have emerged, the problem of surface crusting is less. However, until the crop reaches full ground cover (and protects the surface from raindrop impact) surface crusting continues to reduce infiltration.

All soils seal under raindrop impact; even self-mulching soils seal if they are bare. On some soils, the seal is weak or it cracks as it dries; it offers little resistance to seedling emergence. However, on other soils the seal forms a crust on drying and this crust prevents seedling emergence.

Further light rain will help emergence by softening the surface; further heavy rain will hinder emergence by strengthening the surface crust.

Harrowing when the surface has dried will break a surface crust and assist seedling emergence. More rain followed by surface drying before emergence may indicate the need to repeat the harrowing.

On some soils, the whole topsoil sets into a hard layer as it dries. This is called hard-setting, and is more difficult to manage than crusting. Harrowing is unlikely to break a hard-set topsoil and assist seedling emergence.

Soils that are prone to surface crusting or hard-setting are low in clay and organic matter. They are better suited to pasture than cropping, but may be cropped for a short time between longer pasture phases. During the cropping phases, stubble cover will protect the surface from raindrop impact and reduce the soil's tendency to crust or hard-set.

Go to Chapter E3 for more information on crusting and hard-setting.

Clay soils can crust if the surface is sodic. The treatment for such soils is gypsum.

Go to Chapter B8 for more information on gypsum.

B5 Do I need to deep rip?

Purpose of this chapter

To discuss management options available to deal with a deep compaction problem, and to direct you to other parts of the manual for more information.

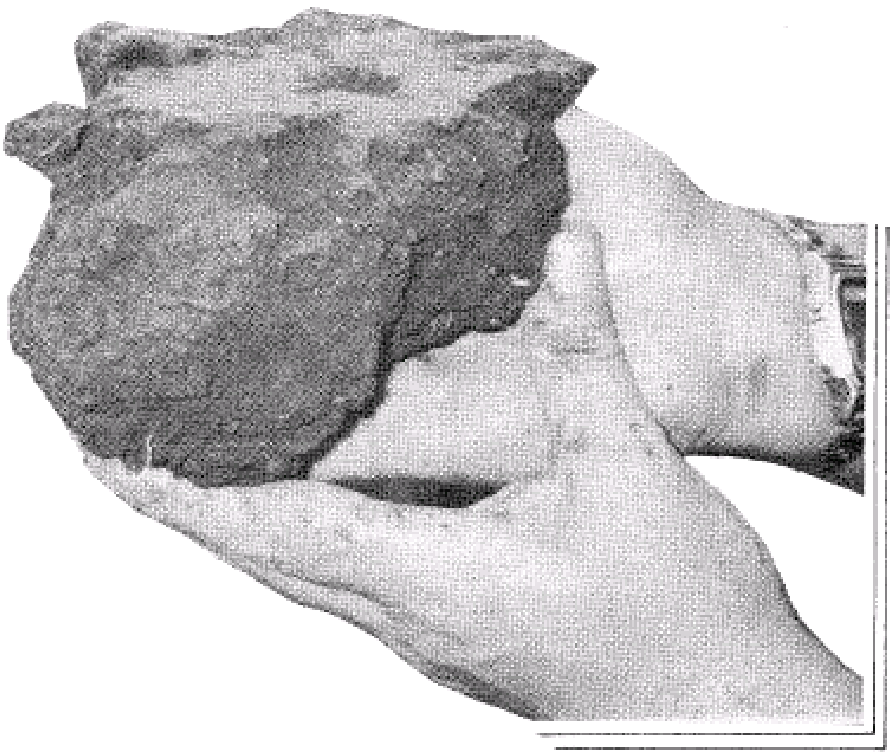
Chapter contents

- compaction management and prevention
- compaction repair
- biological repair
- mechanical repair
- the importance of soil moisture content

Associated chapters

You may need to refer to the following chapters:

- B3: Harvesting on wet soil
- C1 Examining the soil profile
- D-s2 Maintaining and improving soil structure
- D-s6 Soil moisture and tillage
- E4: Organic matter



B5 Do I need to deep rip?

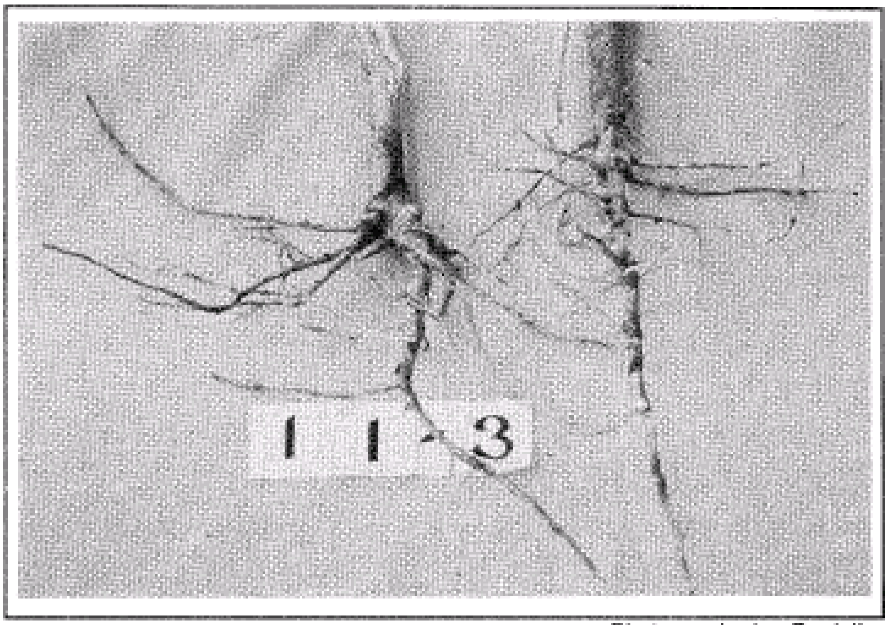
Do I need to deep rip? For a quick answer, go to the box at the end of this chapter.

Compaction management

A small degree of compaction can be beneficial. Soil which is too loose may not be good for plant growth: a loose seedbed dries out too quickly and gives poor contact between seeds and the soil; seeds may not germinate. The optimum level of compaction depends on the soil type, the plant, and the climatic conditions during the growing season.

Too much compaction however, causes yield reduction (depending on the season). A compacted soil has less ability to handle difficult seasons. Where nutrient and water supply are adequately maintained, plants are able to compensate for the lack of rooting depth caused by compaction. They do this by producing more roots in the surface layer. So in a season when the right amount of rain falls at the right time, it is possible to grow a crop on compacted soil with little or no yield reduction. In a dry year, however, compaction can lead to severely reduced yields or a complete crop failure.

Figure B5-1 Root response to soil structure The root on the left has branched in response to a compacted layer. The root on the right, from well structured soil, has a straight tap-root and a proliferation of lateral (side) roots.



Photograph: Ian Daniells

To reduce soil compaction:

- time mechanical operations carefully;
- reduce axle loads;
- keep livestock off wet cropping country;
- confine traffic in laneways; and
- use low ground-pressure tyres (with caution).

Go to Chapter D-s2 for more information on improving soil structure.

The method of repair will depend on the soil's capabilities. A cracking clay that swells and shrinks behaves quite differently from a hard-setting fine-sandy or silty soil. If a soil swells and shrinks on wetting and drying, you can use that natural action to break up a compacted layer. If a hardpan has developed in a soil with little clay, you will need to consider other options.

Soil compaction repair options shown in **Figure B5-2** are:

- biological repair, that is using growing plants to break up a compacted layer (such repair includes 'biological ripping' and 'biological drilling') or increasing soil organic matter content;

- mechanical repair, that is deep ripping or mouldboard ploughing.

Biological repair

Biological repair is using growing plants to restore soil structure. It usually involves a yield penalty. The plants will suffer in restoring the soil structure, and will produce a lower yield. Repair of compaction should therefore work in with the season, prices, and your long-term plans.

Biological repair includes:

- biological ripping (using plants to dry and crack the soil);

- biological drilling (using tap-rooted plants to 'drill' through a compacted layer); and

- increasing soil organic matter content.

'Biological ripping' of cracking clays

The easiest way to restore soil structure in compacted cracking clays is to dry the soil, using any plants with a vigorous root system. Drying causes the soil to shrink and crack, allowing water, air and roots to penetrate through the cracks. This process is called 'biological ripping'.

Go to Chapter B11 for more information on crop rotation.

