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.

D Practical soil management

Purpose of this chapter

This chapter deals with the prevention of soil degradation and the restoration of degraded soil.

Chapter contents

Associated chapters

You may need to refer to the following chapters:

- E: All chapters in Part E

Part D Practical soil management

A productive farming system follows three main rules:

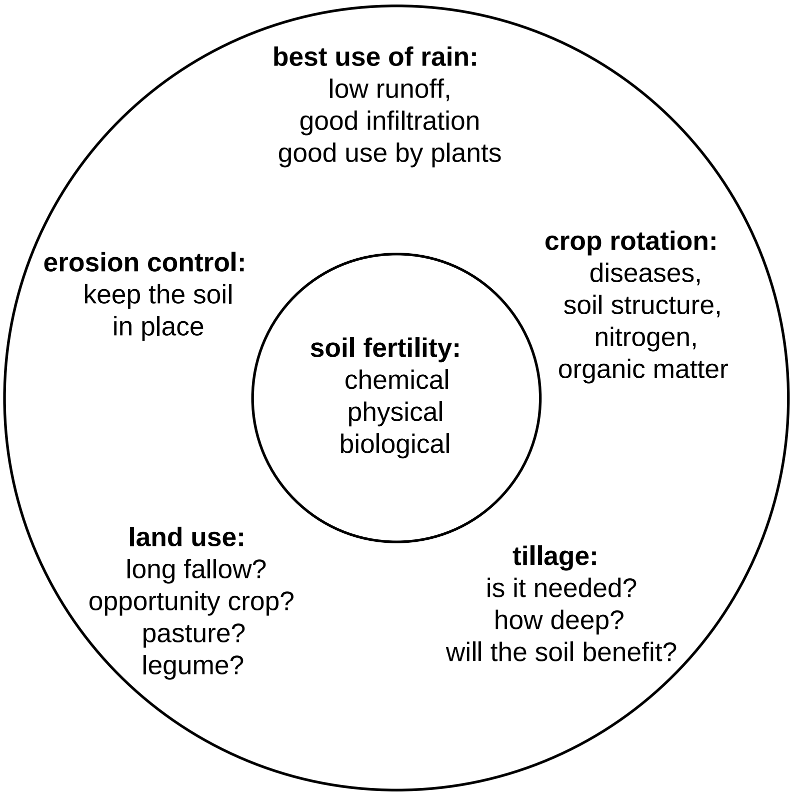
1. control erosion to keep the soil in place;

2. use rainfall effectively;

3. manage soil chemical, physical and biological fertility.

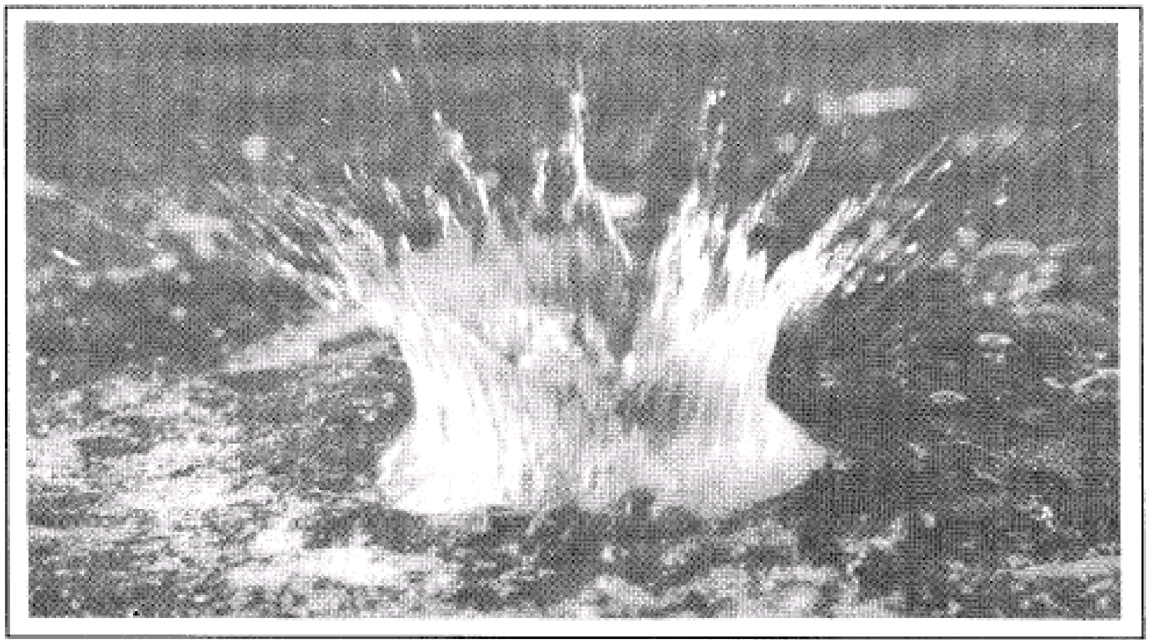
These three rules are interrelated. **Figure D-1** shows some soil management strategies that affect each other. For example, making effective use of rain is a part of erosion control; both include managing rain after it reaches the ground. Managing soil physical fertility (soil structure) helps infiltration, which helps to control erosion and to make effective use of rain.

Figure D-1 Some soil management strategies



Section 1: Erosion control

by Peter Hairsine, Erosion Research Group,
CSIRO Division of Soils, Canberra



Photograph: C.J. Rosewell & J. Van Ghent, Soil Conservation Service of NSW

But erosion came creeping slowly,
then hastened on with a rush;

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 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. In the northern wheat-belt, summer rain is intense and water erosion is the more prevalent problem. However, wind erosion can be a problem on fine sandy soils, particularly on exposed hills and soil disturbed by livestock or tillage.

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, and 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 60-80 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 70-300 t/ha. Erosion losses are particularly damaging on texture-contrast soils which have a shallow topsoil over clay subsoil. Such soils have little enough 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.

Damage to plants

Much of the soil that water erodes from upper slopes on a farm is deposited on the lower slopes and/or in channels above erosion control banks. 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 recommence. 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 above erosion control banks and farm roads.

Off-farm impacts

Environmental impacts

Some sediment and associated nutrients from water erosion will leave the farm and arrive in streams. This can have a significant impact on the ecology of the streams. Sediment and nutrients are related to the occurrence of algal blooms and other water quality problems in our inland rivers. Other common effects 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, self-mulching, loose tilled soil, and tillage up and down the slope. The main methods of reducing this form of erosion are maintaining soil cover, and minimising tillage to maintain the soil in a firm, more erosion-resistant condition.

No-tillage 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 removed by cultivation. It is exacerbated by excessive run-off, concentration of water flow, long slope lengths and the presence of dispersive soils. The main techniques to reduce this form of erosion are maintaining cover to reduce run-off, and earthworks (including diversion channels, erosion control banks and grassed waterways).

Principles of soil conservation

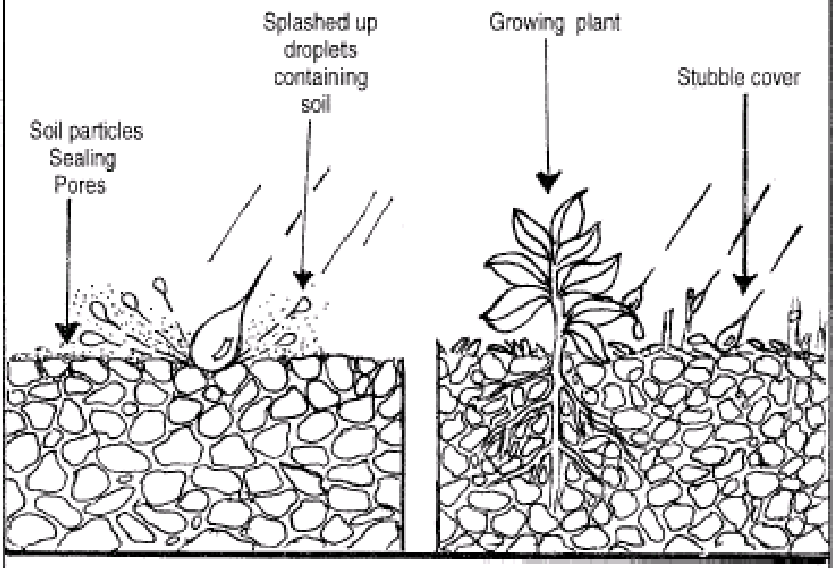
Reduce run-off

Run-off carries soil in suspension. Therefore reducing run-off will reduce erosion. Reduce run-off by:

- protecting the soil surface to maintain 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 (**Figure D-2**). Particularly during times of peak erosion risk, ensure a firm (untilled) soil and adequate surface cover;

- using stored soil water Continuing a fallow past the time when the profile is over 75% full of moisture increases the risk of run-off.

Figure D-2 Soil cover protects the surface from raindrop impact, improving infiltration and reducing erosion



Effects of raindrop splash on bare soil.

Natural plant cover, crops and crop stubble protect the soil from raindrop splash erosion

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 with which water moves across the soil surface determines the amount of erosion. Practices which slow run-off include contour cultivation, maintenance of surface cover 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.

Wind breaks help to control wind erosion by reducing the erosive power of the wind. Note that **wind breaks are not effective on their own**. Surface cover is also necessary to reduce wind erosion.

Keep the soil in place

The soils of the northern wheat-belt are generally highly erodible by water. However, soil management can alter the erodibility 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 (see **Section 2** of this chapter).

Different solutions for different slopes

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

In the uplands, emphasis is always on maintaining soil cover throughout the growing and fallow periods, but surface cover is particularly important during periods of high erosion risk. On slopes greater than 2%, erosion control banks should be installed. Land with slopes greater than 8% should not be cultivated.

Slopes between 1% and 2% pose special problems. The land is too steep for strip cropping without erosion control banks, but not steep enough to easily grade the banks to dispose of water.

Contact your local Soil Conservation Service or Department of Primary Industries office for advice on these measures.

Soil erosion includes nutrient erosion

The majority of soil nutrients are attached to soil particles. This means that soil erosion carries valuable nutrients from a productive area to a place where they often have no productive use. Nutrient conservation provides an economic motivation for erosion control.

"Keeping the soil in place" versus "catching it down the slope"

Some soil conservation practices trap sediment at the paddock edge and reduce the impact of erosion in off-farm areas. These measures include buffer strips, sedimentation ponds and erosion control banks (remember: erosion control banks have an important role in stopping rills turning into gullies). As it is generally uneconomic to move eroded soil back up the slope, these measures do not conserve the soil where it is needed: in the paddock. Therefore these measures should be considered secondary measures to be used in special circumstances, rather than the on-paddock measures described in the following section.

Solutions

Stubble retention

The retention of stubble and straw is the single most important soil conserving step in farm management in the northern wheat-belt. Plant residues act to protect the soil surface from erosion in both the fallow and the period immediately following planting (**Figure D-3**). Residues, by increasing infiltration, also increase the storage of water over the fallow, making more water available to the following crop.

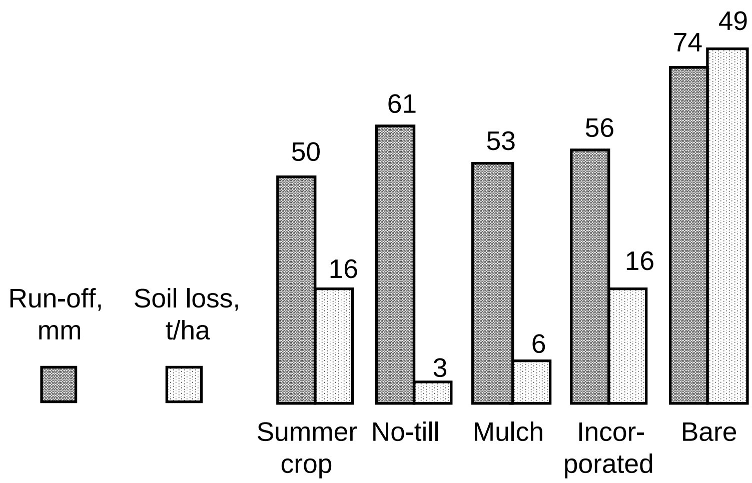
Go to Chapter E6 for more information on using plant residue to manage stored soil moisture

Fallow management: maintaining cover

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

To allow for residue breakdown, cover should be no less than 70% at the start of a fallow period. The level of ground cover can become very low at the end of a long fallow: when, for example, changing over from a summer to a winter cropping pattern. The inclusion of an opportunity crop is a good option in such a change over. Above all, ensure good surface cover (growing plants or plant residues) during periods of high erosion risk.