Under bare fallow in a dry season the soil will dry to some degree, but it is quicker and surer to use plants. Plants extract water from a greater depth and dry the soil more thoroughly than bare fallow.

'Biological drilling' of non-cracking soils

In soils that don't crack, such as sandy, silty or loamy soils, 'biological ripping' is not an option. However, 'biological drilling' is possible.

A strong tap-rooted plant can force its way through a compacted layer and leave root channels for subsequent plant roots to use. This is 'biological drilling. The compacted layer must be moist: no root will enter dry soil. Depending upon how badly compacted the subsoil is, some roots will not be able to penetrate the compacted layer and the crop will suffer.

Increasing soil organic matter

Some soils, such as fine sandy and silty soils depend heavily on organic matter for the maintenance of their structure. Even cracking soils benefit from increased organic matter content. Increasing the organic matter content of a soil is a slow process. A pasture phase incorporated into your rotation is perhaps the most cost-effective way to achieve this.

Go to Chapter E4 for more information on organic matter.

Mechanical repair

Deep ripping and mouldboard ploughing are sometimes useful for quick results, but they are expensive operations. The initial success of the operation depends on the moisture content of the soil and the depth of tillage. Continuing success depends on managing traffic to avoid having machinery on the soil when it is too wet.

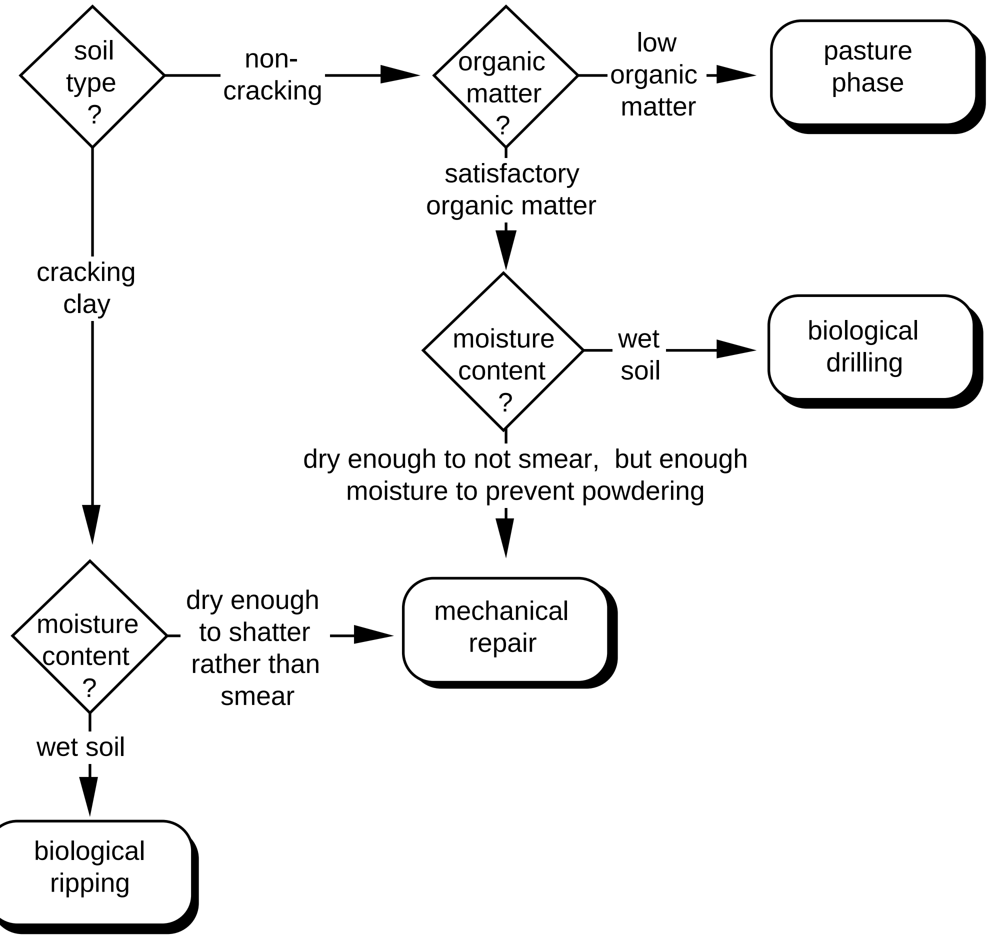
Go to Chapter D-s2 for more information on deep tillage.

The importance of moisture content

Soil moisture content is important when working the soil. A soil (particularly a clay) that is worked too wet will compact, while a silty or fine-sandy soil that is worked too dry may powder. The soil in both instances will then be structurally degraded.

Go to Chapter D-s6 for more information about working soil at ideal moisture contents.

Figure B5-2 Strategies for dealing with deep compaction.



Tip: Before deep ripping, dig a hole to see if there is a compacted layer. If there is, check the layer's depth, thickness, and moisture content. The severity of compaction will also influence your decision on deep ripping.

If there is no compacted layer, there is no need to deep rip. Moreover, deep ripping is expensive and it could do more harm than good if the soil is too wet: a costly way of creating soil structural damage where none existed before!

A compacted layer must be at the right moisture content to benefit from the ripping operation. When cultivating clays (or when the compacted layer is clay) the layer must be dry enough to shatter, rather than smear. When the compacted layer is other than clay, some moisture is desirable so that the layer does not powder.

The depth and thickness of a compacted layer indicate how deep to set the ripper tine. To be effective, the tine should work just below the compacted layer. Dig a hole after a short run and check the effectiveness of the ripping operation.

B6 Does my soil need lime?

Purpose of this chapter

To explain the effects of soil acidity on plants and how to determine when to use lime.

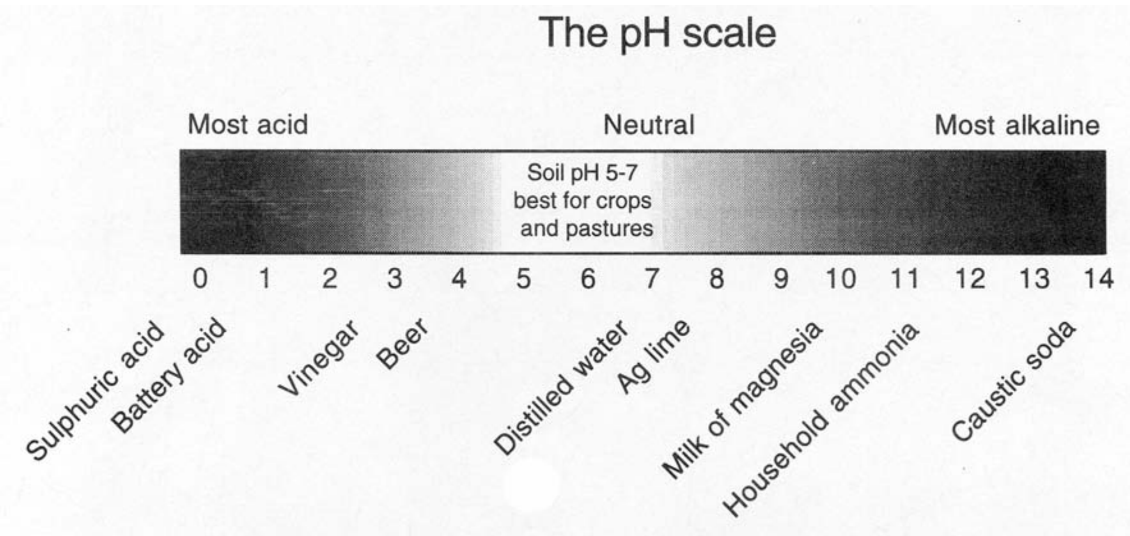
Chapter contents

- occurrence of acidity
- plant symptoms
- testing
- liming
- slowing the process of soil acidification

Associated chapters

You may need to refer to the following chapters:

- B8: Does my soil need gypsum?
- E1: Soils of the northern wheatbelt
- E5: Plant nutrients



B6 Does my soil need lime?

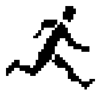
What does lime do?

Lime has two effects on soil. Firstly, it neutralises acidity. Secondly, it **may** be a slow-acting alternative or a complement to gypsum in the treatment of sodic, dispersive clay soils.

This chapter deals with lime as a treatment for soil acidity. **Chapter B8** deals with lime and gypsum as treatments for sodic soils.