Figure D-3 Run-off and soil loss over the summer fallow at the Greenmount experiment



Acknowledgement: D. Freebairn and G. Wockner

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. Implications for the timing and type of tillage are discussed below under 'tillage'.

> Tip: Spread straw from the header onto 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.

How much cover

The following pictures (**Figures D-4** to **D-7**)provide a guide for minimum level of residue cover for typical summer and winter crops.

> **Tip:** To estimate ground cover, 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 cover exceeds 70%. Repeat five times in a paddock, then average out the results.

Figure D-4 30% wheat stubble cover

Figure D-5 70% wheat stubble cover

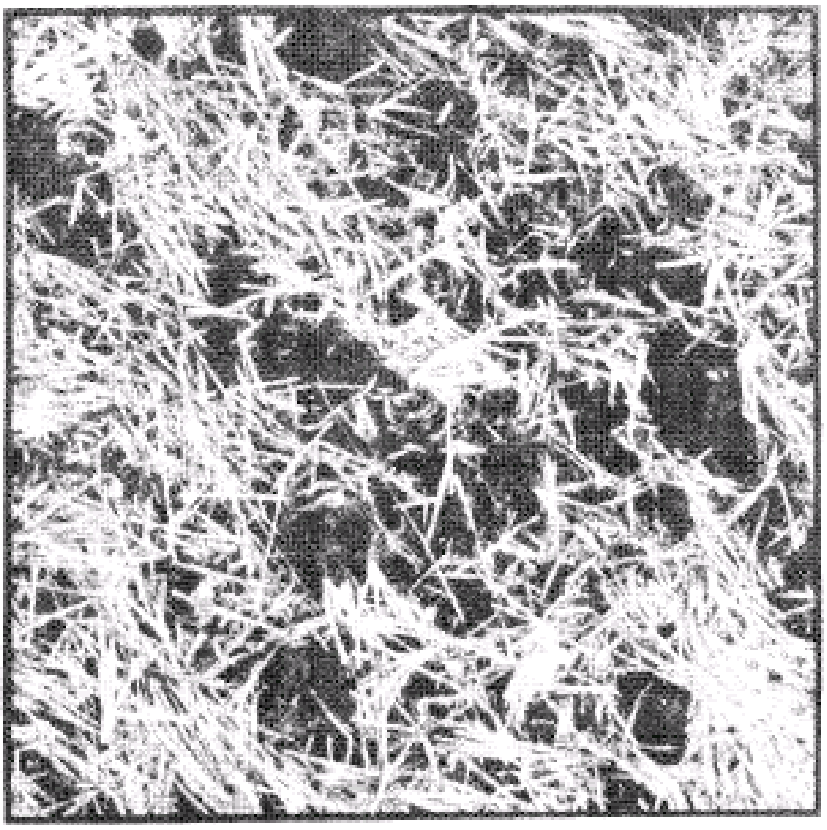
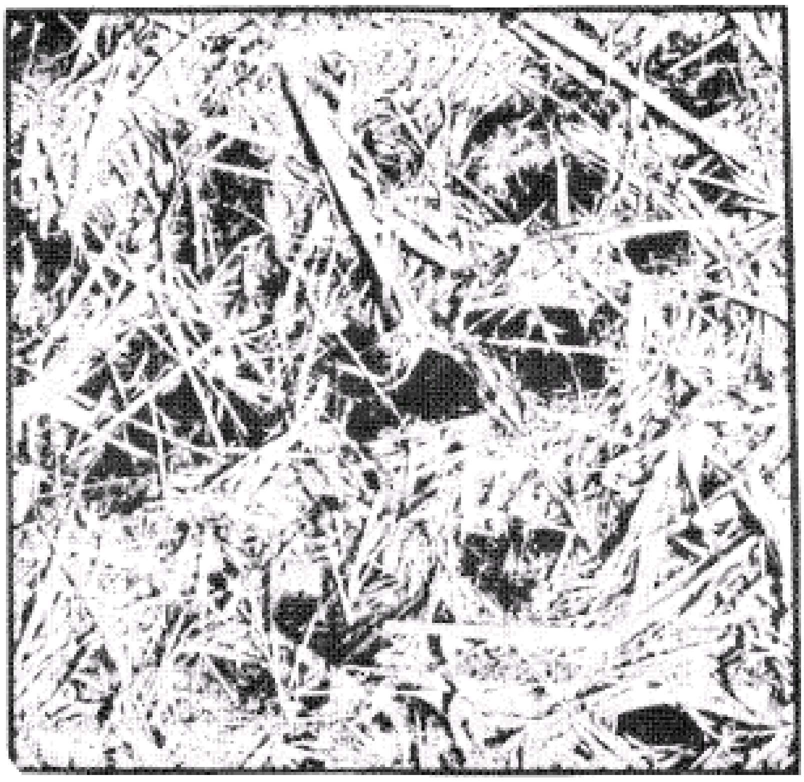


Figure D-6 30% sorghum stubble cover

Figure D-7 70% sorghum stubble cover



Fallow management: 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.

Fallow management: 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% cover. See **Figures D-4** to **D-7**. Removal of stock from a paddock before this critical level is reached requires careful monitoring.

Fallow management: tillage

Tillage reduces the amount of residue available for surface cover. **Table D-1** gives the residue reduction caused by a sample of various implements:

Table D-1 Effects of passes of different implements on residue cover levels

Implement	Percent 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
Blade plough	5 - 10
Rod weeder	1 - 10

Source: L.D. Ward, formerly Q.D.P.I.

Clearly, fallow weed control by tillage is best achieved by using either a blade plough or a rod weeder.

Go to Chapter B2 for more information on weed control

Minimise tillage to the essential, so reducing the time that the soil is in a loose condition.

Opportunity/ double cropping

Opportunity cropping has several important advantages in controlling run-off and erosion. A crop provides soil cover and uses soil moisture. Thus the soil is capable of absorbing additional rainfall.

Go to Chapter E6 for more information on the role of opportunity cropping in improving water use efficiency.

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.

Go to Section 5 for more information on no-tillage.

By using a planter with some stubble handling capability, soil protection can be maintained until the new crop is established.

Contour cultivation

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 providing for delayed but increased water infiltration. Contour cultivation also orientates plant residue across the slope which is most effective in slowing run-off. **Figures D-8 to D-10** show the recommended methods of contour cultivation between erosion control banks.

Figure D-8 Cultivating a headland

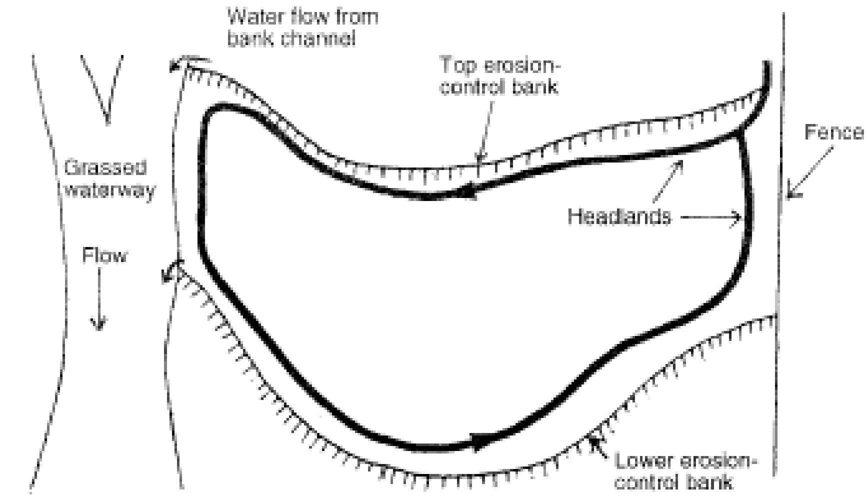


Figure D-9 Working a bay from the top

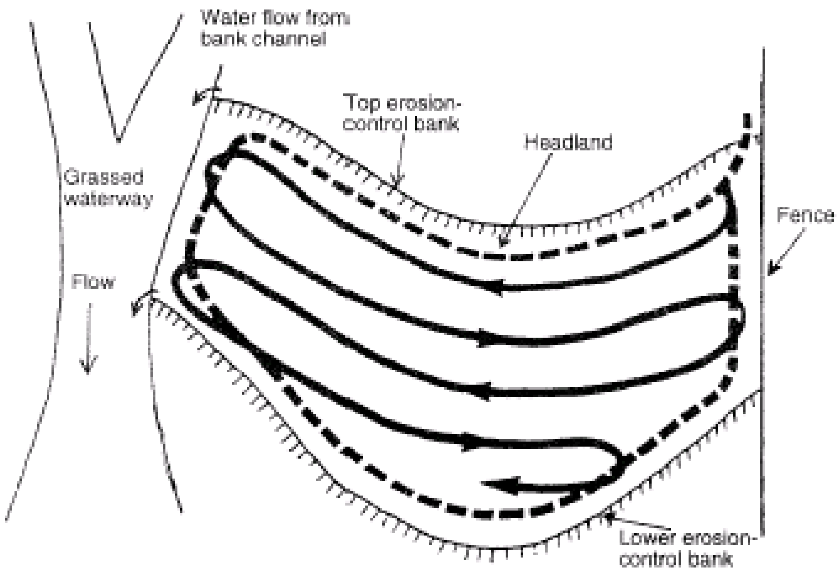
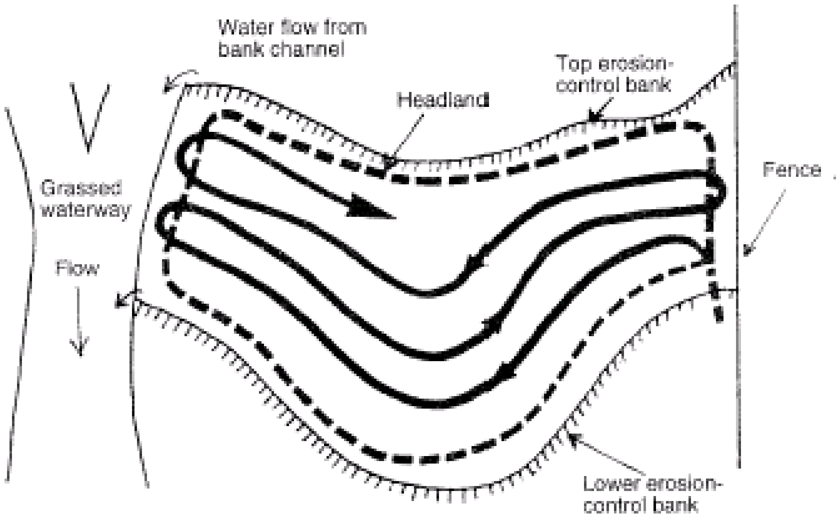


Figure D-10 Working a bay from the bottom



Earthworks (including waterways)

Erosion control earthworks are an integral part of conservation farming in the uplands of the northern wheat-belt. Erosion control banks effectively break the slope into segments which are not prone to the development of gullies. They also provide a means of diverting run-off safely from the field into a grassed waterway.

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.

Contact your local Department of Primary Industries or Soil Conservation Service office for advice regarding the layout of erosion control banks and channels, diversion channels and grassed waterways.

Figure D-11 Eroded topsoil trapped by plant cover

Photograph: Ian Ferris.

Trapping eroded soil

Off-paddock techniques for trapping eroded soil, such as filter strips and sedimentation ponds, reduce the impact of soil erosion off the paddock and off the farm. They do not reduce the impact on the eroded paddock. In **Figure D-11**, soil eroded from the cultivated area in the foreground has been trapped by the no-tilled strip in the midground.

Erosion of flood plains

On flood plains, soil erosion problems require special solutions. The principles of soil erosion control in these areas are:

- minimise diversion and concentration of flood waters;
- use strip cropping to spread flood flows;
- maintain the function of natural drainage lines.

Effective flood control which minimises erosion requires co-operation across farm boundaries to ensure flood flows remain spread and slow. All roads and structures need careful design and maintenance as part of this system.

Contact your local office of Department of Primary Industries or Soil Conservation Service for advice regarding the layout of co-operative flood plain plans and strip cropping systems.

Acknowledgements

Hamish Cresswell, CSIRO Division of Soils, Canberra; Rob Loch, Queensland Department of Primary Industries, Toowoomba; Brian Murphy, Conservation and Land Management, Cowra; and Des Scroder, Conservation and Land Management, Gunnedah.

Figures D-4 to D-7 from photographs in: *A Field Manual for Measuring Stubble Cover* by Jeanette Molloy, Soil Conservation Branch, Queensland Department of Primary Industries.

Figures D-8 to D10 are from QDPI Farmnote SC8817002: *Cultivating between contour banks in broad acre areas* by Mark Genrich and Len Lesleighter.

Section 2: Maintaining and improving soil structure

This section deals with the direct measures that promote good structure. Some of the other sections in Part D deal with farming strategies that, indirectly, have an impact on soil structure.

Factors that promote good soil structure are soil organic matter, root growth, wetting and drying, freezing and thawing, calcium, and the correct use of tillage. Till under the right soil moisture conditions when tillage is necessary, but minimise tillage when soil moisture conditions are not right, or when tillage is not necessary.

Organic matter

Organic matter helps to bind and stabilise the soil. The bonds formed provide resistance to wind and water erosion, and help to maintain an open pore structure. Organic matter is most important in the sandy, silty and loamy soils. In clay soils, the clay itself binds the soil, and organic matter is less important for soil structure. However, never disregard the importance of organic matter in **any** soil.

A pasture phase is a very effective way to restore organic matter lost through cropping. Pastures also encourage soil animals, which incorporate and decompose organic matter, creating pores by their burrowing. Conserve organic matter by including stubble retention, minimum tillage, and opportunity cropping (avoiding long bare fallows).

Go to Chapter E4 for more information on organic matter.

Root growth

Tap-rooted plants and fibrous-rooted plants affect soil structure in different ways. Tap roots make large channels which, when the roots decay, provide ready access for water, air and other plant roots to the subsoil. In soils that do not crack, wetting and drying will not repair a plough pan, but roots penetrating that plough pan improve soil structure.

Fibrous roots are useful for binding the soil. Numerous small roots make intimate contact with soil particles. When the roots die, their remains become well-incorporated organic matter, important to the stability of soil structure.

Wetting and drying

Wetting makes a soil swell, and drying makes a soil shrink. The degree of swelling and shrinking varies. Some soils swell and shrink so little that they do not crack. Other soils swell and shrink enough to crack compacted clods. Clay and organic matter swell and shrink. Smectite clay swells more than illite clay; kaolin clay swells the least.

Go to Chapter E2 for more information on clay minerals.

Soil cracking through wetting and drying is one of the natural processes responsible for forming a well structured soil from a poorly structured mass of soil material. Soil cracking is an effective way of repairing a compacted soil.

Freezing and thawing

Freezing shatters soil as the soil water turns to ice and expands. The soil must contain some water: obviously very dry soil does not form ice! Freezing and thawing have the same effect as wetting and drying, breaking compacted soil into smaller pieces. However, winters in the northern wheat-belt are not cold enough for soil to freeze at depth. It is unlikely that frost would penetrate the 10 or 20 cm depth necessary to repair a plough pan. Frost may, however, help to shatter compacted clods exposed on the soil surface.

Calcium

Calcium, in the forms of gypsum or lime can help to improve a soil's structure if the soil is dispersive. See **Chapter C1** for dispersion tests you can do yourself.

Both gypsum and lime add calcium to the soil. Gypsum generally gives an immediate response (as soon as it dissolves in water), while lime gives a slower, but longer-lasting, response. Lime is less soluble than gypsum, but is preferable for acid soils: as a remedy for both acidity and sodicity. See **Section 8** of this chapter, under 'Sodicity'.

Tillage

Damage to soil structure may be due to mechanical damage (compaction, remoulding or smearing) caused by tillage or traffic when the soil is too wet. Tilling silty soils when too dry damages their structure by pulverising soil aggregates to dust.

Sometimes damage to soil structure is unavoidable. There may be a need to harvest a crop or prepare a paddock for sowing when the soil is too wet. In such circumstances you will damage soil structure. Minimise the damage and plan to repair it.

Chisel ploughing

A chisel plough will loosen a compacted topsoil or a shallow compacted layer. Chisels break up the soil without turning it over. This prevents a subsoil from mixing with shallow topsoil as can happen with a mouldboard plough.

A chisel plough doesn't smear the soil beneath the whole width of the implement, as disc ploughs can do. This smearing is a cause of plough-pans.

Deep tillage

There is a limit to the working depth at which a tined implement will loosen soil. This depth is called the 'critical depth'. The action of a tine is to push the soil immediately in front of it upwards and forwards. If the soil adjacent to the tine is strong enough, it pushes the overlying soil away and loosens it. If the depth is too great, the soil around the tine is not strong enough to lift and loosen the overlying soil. Instead, soil flows sideways or downwards and around the tine, creating a smeared or compacted layer around the foot of the tine. The result is a new compacted layer at a greater depth.

The critical depth depends upon the soil strength. When the soil is dry, it is stronger and the overlying soil is lighter. The critical depth is therefore greater.

Figure D-12 Some deep tillage implements

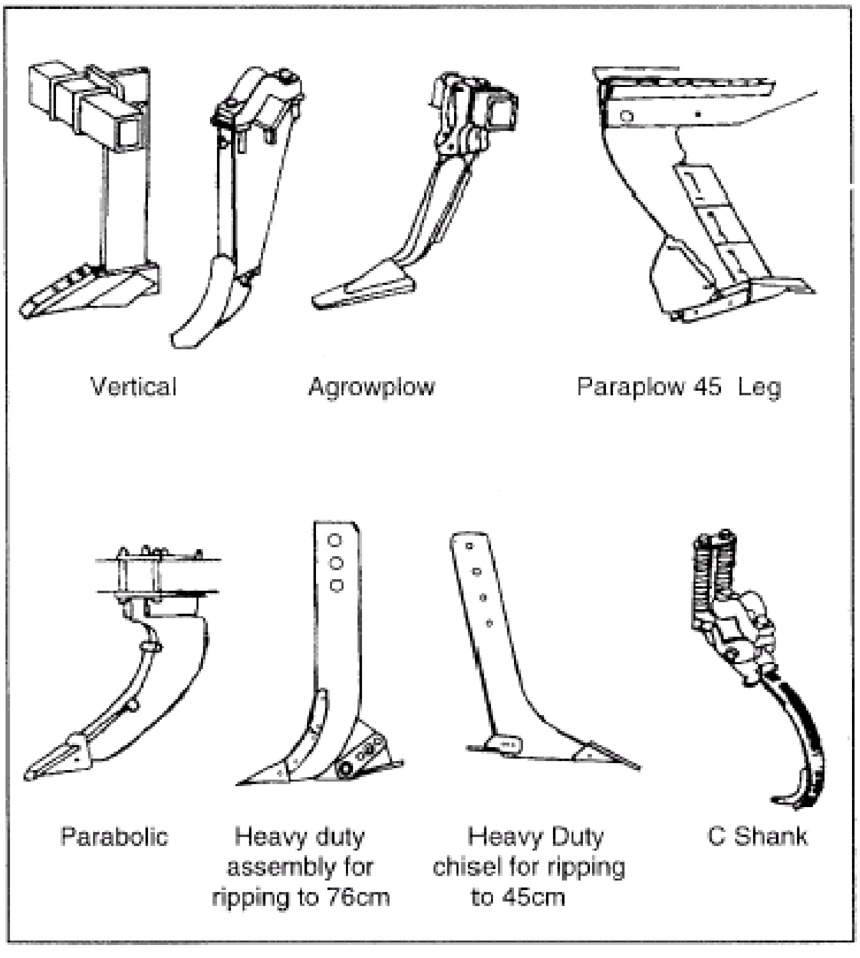


Figure D-12 shows a selection of deep tillage tines. Older designs had tines that penetrated the soil vertically. A sharper angle of entry directs the force upwards, giving more shattering of soil with less draught.

Shallow leading tines

The critical depth can be extended downwards by using shallow-working tines in front of the deep tines. The shallow tines loosen some of the overlying soil. Although the amount of soil overlying the deep tines is the same, it is now weaker which allows more of it to be loosened before it exceeds the strength of the soil at the foot of the deep tine.

The type of tine or share used as the leading tine is relatively unimportant as long as it is working deep enough to loosen some compacted soil. Set leading tines deep enough to fracture any dry topsoil layers and some of the plough pan. If the leading tine is merely re-arranging soil that is already loose, it will have no effect.

An alternative technique is to perform a prior shallow working and then deep rip. However, this means that the tractor pulling the ripper is running on loose soil. Traction is poor, and the loose topsoil is re-compacted. The shallow leading tines technique involves a single pass.

There are no commercial machines with shallow leading tines available in Australia. Farmers can modify implements in their own workshops using off-the-shelf components. Dryland farmers, who are probably not interested in ripping much below 300 mm, could add clamp-on scarifier tine assemblies to the front of a chisel plough or Agrowplow in place of the existing front tines. Such a hybrid is easier to pull than an equivalent chisel plough with all tines set deep.

Livestock trampling damage on wet soil

The trampling of soil by livestock is known as poaching. Poaching damages topsoil structure, particularly when the soil is wet. Both sheep and cattle can cause significant damage. The resulting problems are lower water infiltration and increased soil strength, affecting plant root growth. Soil compaction by stock will decrease yields. Poaching of cropping paddocks may also mean extra tillage to get a crop established.

Recently cultivated soil is vulnerable to re-compaction. No-tilled soil has higher strength and has a higher resistance to poaching.

An effective method of reducing poaching is to defer grazing for a few weeks after rain. Sandy soils are less prone to poaching than clay soils, so one option is to keep some of these sandy soils in pasture and transfer stock there in wet weather. It may also be necessary to use supplementary feed.

Livestock trampling damage on dry soil

Significant topsoil damage also occurs on many soils in Australia when they are very dry. Hoofed animals tend to pulverise silty soils, forming dust and leaving the soil vulnerable to wind erosion.

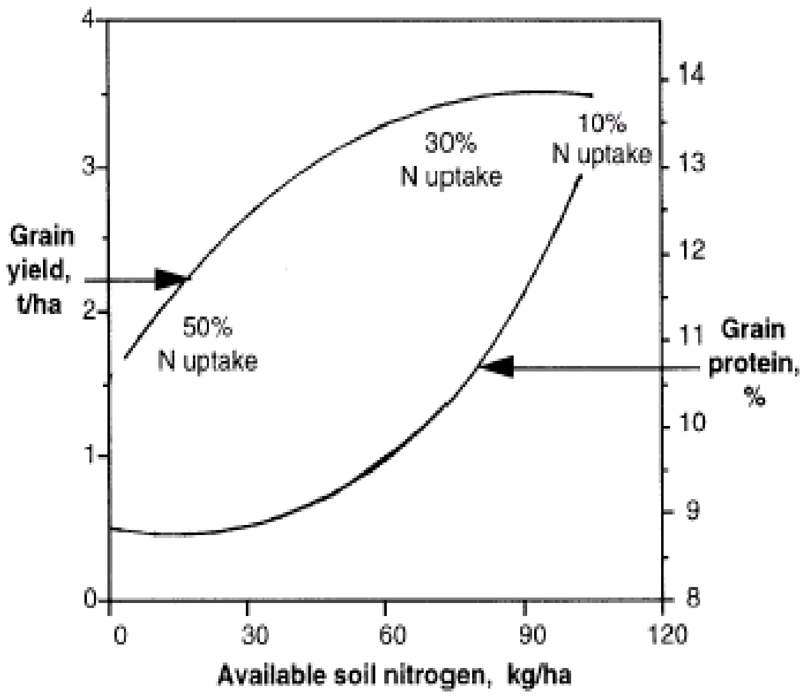
To minimise this problem, keep stock on land with good plant cover in dry times. Alternatively, move stock onto clay soils (such as river flats). A clay soil regains its structure more easily than a silty soil.