Occurrence of acidity

Acidity is not a problem for most of the soils in the wheat-belt of northern NSW and southern Qld, although it could become a problem in the long term. Cracking clays are alkaline to neutral and are strongly buffered against pH change. The soils that have the potential to develop acidity more quickly are the lighter, less fertile, red soils scattered throughout the wheat-belt.



Go to Chapter E1 for more information on soils of the wheat-belt.

The major problems in acid soils are aluminium and manganese toxicity. Some elements, particularly phosphorus, calcium and molybdenum, become less available to plants.

Plant symptoms

Soil acidity results in poor establishment and persistence of plants, particularly barrel medic and lucerne, and thinning out of established legume pastures. Acidity also reduces barley, canola and wheat growth and yield (more so for the acid sensitive varieties).

Plants affected by acidity also become more prone to diseases.

Plants affected by aluminium toxicity have small, dark green, sometimes purplish leaves. Plant growth is slow and lateral root growth is stunted.

Acid soil also limits nodulation and nitrogen fixation by legumes.

Subterranean clover, triticale and oats tolerate some acidity but are affected by strong acidity.

pH testing

You can do a soil pH test yourself to determine whether acidity is a problem. Soil pH kits are available from some garden shops and plant nurseries, but these kits are only accurate to half a pH unit. They measure pH in water, whereas laboratories measure pH in calcium chloride ($CaCl_2$). pH in calcium chloride gives values about 0.5 to 0.8 lower than pH in water.

More expensive kits, costing about $500, measure pH in calcium chloride to an accuracy of about 0.2 pH units. These kits are available from the Centre for Conservation Farming, Charles Sturt University, Wagga Wagga.

Test the subsoil as well as the topsoil to determine the extent of any problem. If the pH as shown by the pH kit is well above 6.0, acidity is not a problem - yet. If the pH is below 6 get laboratory tests done for soil pH and exchangeable cations, and for more advice on what to do.

Soil test results for topsoil pH

Interpret pH of topsoil as follows (these pH values are for pH in calcium chloride):

pH above 5.6, soil acidity is not a problem yet.

pH between 5.1 and 5.5, there is a risk of soil acidity problems. Think about a maintenance liming program and methods that will reduce the rate of acidification.

pH between 4.6 & 5.0 indicates the need to check the exchangeable aluminium percent. If aluminium is present at low levels (1-5%) then sensitive species will be affected. Subsoil pH should not be a problem but test to make sure.

pH below 4.5 signifies a need to check aluminium and subsoil pH. With this level of acidity, the subsoil is probably acid as well. If the subsoil is acid, grow only acid-tolerant plants and adopt a liming program.

Liming

The aim is to apply sufficient lime to reduce soil exchangeable aluminium to zero. Ask the soil testing laboratory for advice on how much lime to apply. Thereafter, apply maintenance applications of lime at 5 to 10 year intervals, depending on the rate of acidification. Don't wait until the problem is seriously affecting yields. When a soil becomes strongly acid, you are already losing production. Acidity is a potential problem on any farm, and its prevention should be a part of soil management.

Most surface soils in this region do not need corrective liming. However, if soil pH is near 6.0 and falling, you may consider maintenance applications of lime to stop the pH falling below 5.0.

Caution: strongly acid soils (pH in calcium chloride less than 5.0, or pH in water less than 5.5) require special care. Large amounts of lime can result in potassium and magnesium deficiencies. Also, in sandy soils, over-liming can cause deficiencies in trace elements such as zinc, manganese and iron. Over-liming causes problems! Get laboratory testing for pH and exchangeable cations before liming.

Go to Chapter B10 or D-s3 for information on improving crop nutrition.

If finely-ground agricultural lime (100% passing a 0.25 mm sieve) is incorporated into the soil, it reacts with the soil that it contacts as soon as moisture is available. However, lime moves very slowly through soil and may take many years to reach an acid subsoil. On pasture, where lime is not incorporated, it may take a year or two to have an effect on the topsoil. Coarse lime is slow to act and it's use is inadvisable.

Minimising soil acidification

As well as liming, better management of nitrogen and soil water will reduce the rate of soil acidification. This strategy includes more use of perennial pasture and deep-rooted plants.

A major cause of soil acidification is the leaching of nitrate from the soil. Use cropping rotations that include deep-rooted plants to use up nitrogen before it is leached. Minimise the chances of water escaping from the root zone during fallow (adopt opportunity cropping). Also, use less acidifying nitrogen fertilisers such as urea, rather than ammonium sulphate, and apply nitrogen in small amounts more frequently, to minimise nitrate leaching.

Lime quality

Agricultural lime comes from naturally occurring limestone that is mined and crushed. The quality, and therefore the effectiveness, of different lime products varies. The sale of lime in NSW is covered by the Fertilisers Act (1985). All liming material must be labelled before it is recognised under the act.

Neutralising value. The capacity of a liming material to neutralise soil acidity is called its neutralising value (NV). The higher the NV, the greater the ability of the product to correct the acidity. Pure lime, that is pure calcium carbonate, is taken as the standard with an NV of 100. Hydrated (slaked) lime and burnt (quick) lime have an NV of 120 and 160 respectively.

Calcium and magnesium content. Pure calcium carbonate contains 40% calcium and no magnesium. Good commercial agricultural lime contains 35-38% calcium and very little magnesium.

Dolomite contains 8-11% magnesium and 13-20% calcium. Magnesite (pure magnesium carbonate) contains 25% magnesium.

If a soil test shows that your soil is deficient in magnesium, dolomite or magnesite are the liming materials to use. However, beware of overdoing magnesium applications. Excess magnesium can interfere with potassium uptake and can aggravate clay dispersion problems. Use soil testing for exchangeable cations; keep magnesium and calcium in balance by sparing use of liming materials containing magnesium.

Fineness. The finer the lime, the more quickly it will react with the soil. A lime with fine particles has more surface area exposed to acid soil and more particles distributed through the soil than an equal weight of coarse material. The percent of particles passing through a 0.25 mm sieve is the measure of fineness.

Types of liming materials

Agricultural lime (calcium carbonate) is the most commonly used liming material. It consists of limestone crushed to a fine powder and is usually the most cost effective material for correcting soil acidity.

Dolomite (also known as maglime) is a naturally occurring rock containing calcium carbonate and magnesium carbonate. It is useful for acid soils where supplies of magnesium are low. On most occasions use agricultural lime.

Magnesite (magnesium carbonate). Made from crushed magnesium carbonate rock, magnesite has an NV of 95 to 105. It may be used where there is magnesium deficiency. On most occasions use agricultural lime.

Wet lime. Wet liming materials are sometimes available at low prices. Their usefulness is determined by the NV and water content. If the water content is 10%, then the lime will be only 90% as effective as dry lime. You need to consider the extra costs of handling, freight and spreading.

Crushed shells of oysters and other shellfish are mainly calcium carbonate, but the shell tends to be contaminated with sand and organic material and is usually too coarse to be effective quickly in soil.

Gypsum (calcium sulphate) is classified by the Fertilisers Act as a liming material, but is not considered one in agriculture because it does not reduce soil acidity. It is used mainly to improve the structure of sodic clay soils.

Further reading

Agfact AC.15: Liming materials.
Agfact AC.19: Soil acidity and liming.

SOILpak

B7 Is my soil saline?

Purpose of this chapter

To identify and classify salinity affected areas

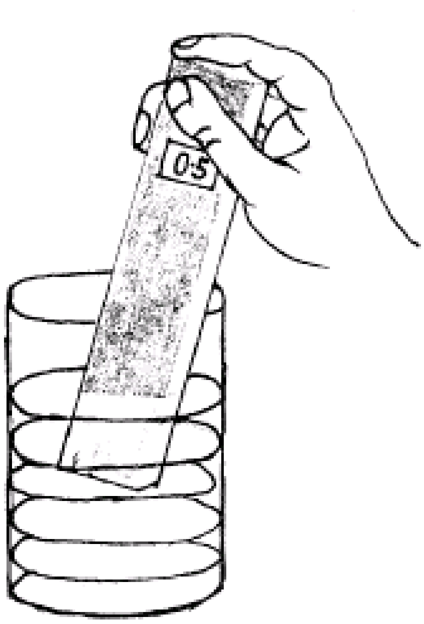
Chapter contents

- causes of salinity
- detecting salinity
- testing for salinity
- classifying salinity

Associated chapters

You may need to refer to the following chapters:

- C2: Chemical tests
- D-s9: Salinity
- E6: Managing the moisture budget for increased water use efficiency



B7 Is my soil saline?