Section 3: Improving soil chemical fertility

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.

Farm profitability and 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.

Figure D-13 Example of response of grain yield and protein to increasing nitrogen supply.   Values for N uptake are the maximum % of available soil nitrogen recovered in the grain



Cereal response to nitrogen

Nitrogen may increase cereal yield, grain protein, or both.   When the soil has a low level of available nitrogen, applied fertiliser nitrogen increases yield but not protein.   In the example in **Figure D-13**, grain yield increases but protein declines between 0 and 15 kg/ha of available soil nitrogen.   At this stage, the grain takes up 50% of available soil nitrogen (as nitrate already in the soil or as applied fertiliser).

At higher rates of available nitrogen, grain yield increases more slowly, but grain protein starts to increase rapidly.   As yield approaches a maximum (usually indicated by protein approaching 11.5% to 12.5%) the uptake of soil nitrogen by the grain falls to 30% or less.   When there is no further yield increase from extra nitrogen, uptake of soil nitrogen by the grain is usually 10% or less.

How much N is required?

Nitrogen requirement can be calculated for expected increases in yield and protein from added nitrogen. The calculation assumes that soil moisture is adequate, and that nitrogen is limiting yield. The calculation uses this formula:

nitrogen in the grain (kg/ha) = yield (t/ha) x protein% x 1.75

Example: Suppose that a paddock has been yielding wheat at 2 t/ha with 11.0% protein.

Nitrogen in the grain = 2 t/ha x 11.0% protein x 1.75
= 38 kg/ha of N.

That is, each wheat crop has been exporting from the paddock 38 kg/ha of nitrogen in the grain.

Your yield goal for the next crop of wheat may be 3 t/ha at 12.5% protein.

Nitrogen in the grain = 3 t/ha x 12.5% protein x 1.75
= 66 kg/ha of N.

The extra nitrogen exported from the paddock in the grain is:

66 - 38
= 28 kg/ha of N.

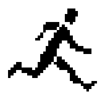
However, because grain takes up only a part of available soil nitrogen, there needs to be more than 28 kg/ha extra available. At, say, 30% recovery the extra nitrogen requirement is:

28 x 100/30
= 93 kg/ha of N

Thus, to raise yield and protein to the desired level would require extra nitrogen, added to the soil either by legumes, or as fertiliser. To add 93 kg/ha of N in the form of urea would require 202 kg/ha of urea. At 1994 prices (80¢ per kg of N) the urea would cost $74.40 per ha).

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 by 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.



Go to Chapter E5 for more information on plant nutrition.

Fertilising pasture

Choose a pasture that will give the greatest response to fertiliser. The high cost of fertiliser makes it necessary to develop a fertiliser program that will produce a reasonable return on the investment. Selective programs may be necessary in tight economic times but some fertiliser has proved to be better than no fertiliser, in terms of production and sustainability. On pasture, a visible growth difference represents a 20% yield increase.

Your priority paddock for fertilising would ideally have the following features:

- large enough to contribute significantly to farm profitability;
- recently sown with a perennial pasture species for fattening and fodder conservation;
- a good component of legume: lucerne, medic or clover;
- good soil depth, good drainage and flat to gently sloping;
- no 'fertility bank' - (has not been fertilised for a long period);
- a southern or easterly aspect.

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

Soil testing for pH, nutrients and exchangeable cations is a good guide to optimum fertiliser recommendations. Plant tissue analysis should be used to test for trace elements. Soil testing for phosphorus, sulphur and pH is the minimum consideration for a pasture phase.

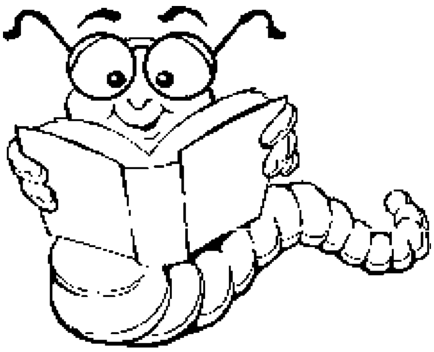
Test strips are an effective way of estimating soil nutrient status. (See **Chapter B8, Figure B8-2** which shows a suggested layout for testing responses to gypsum and fertiliser). Choose legumes in an active growth stage and close it to grazing for 6-8 weeks.

Apply phosphate fertiliser to one strip, and sulphur fertiliser to another strip (crossing the first). The area where the two strips cross will test the effect of phosphate and sulphur together. Compare the response to phosphate alone, sulphur alone, phosphate and sulphur combined, and the untreated area outside the strips.

Assess your fertiliser requirements with the assistance of soil test results and the advice of a farm advisor. Fertiliser can be applied during the early autumn, when annual legumes germinate. Application at other times should take into account good ground cover and weather conditions so as to prevent displacement of fertiliser. Deep, wide cracks in clay will also divert fertiliser from the surface soil where it is needed.

There is increasing concern with regard to excessive nutrients producing algal blooms in waterways. Take care when applying fertiliser around waterways and water storage areas, especially when topdressing by aeroplane.

Section 4: Soil improvement through biological activity



Soil organisms improve soil structure, bring about chemical changes in the soil's constituents and add to soil nitrogen by fixation from the air. Section 2 of this chapter deals with the benefits to soil structure through root growth. **Chapter E5** deals with nitrogen fixation.

The following factors increase biological activity:

- retention, not burning, of crop residues;
- minimum or no tillage and stubble mulching, rather than incorporation of crop residues;
- liming if necessary to increase soil pH;
- well-managed, not over-grazed, pasture;
- good soil chemical fertility to promote plant growth and additions of organic matter to the soil;
- opportunity cropping to avoid long, bare fallows.

Earthworms

Earthworms benefit the soil. Contrary to what many people have thought in the past, Australian cropping soils are not too hot and dry for earthworms. Earthworms can inhabit cropping soils, but they are very sensitive to management changes.

Tillage reduces earthworms because, quite simply, it chops them into pieces. Tillage also destroys their burrows and hastens the decomposition of plant residues, their food supply. By incorporating plant residues into the soil, tillage removes the protective mulch that keeps the soil cool in the day, warm at night, and the surface soil moist for longer after rain.

The amount and type of tillage affects the number of earthworms present. Earthworm numbers under direct-drilling can be up to four times higher than under conventional cultivation. Under reduced cultivation, a single pass with narrow sowing points does not destroy many earthworms. However, the use of traditional broad points reduces earthworm numbers to the same extent as conventional cultivation.

Increased earthworm populations may not show up in the first year of direct-drilling. Increasing earthworm numbers is a long-term process.

Stubble removal reduces earthworm numbers to almost a third. By adding stubble however, you can increase earthworm numbers by up to 50 per cent. Crop residue handling affects the size of earthworms. For example, earthworms are smaller in stubble-burnt paddocks.

Crop rotations that include a pasture phase will result in higher earthworm numbers throughout the rotation, compared with continuous cropping. The amount of food available, which may depend on the previous crop, will influence earthworm populations. Soil moisture is also strongly influential.

Soil acidity reduces earthworm numbers; they will not survive in a soil with a pH (calcium chloride) 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 earthworms need in constant supply.

Earthworm burrowing:

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

Earthworm feeding:

- increases 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;

Termites and ants

Termites and ants eat all forms of plant residues. Soil fertility often increases near their nests. Ants collect seeds and carry them underground; they can be pests if they deplete seed supplies in pastures. These activities help the breakdown of organic matter, and the return of nutrients to the soil. Burrowing provides channels for water movement within the soil, and this is important in drier areas where earthworms are less active.

Bacteria

Bacteria are single-celled organisms with a rigid cell wall. 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 which bind soil particles together.

Fungi

Fungi are organisms that grow as long strands (hyphae) in the form of a mat (mycelium). Under unfavourable conditions, fungi form spores which can survive for long periods.

Most fungi live on dead plant residues. Only a few infect living plant tissues to cause plant diseases. They 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. As such, 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.

VAM

VAM stands for Vesicular-Arbuscular Mycorrhizae: a real mouthful, which is why they are usually called simply 'VAM'. They are several forms of fungus which infect, but do not harm, plant roots. In fact the association benefits the plant and the fungus: it is symbiotic.

VAM colonise the roots of a large number of crop species, assisting the uptake of nutrients like phosphorus and zinc, and generally assisting plant growth. The plant provides sugars in exchange.

Fine, thin-walled tubes (hyphae) of VAM grow away from the plant root and penetrate the soil. In effect, the plant gets an extended root system. Following a period of growth and development, the VAM produce spores that remain in the soil and can infect another seedling.

In agriculture, VAM form a natural part of cropping systems and are valuable in phosphorus and zinc nutrition. They are particularly valuable when either phosphorus or zinc are deficient in the soil, because they can extract these nutrients that seem to be unavailable to plants. Perhaps that is one reason why soil tests for available phosphorus are sometimes difficult to interpret!

VAM decline during long (weed-free) fallows, causing 'long fallow disorder' in the subsequent crop. This is because VAM cannot multiply independently of living roots.

Avoid long fallow disorder by reducing the length of weed-free fallows, whenever rainfall allows extra cropping. Another option is to alternate cereals, which have a relatively low VAM dependence, with crops like grain legumes and oilseeds, which have relatively high VAM dependence.

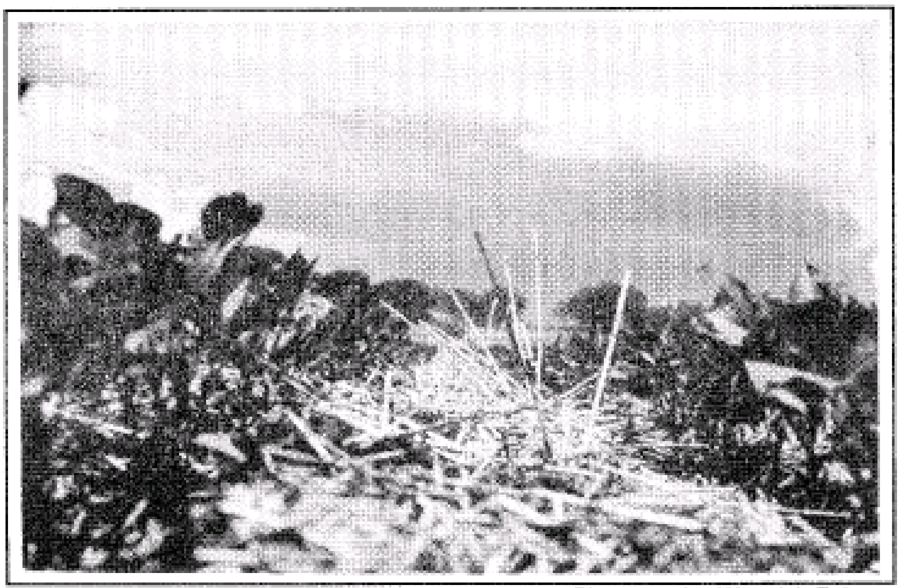
Cereal crops are the best to break a long fallow because they have relatively low VAM dependency, but will build up VAM for the more highly dependent crops such as sunflower. Cereals also make the most of the nitrogen mineralised from organic matter during a long fallow; legumes after a long fallow will use that mineralised nitrogen rather than fix their own.

Aim for a satisfactory plant population. The more roots grown, the more VAM for the next crop.

Some plants, such as lupins and canola, do not depend on VAM and furthermore do not allow the build up of spores for following crops. Growing these crops is the same as having a bare fallow in terms of VAM survival.

When erosion removes soil, that soil carries away VAM, organic matter and nutrients. Land levelling exposes subsoil poor in VAM.

Section 5: No-tillage



Photograph: Warwick Felton.

Comparison of no-tillage and pasture

Improvement in soil structure under pasture depends to a large degree upon the lack of soil disturbance by tillage. Left undisturbed, but with active plant growth, the soil can build its structure. Soil organic matter content increases, soil aggregates can develop without disruption, root channels and the burrows of soil animals are not destroyed, plant residues remain on the surface to protect it from raindrop impact and erosion.

No-tillage cropping has similar benefits through least disturbance to the soil.

We can think of a no-till cropping paddock as a pasture that is resown frequently: but resown with grain, not grass. In a pasture, we may direct-drill new grass or legume seed into existing turf to restore vigour. In a no-till cropping paddock, we sow a new crop into the stubble of the previous crop which has matured, and which we have harvested.

The role of tillage

Tillage may control weeds, prepare a seedbed, break up a compacted layer, or incorporate fertilisers or herbicides. These are all good reasons to till as long as the tillage is not creating a need for further tillage.

The benefits of no-tillage over full tillage depend largely on soil type, the weather, and crop rotations.

For example, if you till a soil that is too wet, you may need to work it again several times to break up a compacted layer or large clods formed by the first tillage.

A soil prone to hard-setting leads to a dilemma whereby tillage is needed to loosen the soil, but at the same time tillage destroys soil organic matter, making the soil more prone to hard-setting ... and so on. The answer to this dilemma is to change to a rotation of several years of pasture and short phases of cropping. The pasture phases increase soil organic matter and improve soil structure. no-tillage, rather than full tillage, during the cropping phase maintains organic matter and soil structure for longer before the soil becomes hard-setting once again.

Tillage effects

Tillage reduces the organic matter content of soil. It does this by:

- mixing the soil and bringing soil organisms into contact with plant residues. This contact leads to more rapid decomposition of organic matter;
- breaking soil aggregates and exposing organic matter that was previously protected from the air and from soil organisms.

Thus, although ploughing mixes plant residues into the soil, the stirring action of the ploughing (and subsequent tillage) has the net effect of decreasing the soil's total organic matter content.

Soil structural stability in silty and fine-sandy soils depends largely upon soil organic matter. All forms of tillage reduce organic matter and soil structural stability.

Incorporating stubble means that the soil is less protected and erosion is more of a risk. However, the nutrients contained in the stubble are more quickly released into the soil. Careful timing of tillage is important to avoid bare soil during heavy rainfall.

Different operations have a different effect upon the amount of stubble cover. Burning can reduce stubble cover to nothing; disc ploughing halves stubble cover with a single pass; even planting in close rows will halve the area covered by stubble. Blade ploughs and rod weeders kill weeds but leave stubble on the surface; such implements are useful for retaining stubble cover whilst controlling weeds, but they may create a smeared layer if the soil is at all moist

Why is stubble important?

Stubble benefits a soil by:

- protecting the surface from raindrop impact, which can degrade surface structure to form a crust or a hard-set topsoil;
- slowing down the movement of water over the surface; and
- reducing (by a few days) the evaporation of water stored in the soil surface.

Figure D-14 Crop established under no-tillage. Good stubble cover

Photograph: Warwick Felton.

More water enters the soil, less runs off, and the surface stays moist longer for the germination of seeds. Therefore stubble helps to control erosion, helps to maximise the storage of rain in the soil, and allows sowing over a longer period.

Go to Chapter E6 for more information on the effective use of rain.

Stubble cover will slow the rate of erosion. However, it will not solve an erosion problem. The greater the slope, the greater the amount of stubble needed to reduce run-off. Stubble can not prevent run-off from a soil that is full of moisture.
Erosion control banks are essential on sloping land.

Go to Section 1 of this chapter for more information on erosion control.

Stubble is particularly useful during fallow, or during crop establishment. These are the times when the soil is not protected from the rain by plant leaves.

Finely tilled topsoil blows away easily. Tillage of silty or fine sandy soils when they are too dry pulverises the soil to powder. The powder blows away easily. On all soils, retain a stubble mulch. This will decrease both wind and water erosion.

Not all stubble is equal: cereal stubble takes longer to break down (and is therefore effective for longer) than legume stubble.

Two of the major limits to crop growth in the northern wheat-belt are water and nitrogen.   The amount of rainfall is an important factor when comparing the effects of tillage systems.   For example:

- In a dry year, when water limits crop growth, a stubble-covered, no-tilled soil stores more water.
- In a wet year, when nitrogen limits crop growth, a fully tilled soil has more available nitrogen.

Retain crop stubble to mulch the surface of any area where you use no-tillage.   A stubble mulch reduces surface crusting, and there is less need for tillage.   In seriously damaged soil, consider a pasture phase after judicious tillage to correct the problem.   It is a good policy to include a pasture phase in your long-term rotation plan, as pasture is a good way to restore soil structure.

No-tillage usually leads to increased infiltration and increased soil water storage.   No-tillage can therefore make more efficient use of rainfall but may lead to some nutrient leaching and deep drainage.   Therefore it is good practice to use the stored soil water by sowing a crop as soon as the soil profile is 75% full of moisture.

Crop rotation

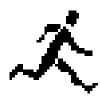
One of the problems with stubble is that it carries many diseases.   No-till wheat grown after wheat is prone to crown rot and yellow leaf spot. Rotate with a crop that is not a host to those diseases, for example a broadleaved crop.

Another option in disease control is to burn the stubble before sowing. This is generally a last option because of nitrogen loss and the erosion risk.   The erosion risk is high at sowing time because the soil is often nearly full of water; it can accept only a little more rain before run-off occurs.

Soil organisms

A stubble mulch or a pasture phase supplies organic matter, which provides a habitat and food for soil organisms.

Earthworms will "till" the soil.   If there are sufficient numbers, they will provide a seedbed, pore space for water entry and storage, and break down the mulch into nutrients for plant growth. Expensive tillage operations, which discourage soil organisms, conventionally achieve these same aims.



Go to Section 4 of this chapter for more information on biological activity.

Weed control

It is best not to rely on only one form of weed control, but to use a method suited to the current conditions. Herbicide resistance in weeds, herbicide residues and plant-back times mean that there is a place for grazing to help control weeds. Generally, control weeds by grazing (or by scarifying if you are not using no-till) when the soil is dry. Control weeds with herbicide when the soil is wet. Estimate soil water content by the methods in **Chapter C4**. The timing, previous weed control and other conditions will influence your choice between grazing, herbicide and tillage.

Sowing

Sowing into a no-till (or even a minimum till) paddock is more demanding than sowing into a finely worked, stubble-free seedbed. However, with the right planter, minimum or no-till allows greater timeliness to take advantage of sowing opportunities. There is more farming flexibility, greater chance of double cropping, and lower fuel bills.

A no-till or minimum till planter should:

- accurately place seed into moist soil at an even depth across the whole paddock;
- cover and press soil over the seed to ensure good seed-soil contact;
- have sufficient clearance under the frame to allow sowing into large amounts of stubble.

There are some good no-till planters available. However, many farmers feel unsure about investing in a new machine until they have proved that no-tillage will work for them. Some chisel ploughs and scarifiers have the features that lend themselves to conversion into a no-till planter.

Narrow points, press wheels and a seed meter can turn a cultivating implement into a no-till planter. Chisel ploughs and scarifiers with narrow frame sections (less than 3 m) and large diameter depth wheels within the frame are best for good depth control.

Clearance under the frame should be 450 mm or more. Tine spacing should at least 600 mm, with at least 450 mm between bars. The space between wheels and tines should be over 250 mm. These features will help stubble to flow through the planter.

No-tilled soil can be hard for tines to penetrate. Tines should be sufficiently rigid, with a minimum of 1.5 kN (340 lb force) break out force. Low tine break out force leads to erratic seed placement and hence poor seedling establishment. Chisel plough and scarifier tines normally have sufficient break out force.

A forward sloping tine with a high elbow, or a 'C' shaped tine helps prevent stubble building up on the tine. Arrange tines so that they don't funnel stubble onto rear tines or wheels.

Press wheels are a once-only cost and are a good investment when converting to no-till. Press wheels improve seedling emergence. They are particularly effective on drying soils, thus extending planting time. They compensate somewhat for poor depth control. Consolidation of soil around the seed helps deter soil insects, and speeds germination so that the seedling is vulnerable to insects or fungi for a shorter time.

No-tillage with stubble mulch:

Advantages:

- Increased water storage, especially in a dry year.
- Less restricted sowing time.
- Increased opportunity for double cropping.

Cautions:

- Cereal stubble ties up nitrogen; more nitrogen fertiliser needed.
- Rotate crops to reduce disease problems.
- Legume stubble decomposes quickly: erosion risk.
- Soil insects (wireworm and false wireworm).
- Danger of herbicide resistance.

Tip: To minimise erosion, avoid a soil that is bare, dry and finely tilled. Bare soil is highly erodible; dry soil will not grow any cover; finely tilled soil does not have cracks or pores open to the surface, nor does it have surface roughness to detain water.

Acknowledgement: Information on zero till planters obtained from an article by Jim Turnour, Peter Walsh, Bruce Radford and George Lambert: 'Planting Machinery', in 'Opportunity Cropping Management - a Profitable, Sustainable System.' Queensland Department of Primary Industries, 1991.

Section 6: Soil moisture and tillage

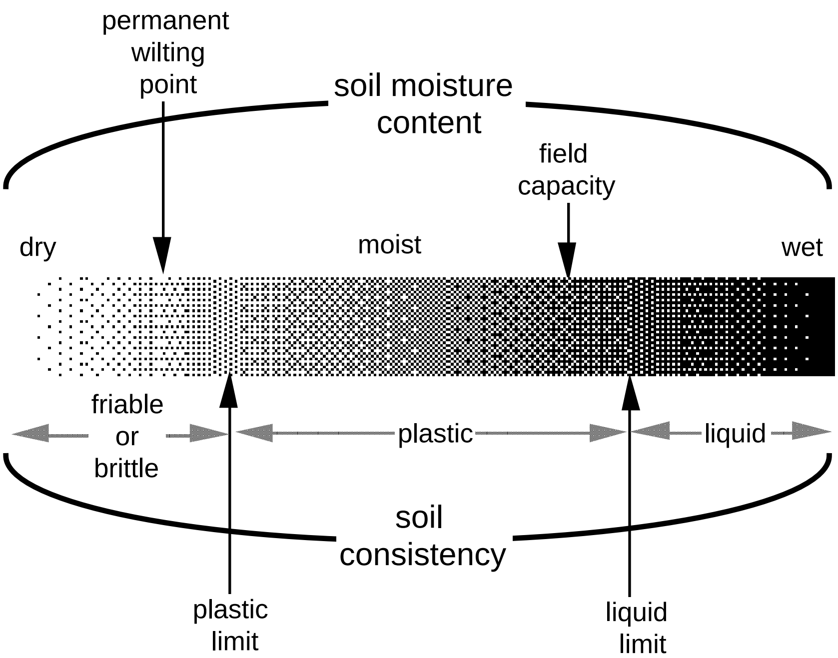
A small change in the moisture content of a soil makes an immense difference to the soil's strength, and therefore the way it responds to external forces such as tillage or traffic.

Tillage at the wrong moisture content can degrade soil structure For example, tilling a soil that is too wet will cause compaction and smearing. This will impair plant growth, restrict water infiltration, and encourage erosion. Sometimes you may need to disturb the soil when it is too wet: timely sowing is an example. Minimise damage by avoiding any unnecessary tillage or traffic.

Go to Chapter C4 for more information on measuring soil water.

As the moisture content of a soil changes, the soil's consistency (hardness or softness) goes through a series of different states. See **Figure D-15** which represents a scale of soil water content from dry to wet. Along this scale are points where the soil's consistency changes.