Causes of salinity

Dryland salinity may be due to one of two quite separate causes:

- erosion of topsoil may expose a naturally saline subsoil. This saline area is called a saline scald;
- groundwater may rise. If the groundwater brings salts up to the surface, a saline seep results. See **Figure B7-1**.

Some farming practices do not fully use annual rainfall. Clearing and resultant replacement of trees (and other deep-rooting vegetation) with shallow rooting vegetation and fallows is the major cause of groundwater rise. Along with this, several factors interact to result in a rising watertable and groundwater seepage. They include, climate, groundwater, geology, soil, terrain and land use. (see **Figure B7-1)**. Salinisation generally occurs first in the lowest parts of the landscape, but not all catchments are at risk from salinisation.

Detecting salinity

General signs of salinity are:

- trees dying in clusters for no apparent reason;
- the spread of bare patches of soil;
- salt-tolerant species thriving;

sometimes, salt crusts on surface soil.

Testing for salinity

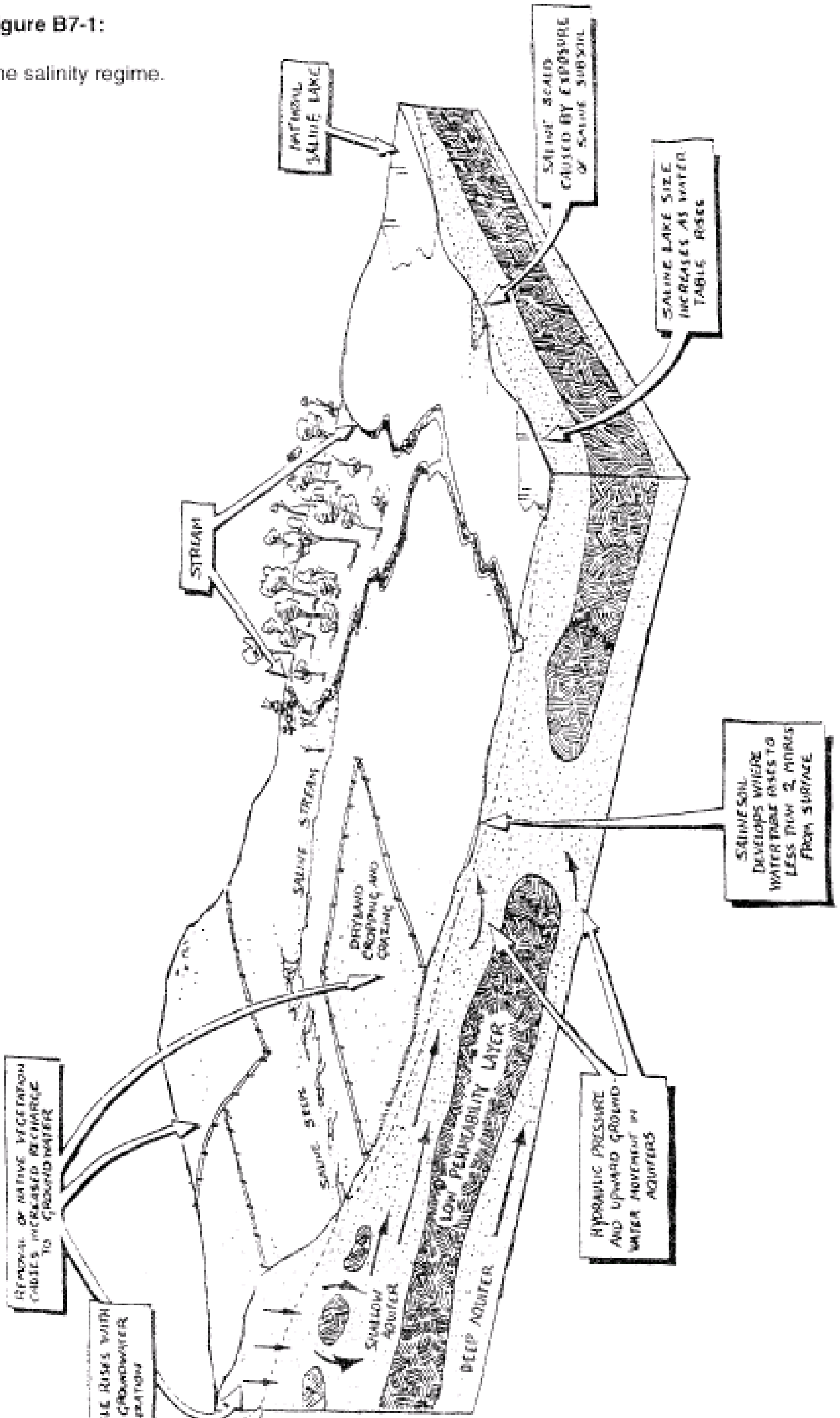
The simplest test of salinity is the taste test. Saline soil tastes salty However, to confirm such an indication and to determine the severity of a problem, get soil samples tested. Soil salinity is measured as the electrical conductivity (EC) of a mixture of soil and water. The higher the salt content, more electrical current that the mixture conducts.

The routine method of measuring EC uses a mixture of (by weight) one part dry soil to five parts distilled water ($EC_{1:5}$). The reading is then converted to an approximate value of EC_e, which is the EC of a solution extracted from a just-saturated soil paste. EC_e applies to any soil type, and is the recommended way to express salinity. Units for EC are decisiemens per metre (dS/m).

Go to Chapter C2 to find out how $EC_{1:5}$ relates to EC_e.

Figure B7-1:

The salinity regime.



Source: Govt of Victoria, 1988

Your district Soil Conservationist or Agronomist will be able to assist you in contacting a Salinity Officer who will advise you on soil testing. Ensure that your soil samples are representative of the area. Avoid sampling from places that may be unusual. For example, you will get a falsely high reading of salinity in a place where bags of fertiliser have been stored.

The problem of salinity can be classed as slight, moderate or severe depending on the EC_e of the soil. EC_e values below 2 dS/m are unlikely to reduce growth of all but the most salt-sensitive plants. Table B7-1 shows the salinity tolerance of some agricultural plants. Seedlings are more sensitive to salt than mature plants. A mature plant's sensitivity may increase again at flowering.

Table B7-1 Guide to salt tolerance of some agricultural plants, showing maximum EC_e values (dS/m) for no yield reduction.

Sensitive (EC_e 0-2 dS/m)		Moderately tolerant (EC_e 2-4 dS/m)		Tolerant (EC_e 4 dS/m or more)	
maize	1.7	peanut	3.2	barley (grain)	8.0
broad bean	1.6	kikuyu	3.0	cotton	7.7
strawberry clover	1.6	lucerne	2.0	tall wheat grass	7.5
white clover	1.5			couch	6.9
cowpea	1.3			barley (hay)	6.0
beans (field)	1.0			wheat	6.0
				perennial ryegrass	5.6
				sunflower	5.5
				safflower	5.3
				oats	5.0
				soybean	5.0
				sorghum (grain)	4.0

N.B. unlike $EC_{1:5}$, these EC_e values are independent of soil texture.
Source: Yo and Shaw (1990).

Associated with each class there are visible signs. 'Slight salinity' does not mean that there is no problem: the growth of many types of plant is affected, and the degree of salinity could become worse.

Slight salinity: EC_e 2-4 dS/m

Earliest visible signs of slight salinity include:

1. Sometimes, one of the earliest signs of rising groundwater is a rise in the level of water in bores. However, rising groundwater does not necessarily lead to salinity.
2. Waterlogged soil is an early sign of a potential salinity problem. However, **not all waterlogging results in the development of salinity.** Wet sites are likely to be located on footslopes, in broad drainage depressions, or on the upstream side of heavily compacted areas such as roads.

A sign of a rising watertable **may** be extraordinary plant growth in spite of little rain. This could happen if a watertable prevents drainage of fresh water from the root zone. However, as the watertable rises further, the root zone becomes waterlogged and plant growth is reduced. If the rising water is saline, plant growth is further reduced.

3. Patches of crops and pastures show reduced growth along with a slight yellowing of leaves. Concentrated salts are toxic to most plants. Plant cells are damaged and destroyed. Older leaves are affected first: the tips and outer edges darken and die. Potassium deficiency shows similar symptoms; a chemical analysis of soil samples will tell the difference.

4. Indicator plants are salt tolerant species such as barley grass, couch, ryegrass and strawberry clover. These plants begin to dominate as other plants die out.

Moderate salinity: EC_e 4-8 dS/m

As the watertable moves closer to the surface the soil solution becomes more salt concentrated and plant roots are less able to take up saline soil water. Plants may dehydrate and die. Small bare patches appear in crops and pastures. Salt-tolerant species replace salt-sensitive species. Species such as strawberry clover, which can only tolerate slight salinity, are less vigorous and may die out.

In a moderately salty discharge area the earlier indicators become more pronounced and additional signs are apparent:

1. The soil surface may become "puffy" as the soil salt content rises and clay flocculates. If rain leaches salt from the surface, the surface is left sodic: the surface soil disperses, crusting or setting hard when dry.

Go to Chapter E2 for an explanation of dispersion and flocculation in clays.

2. Stock congregate on an area and lick the soil surface.

3. Water in streams and dams is very clear (salt in the water flocculates suspended clay which settles as sediment).

Severe salinity: EC_e above 8 dS/m

Severely affected sites have a salinity test recording in excess of 8 dS/m and can be as high as 30 dS/m. The more salt-tolerant agricultural plants can survive at the low end of this range of EC_e, but their growth and yield is much affected. At the high end of this range (EC_e approaching 30 dS/m) only very salt-tolerant plants survive.

The signs of severe salinity are:

1. Large bare areas with salt crystals visible when dry.

2. All but very salt-tolerant species die out.

3. Surface of the bare soil is "puffy" to walk on when dry.

4. Sheet and gully erosion (but not necessarily caused by salinity).

Salinity acts as a focal point for erosion to develop. By killing off plant growth, saline seepage can contribute to erosion and cause sedimentation of streams and dams. Water quality is severely affected.

Further reading

The Department of Land and Water Conservation can supply booklets on dryland salinity. Contact your Soil Conservationist.

SOILpak

The Latin word for salt is *sal*. Roman soldiers were paid a *salarium* to allow them to buy salt, essential in the human diet and a scarce commodity in parts of the Roman Empire. From *salarium* comes our modern word 'salary'.

B8 Does my soil need gypsum?

Purpose of this chapter

To help you decide whether gypsum will help a soil that is crusted or compacted.

Chapter contents

- dispersion
- test strips

Associated chapters

You may need to refer to the following chapters:

- C1: Examining the soil profile
- C2: Chemical tests and soil structure
- D2: Sodicity
- E1: Soils of the northern wheatbelt
- E2: Clay minerals
- E3: Crusting and hard setting

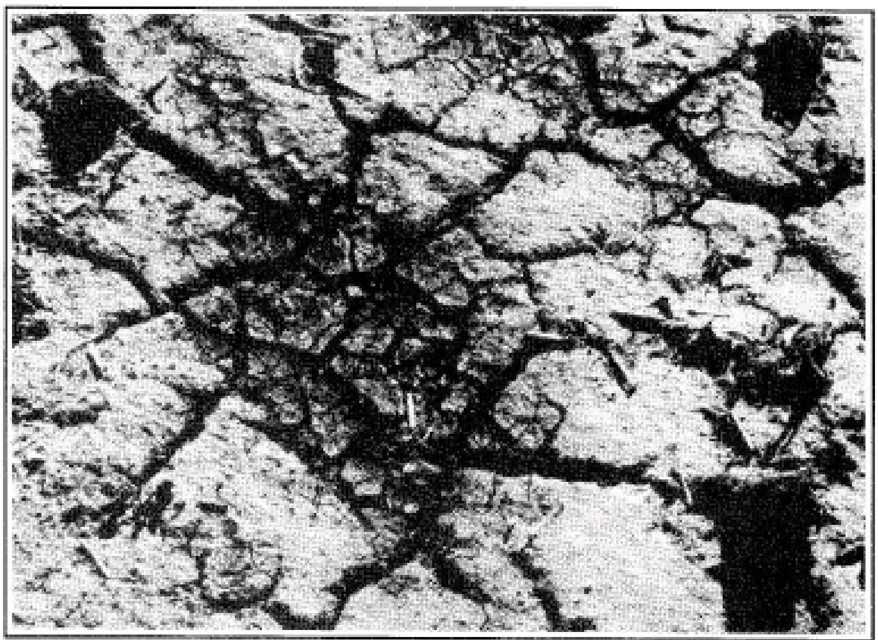
B8 Does my soil need gypsum?

Gypsum is often promoted as a 'clay breaker'. It does indeed improve the structure of sodic clays (clays with more than 5% exchangeable sodium, and low salinity). However, it does little to improve the structure of clays that are not sodic, or the structure of soils containing only small amounts of clay.

Behaviour of sodic clays

Sodic clay surface soils disperse in water. Dispersion of the surface soil causes crusting. Sodicity also causes excessive swelling with water. The excessive swelling of a sodic subsoil closes large pores and reduces infiltration and drainage. Waterlogging may result.

Figure B8-1: Crusting, also showing thin flakes of dried-out dispersed clay (dark area left of centre).



Photograph: K. Rose and L. Banks

Sodicity is most oSodicity is most obvious on the soil surface, when clay dispersion leads to crusting. If your soil is prone to crusting, it could be dispersive, and could respond to gypsum. Subsoil sodicity is harder to detect by eye, but sodic subsoil exposed by erosion or earthworks will show dispersion. Such exposed subsoil is very prone to erosion, and gypsum application should complement other erosion-control measures.

Deep tillage may bring up sodic subsoil to the surface where it will disperse on wetting by rain. Gypsum is needed to treat the newly-created crusting surface.

Subsoil that is not exposed is very difficult to treat with gypsum: the problem lies in getting gypsum down to the sodic layer. Such treatments may not be economic.

Testing for clay dispersion

It is easy to test a soil for dispersion. Drop small, dry crumbs of soil (3 to 5 mm diameter) into rain water or distilled water and leave undisturbed. If a milky halo of dispersed clay develops around the crumb, it is likely that gypsum would improve soil structure. In a very dispersive soil, the halo will develop within 10 minutes. A moderately dispersive soil will show a halo within two hours. A non-dispersive soil will not show a halo at all, even by the next day.

Go to Chapter C1 for full details of the dispersion test and E2 for an explanation of dispersion.

If the test shows your soil to be dispersive, have the soil analysed for exchangeable cations and electrical conductivity in a laboratory. Sample subsoil as well as topsoil to determine the extent of the problem. Analysis results showing high exchangeable sodium and low electrical conductivity indicate a soil prone to dispersion. Generally, a soil with exchangeable sodium percentage above 5 will disperse on wetting. However, a soil with an exchangeable sodium percentage lower than 5 will disperse if the electrical conductivity is exceptionally low (very low salinity).

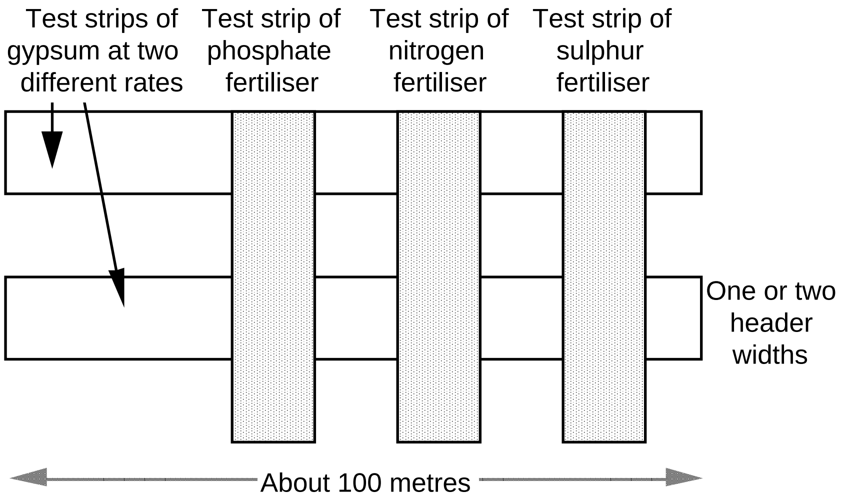
You may also try some test strips of gypsum at various rates (for example, try 2.5 t/ha and 5 t/ha). If you decide to treat a whole paddock with gypsum, leave a strip untreated to show the benefits. If the treated soil responds to gypsum, you will notice increased soil friability, less power needed for tillage, improved infiltration of rain, less waterlogging (the soil surface dries out sooner after rain) and better seedling emergence. Measure yields on the treated and untreated strips, even if the response is not visible.