Figure D-15 Soil moisture content and consistency



Dry soil is friable (crumbly if loose or brittle if compacted). At such moisture contents, tillage fractures and loosens soil. Dry tillage benefits clay soils because of the shattering. However, silty soils may pulverise (turn to powder) if tilled dry.

The plastic limit is the moisture content above which a soil becomes plastic (can be remoulded). Tillage will smear or compact clay soils that are even slightly moister than the plastic limit. Silty or fine-sandy soils may be tilled at the plastic limit (or slightly moister) to avoid pulverising.

The liquid limit is the moisture content above which the soil starts to flow like a liquid when disturbed. All soils will be damaged if they are tilled this wet.

Cracking clay soils

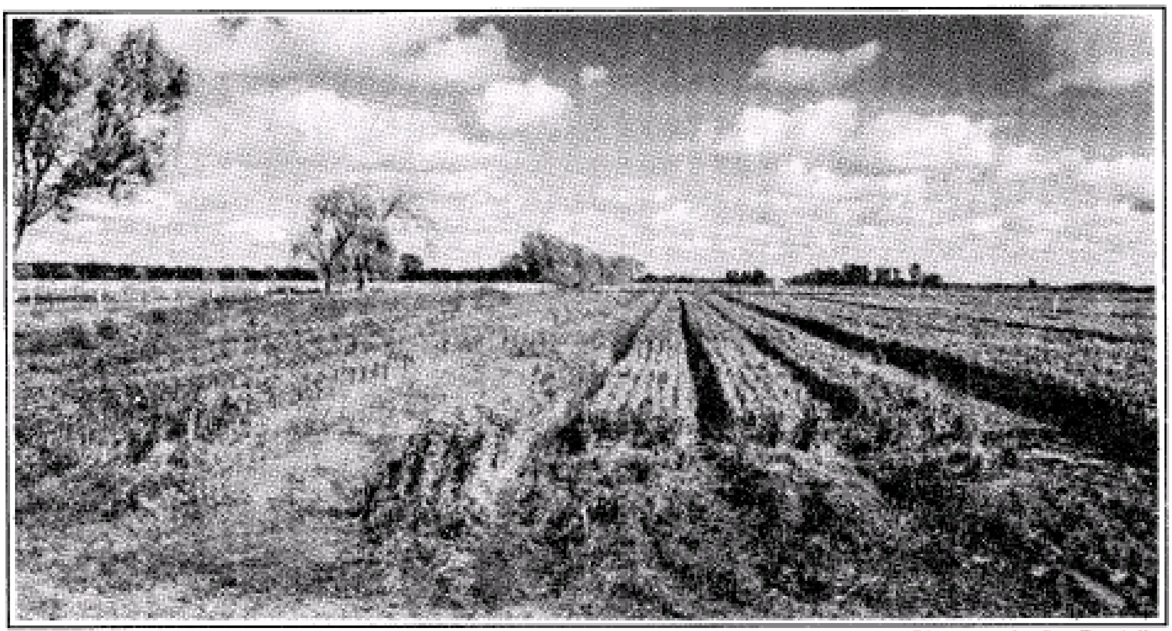
A moisture content drier than the plastic limit is best for tilling clay soils. That is not to say that you will never work a clay that is wetter than the plastic limit; there will be times when you can not avoid doing that. However, be aware that you are damaging the soil structure, and disturb the soil as little as possible.

The deeper you till, the more important it is for the soil to be dry through the full depth of tillage (and deeper). One option if the subsoil is too wet is to reduce the tillage depth.

Silty and sandy soils

Tilling a silty or sandy soil when too dry can pulverise the soil into dust. Subsequent rain may form a surface crust. Infiltration is reduced and erosion is likely. Silty and sandy soils, particularly when low in organic matter, are best tilled when the soil is moderately moist.

Section 7: Bed farming



Photograph: Ian Daniells

What is bed farming? Bed farming is a system of growing plants on raised beds.   It restricts wheel compaction to permanently located traffic lanes.   These lanes remain permanently compacted: no management inputs go into trying to relieve compaction in the lanes.   The plant beds receive no traffic and are not affected by wheel compaction.

Why bed farm? Advantages of bed farming include the following:

- energy input is less than half that of conventional farming;
- greater timeliness of field operations;
- control of soil compaction;
- less waterlogging (in some cases).

Soil compaction Soil compaction is an unavoidable consequence of mechanised farming. The degree of compaction can be minimised to some extent, or isolated to specific locations in a paddock, but it can not be totally avoided.

Common strategies for managing compaction aim to reduce the pressure on the soil beneath a vehicle.   Spreading the load over a wider area reduces the ground pressure where the vehicle contacts the soil.   Wide tyres, reduced tyre pressure, tracked vehicles, and dual wheels all spread the load.   This approach also advocates so-called 'flotation' tyres. 'Flotation' is an inappropriate term, because the only vehicles to 'float' over the ground are hovercraft and hot-air balloons.
Spreading the load over a wide area reduces surface damage.   It allows vehicles to travel over soil that is too wet to support normal vehicles.   But when the soil reaches a critical water content, even a wide tyred vehicle will exceed the soil's bearing strength.   When that happens, a wide, deep zone of compaction results.

Wide tyres do not reduce compaction. Narrow tyres on soft (wet) soil sink easily and damage surface soil structure. But surface soil structure in permanent traffic lanes is not a concern. Wide tyres appear to help a vehicle 'float' better on wet soil, leaving little trace. However, the **depth** of compaction depends on the **axle load** (which depends on the distribution of the total weight of the vehicle). When the soil is so wet that even a wide-tyred vehicle sinks, a wide, deep zone of compaction results. *Deep* compaction is difficult to repair. *Wide* compaction may extend under the plant beds.

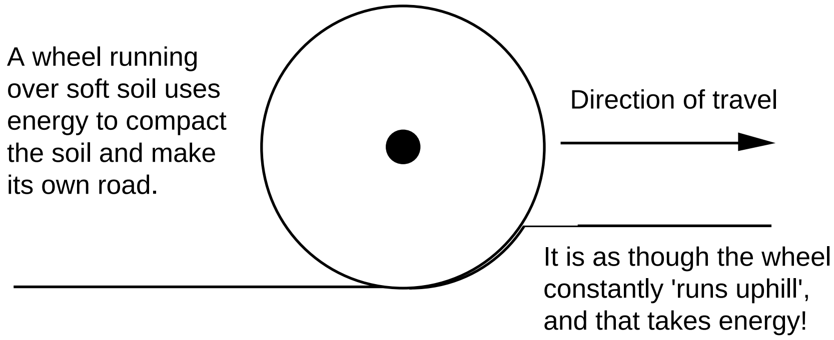
The practice of bed farming aims to confine compaction to well-defined areas: permanent traffic lanes (wheel tracks. Bed farming is a way of controlling compaction by controlling traffic. It makes a distinction between the traffic lane and the plant bed. This concept then makes it possible to optimise soil conditions for these two directly opposed requirements in the same paddock:

- compacted soil for vehicle operation; and
- non-compacted soil for plant production.

Compaction is generally regarded as bad because of its effects on crop establishment and root development. However, compaction is good in terms of vehicle operation. Vehicles travelling over compacted soil have better traction and reduced rolling resistance. Compacted traffic lanes allow earlier access to the paddock after rain.

It takes a large amount of energy to create compaction: in a conventional tillage operation, only one-third of tractor horsepower goes into the tillage; the other two-thirds goes into compacting the soil to support the vehicle (**Figure D-16**). In a bed-farming system, wheels run on already-compacted soil and less energy is needed to propel the tractor and implement forward.

Figure D-16 A wheel on soft soil uses energy to make its own road



Between the traffic lanes are the plant beds which, ideally, are never trafficked. There is no need to till to remove wheel compaction because there is no wheel compaction in the plant beds (ideally). Light, shallow tillage may be necessary to break a crust or kill weeds. If a tilth is desirable for sowing, the tillage may be confined to narrow strips along each planting line.

> **Tip:** Lower power requirements for tillage, and better traction mean that lighter tractors can cope with the work. Lighter tractors can have narrower tyres, which further confines compaction to the traffic lanes and off the plant beds. With bed farming, there is less need for big tractors with wide tyres.

Controlling waterlogging

Furrows formed to act as traffic lane markers can also act as surface drains. The plant beds are higher than the furrows, and this helps to reduce waterlogging.

On low slopes, direct the furrows downhill to help drain the paddock. On more sloping country, direct the furrows across the slope to reduce the danger of erosion in the furrows. In strip-farmed paddocks, furrows have to run across the slope, following the strips. In high rainfall areas, furrows need to be deep (making the plant beds higher) if they are to help reduce waterlogging.

There is a danger of concentrating water in low areas, causing ponding. Plan the direction of tracks to follow contours, and provide stable (preferably grassed) outlets for water from low areas.

Erosion along wheel tracks is another danger. You may have to move the wheel tracks every few years, if the tracks become too deep. Alternate the tracks between two positions, rather than relocate to a new place at each move.

Farm machinery

Within the bed farming system, the axle width (wheel spacing) of farm machinery determines the furrow spacing, and therefore bed width. Farm machinery in Australia is built to the imperial system of measurement (feet and inches). The machinery used in row crop farming suits a row spacing of 30", 36" or 40". Therefore the available machinery restricts the choice of bed width to a multiple of these standard row crop spacings.

Bed widths

The main options for bed widths, each with a single row of plants are:

30" = 0.76m

36" = 0.92m

40" = 1.02m

Options for wider beds (with multiple rows of plants) are:

2 x 30" rows =	60" beds	=	approximately 1.5m
4 x 30" rows =	120" beds	=	approximately 3m
2x x36" rows =	72" beds	=	approximately 1.8m
2 x 40" rows =	80" beds	=	approximately 2m

Wheel spacing of harvesters and tractors

The wheel spacing of harvesters and tractors is the major consideration in selecting a bed width.

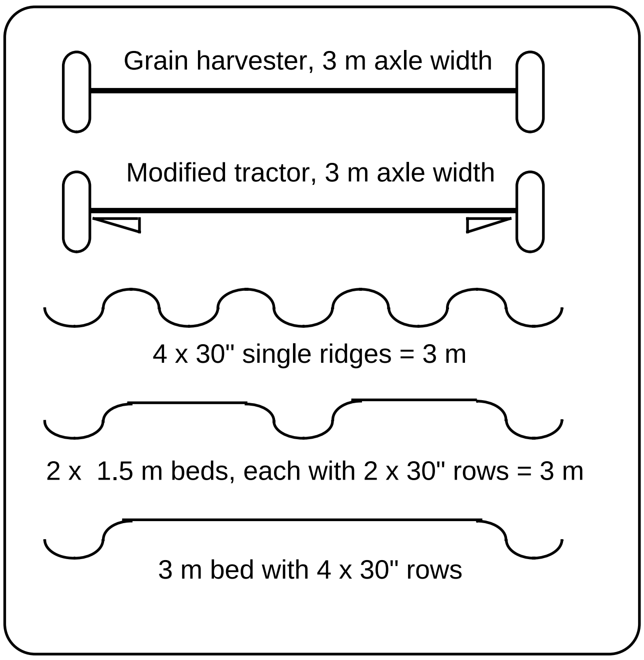
grain harvesters suit	1.5m or 3m beds
cotton pickers suit	2m beds
tractors suit	1.8m or 2m beds

Modifying tractors

Standard tractors have axle widths that fit 1.8 m or 2 m bed systems without modification. To fit 1.5 m or 3 m beds, extend the axles to 3m (**Figure D-17**).

Outrigger assemblies are essential to carry the stresses and avoid rear axle failures.