If gypsum improves soil condition but there is little yield improvement, something else may be limiting plant growth, possibly plant nutrients Improvement in water infiltration can, in a wet year, result in greater leaching of nitrogen. Improved nitrogen nutrition may be needed. On some soils, sulphur is deficient. Crop response to gypsum may then be a response to the sulphur (gypsum is calcium sulphate) rather than a response to improved soil structure

A test strip of gypsum is more informative if combined with test strips of other likely remedies, such as nitrogen, phosphorus and sulphur fertilisers.

Figure B8-2 shows a suggested layout for test strips in a paddock. Make sure that you can identify the strips in two or three years time. Record the position of at least one corner of the trial: locate its position relative to a permanent marker such as a tree, rock or building, with compass bearings if necessary. Measure distances for future reference, by tape or by pacing. Draw a sketch map. Apply treatments to strips that are one or two grain harvester (header) widths. Each strip may be about 100 metres long.

Figure B8-2 Test strips to show the effect of gypsum and fertiliser alone, and in combination



The figure shows a suggested layout that will compare the untreated areas with:

- gypsum alone, at two rates;
- nitrogen fertiliser alone;
- phosphate fertiliser alone;
- sulphur fertiliser alone;
- gypsum with nitrogen fertiliser;
- gypsum with phosphate fertiliser; and
- gypsum with sulphur fertiliser.

Gypsum and lime

Applications of gypsum (calcium sulphate) and lime (calcium carbonate) supply calcium to soil. Lime is preferable for strongly acid soils (pH ($CaCl_2$) less than 5). 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 pH ($CaCl_2$) between 5.0 and 6.5.

Further reading

Agfact AC.10 Improving soil structure with gypsum.

B9 How do I control erosion?

Purpose of this chapter
To answer some common questions about erosion.

Chapter contents

- on-farm and off-farm impacts of erosion
- erosion control banks
- cultivation
- ground cover
- slope

Associated chapters
You may need to refer to the following chapters:

- B2 Weed control
- B11 Choosing the next crop
- C4: Measuring soil water
- Ds-1 Erosion control
- D-s5 No-tillage
- E6 Managing the moisture budget

B9 How do I control erosion

Why control erosion?

On-farm benefits of erosion control are:

- reduced loss of soil
- reduced loss of nutrients attached to soil particles
- reduced damage to plants by burial and sandblasting
- less gullying to interfere with paddock operations
- reduced damage to fences and roads
- less silting of dams and channels

Off-farm benefits of erosion control are:

- Less pollution of watercourses with sediment and nutrients
- Less silting of off-farm roads, dams and drains.

How do I control sheet and rill erosion?

Soil cover of living plants or stubble is most effective in reducing sheet and rill erosion. Maintain a minimum of 30% cover throughout the year; 70% cover is desirable. Particularly during times of peak erosion risk, ensure a firm (untilled) soil and adequate surface cover Minimise tillage to the essential; till across the slope, rather than up and down. Do not extend the fallow once the soil profile is 75% full of moisture.

Will erosion control banks control erosion?

Erosion control banks alone will not control erosion. Other control measures, particularly surface cover, are essential. The role of erosion control banks, together with diversion drains and grassed waterways, is to control the flow of water on the farm: slowing and directing, and disposing safely to watercourses. Thus earthworks stop rills becoming gullies.

Contact your local Department of Primary Industries or Soil Conservation Service for advice on the layout of erosion control earthworks.

How do I stop sediment filling channels?

Stop erosion at its source. See the solution above and **Chapter D, Section 1**.

How should I cultivate between erosion control banks?

Cultivate across the slope. **Chapter D, Section 1** has diagrams to show the pattern of cultivation and turning.

How much ground cover on pasture to control erosion?

Maintain 70% plant cover. Below this value, areas of bare soil join up and run-off becomes serious.

How much stubble cover on fallow to control erosion?

Start the fallow with at least 70% stubble cover. This value allows for some decomposition of stubble over the fallow. Maintain a minimum of 30% cover.

How can I sow if the ground is covered in stubble?

Planters suitable for no-till or minimum till can cope with stubble. See **Chapter D, Section 5** for information on converting a scarifier or chisel plough into a no-till planter. Burning stubble is a last resort.

I need to burn my stubble. When should I do it?

If burning is absolutely essential, burn at the end of the fallow period, to minimise the length of time that the soil is unprotected. See **Chapter B2** for weed control strategies that minimise erosion risk.

If you are considering burning stubble to prevent the carry-over of plant disease, consider crop rotation instead. See **Chapter B11** for crop rotation options.

If you are considering burning stubble because it interferes with planting, consider controlled grazing instead of burning.

How do I control weeds without getting serious erosion?

Weed control does not necessarily require tillage. Grazing and herbicides are alternatives. See **Chapter B2** for information on weed control strategies in fallow. Rod weeders and blade ploughs leave more stubble on the surface than do disc ploughs.

How do I tailor soil conservation measures to a particular paddock?

Flood plains: Use strip cropping. Slow and spread flood flows. Contact your Department of Primary Industries or Soil Conservation Service for advice.

Low slopes (less than 2% slope): The emphasis is on maintaining surface cover, (minimum of 30%, but 70% is desirable) particularly over the summer when the risk of erosion is highest. See **Chapter D, Section 1** for photographs of cover levels.

Moderate slopes (2 to 8%): require earthworks in addition to surface cover.

High slopes (greater than 8%): should not be cultivated. Such land is best suited to grazing or forest.

Acknowledgement Peter Hairsine, CSIRO Division of Soils, Canberra.

B10 Does my soil need fertiliser?

Purpose of this chapter: To give a guide to fertiliser usage.

Chapter contents:

- yield and grain protein of cereals
- yield goal for cereals
- poor growth of pastures
- plant deficiency symptoms
- collecting a soil sample

Associated chapters: You may need to refer to the following chapters:

- C2: Chemical tests and soil structure
- D-s3: Improving soil chemical fertility
- E5: Plant nutrients

B10 Does my soil need fertiliser?

Paddock records of crop and pasture rotations, fertiliser use, plant yields (and if appropriate, grain protein) are useful to help estimate plant nutrient requirements.

Fertiliser can supply some of the plant nutrients needed by a crop or pasture. Nutrients can come from other sources as well: from the decomposition of soil organic matter, from the weathering of soil mineral matter, and from nitrogen fixed from the air by legumes and by free-living organisms.

Five ways to determine nutrient requirements

Use a combination of these five ways to estimate nutrient requirements for a paddock:

- for a cropping paddock, review the yield and grain protein of previous cereal crops;
- set a yield goal and increase plant nutrients to achieve that goal;
- for pasture, be alert to signs of poor productivity;
- observe plant symptoms for possible nutrient deficiencies; and
- send soil samples or plant tissue to a laboratory for chemical testing and use test strips of fertiliser in the paddock to confirm the results of these tests.

Regular soil testing, combined with paddock history and the information you gain from test strips, is the best way to predict plant nutrient requirements. Observing plant symptoms and plant tissue testing are generally of no use for the current crop, but can help to predict nutrient requirements for the following crop.

Yield and grain protein of cereals

Declining yield and grain protein in cereals is a sign that soil nutrients are seriously depleted. Paddocks that repeatedly produce grain with protein below 11.5% are likely to be nitrogen deficient. Harvesting continually removes nutrients. Replace them continually, not only when they are almost exhausted.

A paddock with a long history of cereal cropping, with no legumes and no fertiliser will usually respond to nitrogen fertiliser. However, other nutrients may be lacking as well. Poor plant response to one nutrient may be due to a deficiency in another nutrient.

Seasonal conditions can mask the status of soil nitrogen. When good seasons result in high yields, grain protein will tend to be lower because it is diluted (less nitrogen is available for each tonne of grain). If soil nitrogen, the main constituent of protein, is already at low or marginal levels, grain protein will be disastrously low.

Use average grain protein over the last three years to determine a paddock's nitrogen status. (Bear in mind the effect of yield upon protein.)

Repeatedly less then 11.5% protein indicates that the soil is nitrogen deficient. Grain yield would have increased had more nitrogen been available or been applied, and grain protein **might** have increased.

11.5% to 12.5% protein: it is uncertain whether grain yield would have increased had more nitrogen been available, but grain protein almost certainly would have increased. Compare the yield with the district average: an above-average yield may have depressed grain protein.

Higher than 12.5% protein indicates that nitrogen is not deficient. More nitrogen would not have increased yield. However, poor soil moisture supply may have limited grain yield, resulting in small, high protein grain.

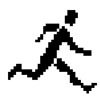
The secret of a profitable crop is to lift both yield and protein together by making sure the crop has a good supply of nitrogen. Nitrogen may come from soil organic matter (mineralised during fallow), from manufactured fertiliser (for example, anhydrous ammonia or urea) or from a legume phase (preferably three or more years of lucerne).

Estimating nitrogen status from grain yield and protein:

Advantages:	**Cautions:**
• Easy to review from silo dockets or farm diary.	• High protein may be due to low yield in a dry season. • Doesn't tell you how much fertiliser to apply.

Yield goal

Work on a realistic yield goal, and increase plant nutrients to achieve that goal. The yield goal is your estimate of yield based upon paddock history, soil moisture at sowing, and expected in-crop rainfall. This is an inexact method, because no-one can predict in-crop rainfall.



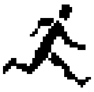
Go to Chapter D-s3 for more information on nitrogen requirements.

Under-fertilising in a year that turns out to be a good year for in-crop rain leaves the crop with insufficient nitrogen to make the most of the plentiful soil water. Over-fertilising in a year that turns out to be dry leaves unused fertiliser in the soil. But even this excess fertiliser may not be wasted. Research has shown that much of the surplus nitrogen may remain in the soil for the next crop.

Unusually wet weather in the fallow before the next crop may remove much of the surplus nitrogen fertiliser (by leaching nitrate from the root zone or by denitrification).

Go to Chapter E5 for more information on nitrogen in the soil.

However, you can take advantage of unusually wet weather. When the soil is 75% full of moisture, plant an 'opportunity' crop to take advantage of that soil moisture, and to use the surplus fertiliser before too much is lost. Opportunity cropping uses the fertiliser productively, and minimises pollution by leaching and denitrification.



Go to Chapter B11 for more information on choosing the next crop.

When soil nitrogen fertility is low, raise it to achieve higher yield and grain protein. You may raise it by:

- adopting a legume pasture phase; or
- using manufactured fertiliser.

When soil nitrogen fertility is satisfactorily high, include grain legumes in the crop rotation. Grain legumes will help to maintain nitrogen fertility, permitting a longer cropping phase between pastures.

Poor growth of pastures

Poor growth, small size of leaves, pale leaf colour, lack of legumes, weediness or loss of ground cover are signs that a pasture **may** need fertiliser. A pasture that is deficient in one or more plant nutrients often has poor plant cover and responds poorly to rain.

Pastures containing sufficient legumes (about 40% medic, lucerne or clover) should not need nitrogen fertiliser. If a pasture has a poor legume component, it is likely to be nitrogen deficient, or will soon become so. Nitrogen deficiency restricts growth of the grasses, and makes them unresponsive to other fertilisers. Sow the best adapted legume.

Common nutrient deficiencies in pasture are phosphorus and sulphur. Molybdenum deficiency is common on light, acid soils.

Table B10-1: Plant nutrient deficiency symptoms.

Symptom	Likely deficiency	Notes
Yellowing of the older leaves	Nitrogen	Cold weather, waterlogging or continued dry soil may prevent the formation of available nitrogen, and cause deficiency
Edges of older leaves turn yellow, then brown. Lucerne shows white spots on leaves	Potassium	
Yellowing between veins of older leaves, giving streaked effect in grasses and cereals; often followed by brown spots and brown edges to leaves	Magnesium	
Older leaves become discoloured, dead patches develop	Zinc	Alkaline soils and areas stripped of topsoil
Dark green leaves, followed by reddish or purplish colour on underside of leaves and in leaf bases	Phosphorus	
Dark green new growth	Molybdenum	
Death of tissues at growing points. Lower leaves of cereals roll inwards	Calcium	Low soil pH, therefore complicated by effects of acidity, and toxicity of aluminium and manganese
Light green to yellow young leaves. Stunting in clovers	Sulphur	
Yellowing of younger leaves, usually mottling between veins while veins and a strip either side remain green. Oats show grey spot near leaf tip	Manganese	Alkaline soils
Yellowing of younger leaves	Iron	Associated with alkaline soils

Deficiency symptoms

Plant symptoms of nutrient deficiency are not easy to diagnose. By the time that deficiency symptoms appear, production has already been lost. For some nutrients, particularly phosphorus, it may be too late to make up lost crop yield by applying fertiliser: make sure that the next crop receives adequate amounts. For trace elements such as zinc, a foliar spray will get the element into the plants quickly. Apply fertiliser to pasture to ensure that further growth is not restricted by lack of nutrients.

Nutrient deficiencies show as symptoms of abnormal growth in the plant. Such symptoms can be a good, simple guide to soil fertility, but occasionally there are complications. For example, a deficiency in different nutrients can produce similar symptoms. A high level of a nutrient can be toxic, and that too causes abnormal growth. Plant disease or insect attack may cause symptoms similar to nutrient deficiency, or may mask the symptoms.

Plants can move some nutrients, such as nitrogen, phosphorus and potassium, from one part of the plant to another part. When the plant is deficient in one of these 'mobile' nutrients, the growing points take priority. The plant moves these nutrients from older parts to newer growing points; thus the older parts show deficiency symptoms before the newer growing points.

Other nutrients, such as calcium and boron, are not mobile. The plant can not move them from older parts, where they were first stored, to the growing points. Therefore deficiency symptoms show in the younger leaves.

Use the descriptions in **Table B10-1** as a guide. Confirm with soil chemical analysis, or plant tissue testing, as a part of your soil management routine.

Soil testing

Soil testing (chemical analysis of soil samples) helps to identify nutrient deficiencies and toxicities, and to estimate soil nutrient requirements. Interpret the results in conjunction with other methods of estimating fertiliser requirements, for example test-strips of fertiliser. Soil testing is useful for:

- showing the availability of the major plant nutrients (nitrogen, phosphorus, potassium, sulphur, calcium and magnesium);
- problems related to sodicity;
- problems related to acidity; and
- problems related to salinity.

Soil testing is **not** a good indicator of **trace elements**; plant tissue testing is better.

Soil sampling

Soil testing is only as good as the samples of soil that the laboratory receives. Errors introduced by sampling, and by the way that you treat the samples, are usually bigger than any laboratory error.
One cause of errors in sampling is the variability in the soil across a paddock.

Do not take samples from areas that are obviously different from most of your land. Divide your property into sampling areas with similar soil type, landscape and paddock history. Avoid obviously unusual areas such as stock camps, around trees, wet areas, gateways and fence lines.

Another cause of errors in sampling is the way in which soils can vary with depth. Sample all soil horizons separately, or if horizons are not obvious, sample by arbitrarily fixed depths.

On pastures, sample 0-7.5 cm for extractable phosphorus. Sample 0-15 cm for exchangeable cations, pH, electrical conductivity and all other tests.

On cultivated ground, sample to the depth of cultivation. In no-till cropping paddocks, sample 0-15 cm.

When sampling to estimate available soil nitrogen, deeper samples are required. Various farm advisers and laboratories have different opinions on the necessary depth. A minimum depth of 30 cm is advisable.

Take 20-30 small cores from each sampling area, at points scattered over the area. Mix the samples together, keeping depths separate if appropriate.

If sampling to help solve a problem, identify 'good' and 'poor' areas and sample separately. The comparison between 'good' and 'poor' greatly assists in determining whether or not the soil is causing the problem.

For further advice contact your soil testing laboratory or farm adviser.

Caution: Leaving soil samples in a warm, damp condition stimulates soil micro-organisms that convert soil nitrogen from one form to another: with grave consequences to the soil test result. Some people prefer to put soil samples into paper bags (not plastic) so that they can begin drying immediately. Whatever bags you use, air-dry the samples as soon as possible. Crumble the samples and spread them out in trays or on newspaper. Leave them in a well ventilated place to dry before sending them to a laboratory.

Also, do not dry soil samples above 40°C. Excessive heat changes the solubility of certain nutrients, affecting the measurement of nutrient availability.

B11 Choosing the next crop

Purpose of this chapter

To help in planning rotations that match paddock capabilities.