Figure D-17 Modified tractor to match 3m grain harvester axles

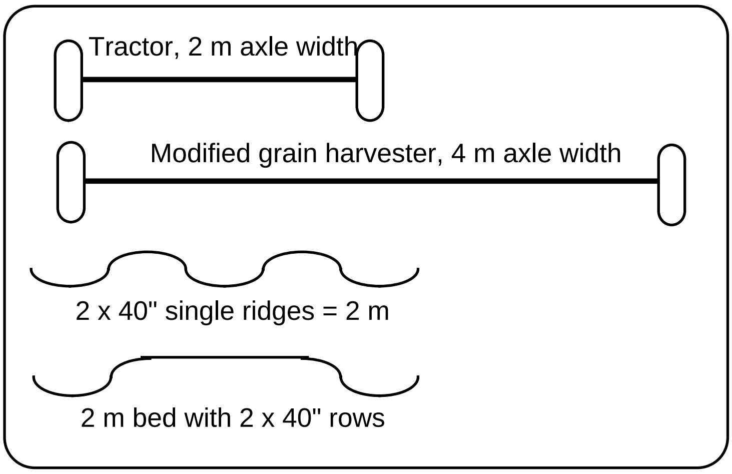


This 3 m system needs a modified tractor. Use outriggers to extend the tractor axles to 3 m.

Modifying grain harvesters

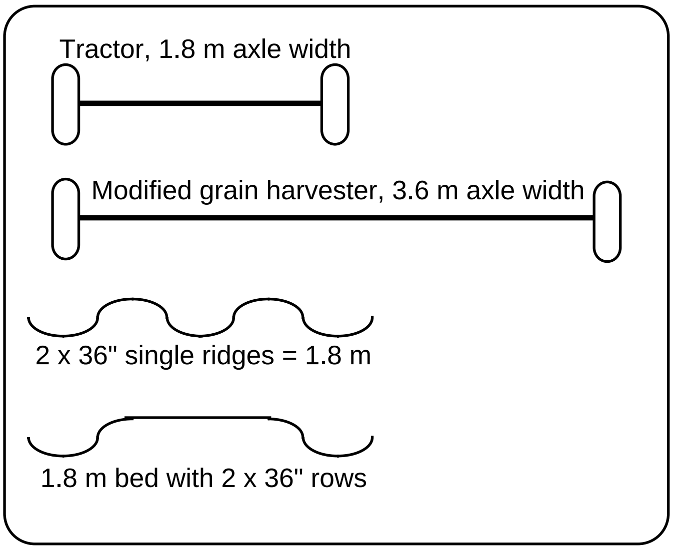
Manufacturers design the axle widths and tyre sizes of grain harvesters for broadacre cropping, not bed farming. The design aims to improve the storage capacity and operating width of the machine, and to improve trafficability on wet soil. The bed farmer who wants to minimise wheel compaction in 1.8 m or 2 m beds, has to modify both the wheelbase and tyre size (**Figures D-18** and **D-19**).

Figure D-18 Modified grain harvester to match 2 m tractor axles



This 2 m system needs a modified grain harvester. Extend the axles to 4 m so that the harvester straddles four rows.

Figure D-19 Modified grain harvester to match 1.8 m tractor axles



This 1.8 m system needs a modified grain harvester. Extend the axles to 3.6 m so that the harvester straddles four rows.

Extensions to the wheelbase ('stretching') of grain harvesters requires extensive modification to both the front and rear axles. Manufacturers provide some capability for adjusting the wheelbase:

- swapping wheels from one side to the other (dish in to dish out);
- wheel or hub spacers; and
- axle spacers or extensions.

These adjustments are generally not sufficient to extend the wheelbase out to the required 3.6 m or 4 m. Longer axles and stabiliser bars are needed.

Narrow tyres reduce compaction of the sides of beds. However, because most of the weight of a grain harvester is borne by the front wheels, changing to a narrower tyre is not simple. Narrow tyres on the front of a harvester may not support the weight of the machine. Modifications need to move the weight towards the back of the harvester.

Other modifications Support equipment (such as field bins used for unloading) may also need modified wheelbases. Also, the length of the unloading auger on the harvester needs to reach field bins on adjacent traffic lanes.

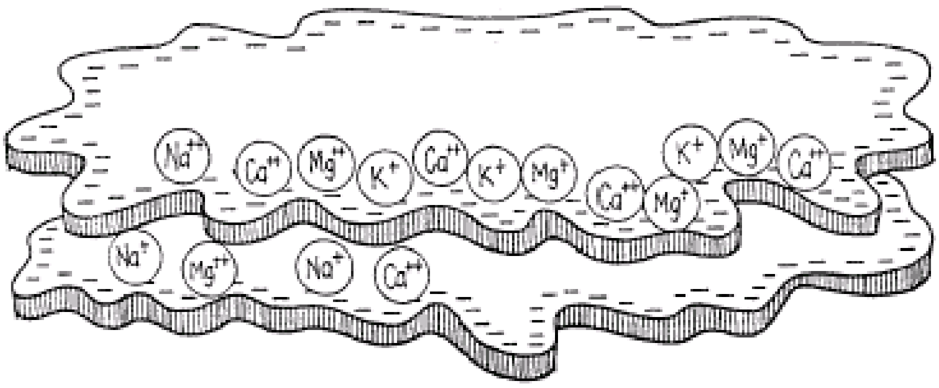
Bed farming:

Advantages:	Cautions:
• Reduced energy inputs. • Less compaction in the plant bed. • Better traction in the traffic lanes. • More timely operations. • Better plant growth in the plant beds.	• Machinery modification needed. • Machines wander, and traffic lanes become wider and encroach on beds; eventually whole paddock needs restoration. • Tillage at wrong soil water content will still damage soil structure. • Better plant growth in the plant beds may not make up for loss of yield in the traffic lanes.

Acknowledgement: Based on 'Permanent Wide Beds - a Controlled Traffic System for Irrigated Vertisols'. Technical Bulletin by Mike Lucy, (1993) Queensland Department of Primary Industries, Pittsworth.

Minimising compaction? Horses were not commonly used for farm work until the twelfth century, because the chest harness in use since Roman times was inefficient. The invention of the shoulder harness, the "horse collar", enabled them to pull a much greater weight and to therefore pull farm implements.

Section 8: Sodicity



> Cation Exchange Capacity is a measure of the ability of soil to attract and
> hold cations by electrical attraction.

Sodicity is a measure of the *exchangeable sodium in a soil.* Exchangeable sodium, like other exchangeable cations, is held loosely on negatively-charged clay particles. A soil is defined as sodic when sodium makes up more than 5% of the total exchangeable cations, and the salinity is low. A soil chemical test reports sodicity as exchangeable sodium percentage (ESP); an ESP of more than 5 suggests a sodic soil.

High sodicity causes clay to swell excessively when wet. The particles move so far apart that they separate (disperse). This weakens the soil, causing structural collapse. However, a high concentration of salts (salinity) in the soil water prevents clay dispersion. The clay remains flocculated (clumped together). So, a soil that is both sodic and saline can have a better structure than a soil that is only sodic.

Go to Chapter E2 for more information on the effects of sodicity and salinity on clay.

Causes of Sodicity

Many subsoils in Australia are naturally sodic. The sodium has weathered from a parent rock such as basalt, granite or marine sediments.

Bore water can be sodic. 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 **may** contain sodium, the concentration depending on the animals' diet. Such manure spread over paddocks will contribute to soil sodicity.

Problems Caused by Sodicity

Sodic clay soil at the surface tends to disperse when wet. As it dries, the dispersed clay packs down tightly, leaving very little pore space for water or air entry. A crust forms on the soil surface. The soil will remain crusted if it has no swelling potential and little organic matter. This causes problems with seedling emergence, and water and air penetration.

Dispersed soil has very little strength when wet and rain easily erodes it. It is very prone to gullying or tunnel erosion. Sodic clay subsoil is a major problem if the topsoil is removed by erosion or earthworks.

The extreme swelling of sodic clays can close off subsoil pores and reduce drainage. With a sodic subsoil, a perched watertable may develop at the bottom of the topsoil, causing waterlogging. A lack of oxygen in the root zone will affect the crop.

Management

The first step managing a sodic soil is to increase the concentration of salts (preferably calcium salts) in the soil solution. A more concentrated soil solution reduces clay swelling and prevents clay dispersion.

Longer term aims are to replace exchangeable sodium with calcium and use organic matter as a soil binder.

Application of calcium in the form of gypsum (calcium sulphate) achieves the first step, and starts the process of replacing sodium with calcium. Lime (calcium carbonate) also supplies calcium and is preferable for strongly acid soils (pH ($CaCl_2$) less than 5). Lime is not recommended for alkaline soils.[1]. 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.

Adding calcium is a short to medium term solution, and the time it lasts depends upon how soon it is leached. Leaching lowers the salt concentration of the soil water, and usually sufficient sodium remains on the clay to cause dispersion once more. Maintain the salt concentration of the soil solution by further applications of calcium.

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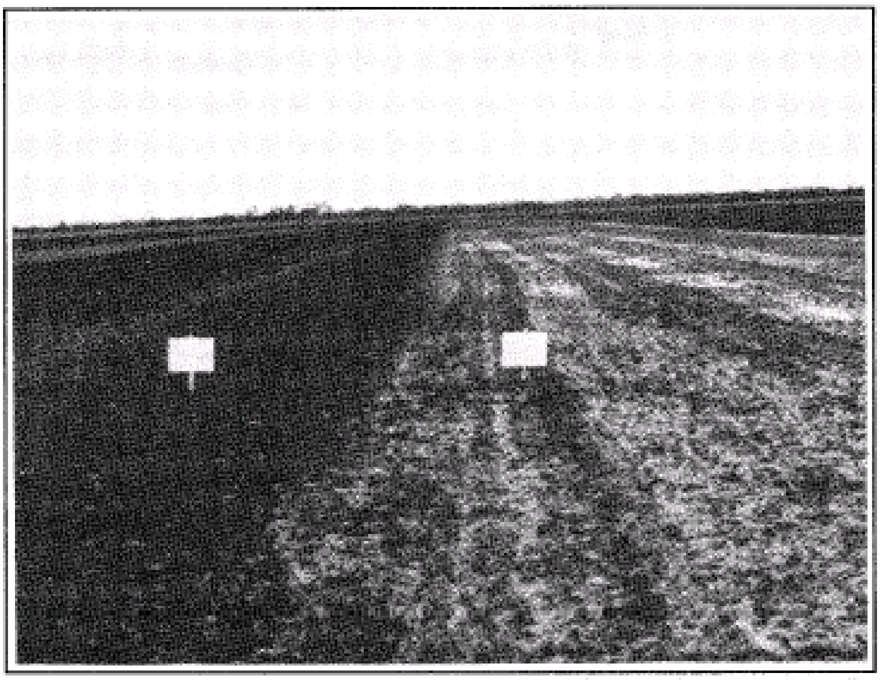
[1]Lime is virtually insoluble in alkaline liquids. However, lime does dissolve slowly in alkaline soils. The following account explains how.

When we measure the pH of a soil, we are really measuring the average pH of a mixture of soil and water (or properly, a mixture of soil and calcium chloride solution). Moreover, that soil sample comes from a larger sample which is thoroughly mixed, air dried and ground. The pH in the field may vary from the measured value, both from point to point and over time. For example, buried organic matter releases organic acids as it decomposes. Respiration by roots and soil organisms produces carbon dioxide, a weak acid when dissolved in water. Thus there may be minute volumes of soil which, from time to time, are sufficiently acid to dissolve some lime. Of course, the dissolved lime can be re-precipitated when conditions become alkaline, but it may move a short distance before this happens. Thus the lime is slowly incorporated with the soil. While dissolved, the lime supplies calcium ions to displace other ions on the exchange sites.

Figure D-20 Rain one month after treatment on the left, application of gypsum results in good infiltration. The lime treated strip on the right shows ponding



Photograph: Tony Bernardi.