Chapter contents

- Making the most of soil moisture
- protecting the soil
- managing soil structure
- reducing the weed burden
- minimising the effect of disease
- making the nitrogen cycle work for you

Associated chapters

You may need to refer to the following chapters:

- B10: Does my soil need fertiliser?
- C1: Examining the soil profile
- C4: Measuring soil water
- D-s1 Erosion control
- E4: Organic matter
- E5: Plant nutrients

B11 Choosing the next crop

Major considerations when choosing the next crop to grow in each paddock are: profitability, risk of crop failure and your attitude to that risk, and previous experience in growing various crops. A paddock's capability is also important. Capability depends upon soil type, erosion hazard, weed burden, disease risk, chemical fertility and stored soil water. Also consider a crop as a part of a rotation, and how it affects weeds, diseases, insects, soil erosion and chemical fertility for the crops **after** this next crop!

Further information

NSW Agriculture and Queensland Department of Primary Industries both produce farming notes each year. The notes cover crop choice, agronomic information such as planting time and sowing rate, current costs and prices, and lists of registered chemical-control sprays. **Appendix 2** lists some of the booklets.

Particularly relevant to this chapter are these excellent publications:

- 'Crop Management Notes' by Queensland Department of Primary Industries for various regions;
- NSW Agriculture's planting guides for winter cereals, grain sorghum, maize hybrids, sunflowers and various winter grain legumes; weed control in winter crops and summer crops; budget handbooks for winter crops and summer crops; and a rotation guide.

We strongly recommend that you do your own budgets before choosing the next crop, but bear in mind the far-reaching effects that your choice may have on sustainability.

Effect of crops on soil

As far as soil management is concerned, different crops have a different effect upon:

- stubble residues: their bulk, and the time that they take to decompose (wheat stubble is long-lasting, whilst legume stubble decays quickly);
- soil physical fertility (soil structure);
- soil chemical fertility (particularly soil nitrogen); and
- soil biological fertility (plant diseases and beneficial organisms such as VAM).

When considering which crop or pasture to grow, check if it will:

1. make the most of soil moisture;
2. protect your soil from erosion;
3. make the most of good soil structure, or improve damaged soil structure for a following crop;
4. reduce the weed burden and suit your herbicide plans;
5. minimise the effect of plant disease; and
6. work with the nitrogen cycle.

There is no easy answer to the question of crop choice. Every farm is different, and the six factors listed above all have a bearing on the choice. Use the following notes to help your decision.

1. Use rotations to make the most of soil moisture

Dry (soil profile less than 50% full) Continue fallowing. Don't sow unless you can graze or bale a failed crop.

Moderate (soil profile 50-75% full) Estimate how much yield the soil moisture will allow. Decide whether the yield will cover costs.

Wet (soil profile more than 75% full) Use the soil moisture by sowing a crop. Continuing the fallow past the point where the soil profile is three-quarters full of water increases the risk of run-off and erosion, and possible deep drainage to groundwater.

2. Use rotations to protect your soil from erosion

Low amount of stubble cover (less than 30%)

Reduce tillage. If the soil is bare and cracked, do not till, but leave the cracks open to accept rain. If the soil is bare and not cracked, till to create a rough surface to trap rain.

If there is adequate moisture, sow a crop to get some ground cover. Cereals provide earlier cover and more stubble than broadleaf crops.

Adequate stubble cover

The desirable amount of stubble cover is 70%. This amount will decrease over a fallow, but aim for a **minimum** of 30% cover (loose stubble) by sowing time. If the stubble is standing, more than 30% minimum ground cover is desirable (loose stubble forms a more protective mulch). Ideally, keep some standing stubble to anchor the loose stubble.

High amount of stubble cover

This is the safest way to fallow. Manage the stubble (by judicious grazing and possible late burning) to leave the maximum amount that your sowing equipment can handle.

3. Use rotations to manage soil structure

Poor soil structure

Use a crop that is cheap to grow. Any crop is likely to yield poorly, so choose the one that will cost the least. This is not the paddock to try dryland cotton!

Go to Chapter B5 or D-s2 for more information on improving soil structure.

In cracking clays, use a crop to repair damaged soil structure by drying and cracking compacted soil ('biological ripping').

If surface crusting or hard-setting is a problem use pasture to increase soil organic matter. On dispersive soils, gypsum may remedy the problem. Examine the soil profile for signs of a hard pan: deep tillage may be necessary before establishing pasture.

Go to Chapter E3 for more information on crusting and hard-setting.

On non-cracking soils, repair a plough pan by 'biological drilling' (using tap-rooted plants to penetrate compacted soil, leaving root channels for subsequent plants). Severely compacted soils may require deep tillage in addition to biological drilling.

On any soil, if soil moisture is adequate, growing plants will improve soil structure. Fallow will not improve soil structure, and may degrade soil structure by reducing the level of soil organic matter.

Good soil structure	This is a valuable paddock, and will remain so for as long as the soil structure remains good. If this paddock also has good soil moisture, beneficial soil organisms and high chemical fertility, it allows you the greatest range of options in crop choice.

4. Use rotations to reduce the weed burden

Few winter grass weeds	An ideal paddock for winter cereals.
Moderate amounts of winter grass weeds	To grow a winter cereal, you will need to control wild oats, phalaris and rye grass. Some herbicides and an increased cereal sowing rate will help. Consider sowing a broadleaf winter crop or a summer crop instead.
High amounts of winter grass weeds	A rotation with a broadleaf winter crop or a summer crop gives the best opportunity to reduce the grass weed burden. Consider a pasture phase.

Few broadleaf weeds	Make the most of this paddock by sowing a broadleaf crop.
Moderate amounts of broadleaf weeds	There are effective pre-emergent and post-emergent herbicides for use in cereals to reduce the burden of broadleaf weeds. Canola is more competitive than chickpeas against broadleaf weeds.
High amounts of broadleaf weeds	The herbicide options are limited in broadleaf crops. In particular, avoid paddocks with wireweed or black bindweed.

5. Use rotations to minimise the effects of disease

Low level of yellow spot on wheat	Suitable for zero-till wheat.
Moderate level of yellow spot on wheat	All wheat varieties are susceptible to yellow leaf spot. Durum has some tolerance. Barley is tolerant, but will carry the disease to wheat if that is the following crop. Late cultivation or late burning will minimise the problem.
High level of yellow leaf spot on wheat	Rotate with oats, chickpea, canola or any summer crop. One winter out of wheat will give reasonable control.
Low level of cereal root rots	A suitable paddock for winter cereals. If you continue to grow winter cereals, expect a gradual build-up of root rots, and expect to lose some yield in good years.

Moderate level of cereal root rot	Some wheat varieties have moderate resistance to root rots. Burning stubble before sowing will reduce but not eliminate crown rot. Sow chickpea, canola, oats or a summer crop. Summer crops are best to control root rots.
High level of cereal root rot	Sow chickpea, canola, oats or a summer crop. A break of one year will reduce the disease level, but a break of two years is better. Keep fallow free of grass weeds.
Low level of Phytophthora on chickpea, medic or lucerne	This is a good paddock for chickpea, or pasture with medic or lucerne.
Moderate level of Phytophthora on chickpea, medic or lucerne	Chickpea, medic and lucerne are risky, particularly with waterlogging early in the crop's growth. The risk is higher in poorly drained paddocks.
High level of Phytophthora on chickpea, medic or lucerne	It could take three or four years without legumes to reduce this disease. If soil nitrogen is high, and soil structure is good, make the most of this opportunity by growing cereals. Legumes in cereals are now weeds!
Low level of blackleg on canola	This is a good paddock for canola. However, check the proximity to other canola crops. Blackleg spores can travel 3 km in wind.
Moderate level of blackleg on canola	There is some risk in growing canola. Check the proximity to other canola crops.
High level of blackleg on canola	A break of four years from canola may be necessary to reduce blackleg.

6. Use rotations to make the nitrogen cycle work for you

Low level of available soil nitrogen

A suitable paddock for a legume-based pasture to build up soil nitrogen. The low soil nitrogen will make the legumes 'work harder' and get some of their nitrogen from the air rather than from the soil.

Moderate level of available soil nitrogen

If you are growing a winter cereal or canola, estimate soil moisture to determine a target yield and hence how much nitrogen fertiliser to apply. Malting barley needs less nitrogen than wheat or canola.

Grain legumes are an appropriate crop: they will use some soil nitrogen and fix some from the air. They will delay the inevitable decline in soil nitrogen status under cropping.

High level of available soil nitrogen

The main restriction on crop choice is that barley may be too high in protein to make malting grade. Legumes will grow well, but will use soil nitrogen rather than fix it from the air; they will be 'lazy' nitrogen fixers. Durum wheat, prime hard wheat or canola are good choices for this paddock.

Acnowledgement: Peter Hayman, NSW Agriculture

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