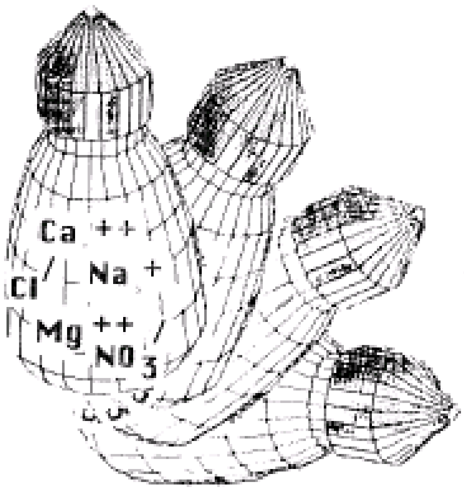
Caution 1: Micronutrients (eg zinc) may become unavailable if lime is added to a soil with pH ($CaCl_2$) greater than about 6.5.

Caution 2: Gypsum application can, by improving infiltration and drainage, increase leaching of nitrate and induce nitrogen deficiency. Monitor soil nitrogen status, and be prepared to use a little more nitrogen fertiliser or make more use of legumes

A pasture phase is a good way to add organic matter and improve soil structural stability. The root systems of grasses bind soil particles and help overcome the instability created by sodicity.

Go to Chapter E4 for more information on organic matter.

Section 9: Salinity



Salinity refers to the *concentration of salts in the soil solution*. These are positive and negative ions dissolved in the pore water (for example calcium, magnesium, carbonate, chloride). Any ion present in the soil water will add to soil salinity. A low level of salinity is desirable: a soil with **no** salinity would not contain any plant-available (soluble) nutrients, and also it may disperse. However, when we talk about salinity, we usually mean **excessive** salinity. (see **Chapter B7** for a description of the signs of salinity).

Causes of salinity

- A rising watertable may cause salinity if the water brings up concentrated salts from deep down.
- A "saline scald" is not the result of a rising watertable. It occurs when erosion exposes a naturally saline subsoil.

Salts occur naturally in many soils in Australia. Sea spray enters the atmosphere and can be carried long distances in clouds. Minerals in rocks contain elements that can form salts; 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 covered that part of the land.

Normally, these salts are deep in the soil. Before European settlement, natural vegetation used up most of the rainfall and little was left to drain below the root zone. Since then, certain farming practices - large-scale clearing of trees and replacement by shallow-rooted plants, overgrazing and long bare fallows - have allowed more of the rain to pass through the root zone and reach the groundwater. If that happens, the watertable rises and brings the salts up with it. When the watertable is within 1-2 metres of the soil surface, the water and salts rise to the surface by capillary action, causing the root zone to become saline.

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.

At high concentration, chloride is toxic to plants, resulting in crop loss and lower yield. It also leaves fewer options for crop choice. Salinity is also linked with:

- high levels of salt in livestock drinking water;
- greater potential for soil waterlogging;
- increased erosion due to loss of ground cover; and
- increased turbidity and siltation due to accelerated erosion of saline soils. (Conversely: clear water in streams and dams can be due to a high salt content settling the sediment.)

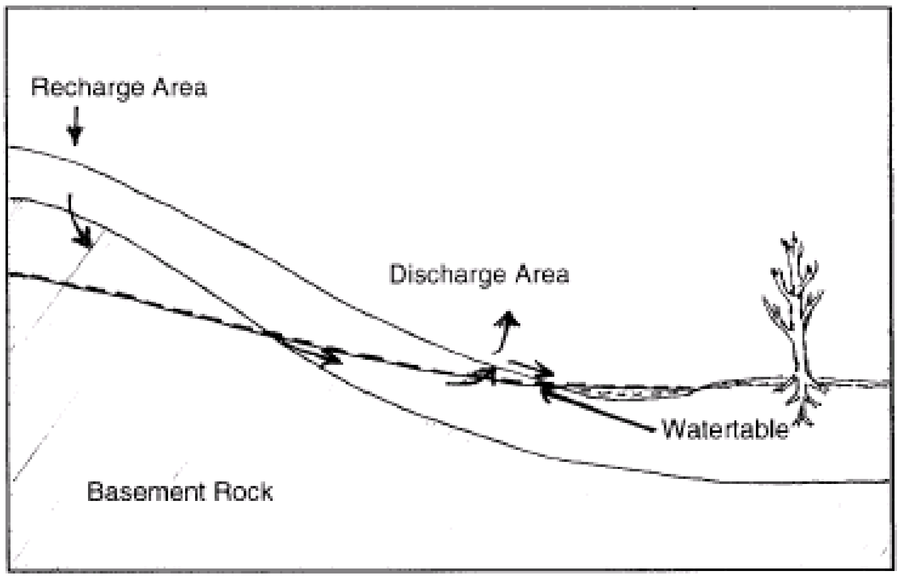
Management of salinity caused by a rising watertable

Effective treatment of salinity should result in the lowering of the watertable. This may be done by planting deep-rooted perennial pastures and trees in key locations.

This includes:

- planting trees or perennial pasture in the r*echarge area* (**Figure D-21**) of the catchment to reduce the water intake, and
- planting more salt-tolerant species in the *discharge areas* to lower the watertable.

Figure D-21 Recharge and discharge areas in a groundwater system

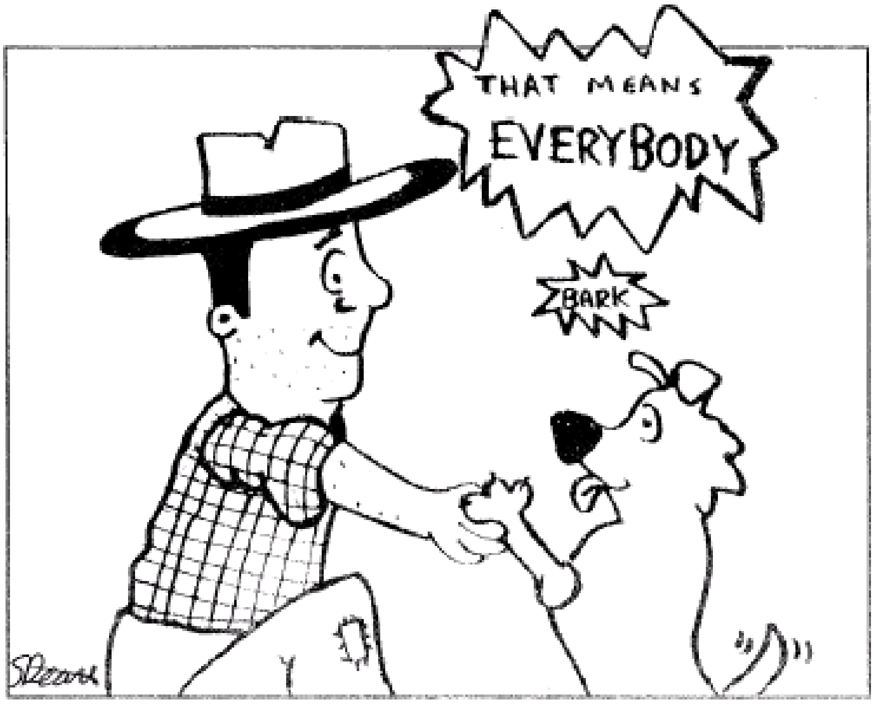


Reversing the causes of salinity

Native trees are effective water users. Capable of using more than the annual rainfall, in the right situation they can use groundwater (lowering the watertable). Deep-rip 4-6 months before planting trees in spring. After initial watering to get the trees established, don't water again.

Consider converting part of your farm to agroforestry. Alley cropping is a farming system in which widely spaced rows of trees are planted within crops & pastures. Alternatively, plant trees along fence lines, waterways, and roads where they will interfere least with your farming operations. Woodlots provide timber for fencing and firewood.

Dryland salinity is a catchment problem that does not stop at property boundaries. The farming practices that you are following may be adding to the problem in your catchment (offsite), whilst you may not be directly affected (onsite), by salinity. Doing nothing is a form of resource degradation and you may be handing on the costs to another generation.



Salinity control involves all landholders in the catchment. Join your local Landcare group, or form a new one. Co-operate with neighbours to tackle the problem in a catchment-wide 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 Soil Conservationist or Agronomist for help.

Preventing the spread of saline areas

Develop a less "leaky" farming system by preventing water from moving below the root zone and adding to groundwater. Avoid long fallows that continue past the time when the profile is 75% full. Fallow only long enough to refill the profile for the next crop. Use opportunity cropping strategies: once the soil profile has sufficient moisture, plant a crop suited to the time of year.

The roots of *annual pastures*, generally, do not grow beyond a depth of 60 cm. Once rainwater infiltrates beyond the depth of the roots there is nothing to stop it entering the watertable.

Perennial pastures can use twice as much soil water as annual pastures. They reduce fallow times which add recharge to the groundwater. Practices such as fertiliser application, which increase leaf area, will increase water use.

Choose a fertiliser with a low salt index (salinising effect). Sodium nitrate and ammonium nitrate have a higher salt index than urea ammonium phosphate. Gypsum, superphosphate and lime have low salt indexes.

Avoid overgrazing as this reduces leaf area. Allow lucerne at least 90% flowering annually, whilst rotating the grazing - one week on and 6 weeks off. Phalaris should not be grazed beyond a 70% ground cover.

Do not neglect drainage Repair leaking dams and don't allow water to pond for more than 24 hours.

If groundwater quality is suitable (Table D-2), use it for stock or farm use.

Table D-2 Water quality limits and uses

	electrical conductivity, dS/m
Desirable limit for humans	0.83
Absolute limit for humans	2.5
Limit for poultry	5.8
Limit for pigs.	6.6
Limit for dairy cattle	10.0
Limit for horses	11.6
Limit for beef cattle	16.6
Limit for adult sheep on dry feed.	23.0

Production on salt affected areas

If possible, establish salt tolerant species before the area becomes bare. This will reduce the risk of soil erosion, minimise evaporation and lower the watertable. High levels of salt on the surface of bare patches means a reduced range of plants will grow on that site.

The costs of establishing salt tolerant species varies. As a guide, the planting of vegetation such as saltbush, on a severe salinity site, will cost approximately five times the establishment costs of pasture production, on a slightly saline site.

It may take up to 10 years for saltland vegetation to completely establish. Fence off the discharge area. Use an electric fence which can be moved should the discharge area spread further before stabilising.

Consult your District Soil Conservationist for advice on open or relief drainage which will redirect run-on water.

In preparation for revegetation, graze the area heavily (preferably with sheep) in early spring to reduce the bulk of surviving pastures. Spray weeds and unwanted salt tolerant species such as sea barley grass in late spring/early summer.

On *flatter sites*, use a conventional combine without harrows to dilute surface salts (to mix the very concentrated surface salts with less salty underlying soil). Drop the seed on top to avoid burial. On *steep sites,* minimise erosion by direct-drill seeding. Sow as shallow as possible so that seed does not lie in water. Mounding provides a salt reduced, drier environment for plants and is extremely important for saltbush if the site is waterlogged. Sow salt tolerant pastures between the mounds.

Fertilise with nitrogen and phosphate. To reduce surface crusting, broadcast (but don't incorporate) gypsum at the rate of 500 kg/ha.

Keep stock off revegetated areas for at least a year or two. Once salt tolerant species have been established, graze for short periods.

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 grazing salt tolerant species such as saltbush or bluebush.

Salt-tolerant trees include river red gum (*Eucalyptus camaldulensis*), white ironbark (*E. leucoxylon*), several wattles (*Acacia*), paper-barks and myrtles (*Melaleuca*). Some salt-tolerant plants produce oils in quantities worth harvesting. Get local advice on suitability of salt-tolerant trees for your area.

Managing saline scalds

Saline scalds form when erosion removes topsoil, exposing a naturally saline subsoil. The bare soil continues to erode faster than rain can leach salt from the surface; once formed, a saline scald perpetuates itself.

Repairing a saline scald does not involve controlling a watertable; it involves establishing vegetation to control further erosion, and leaching salt away from the surface.

Establish salt-tolerant plants as described above. Once the soil has some plant cover, run-off and erosion are reduced. Water entering the soil can leach salt downwards.

The most common salt in saline areas is sodium chloride. A saline soil, then, has excessive exchangeable sodium. While saline, it does not disperse. However, as salt leaches and the soil solution becomes less concentrated, the soil is likely to disperse. Infiltration decreases, and the repair process slows. Apply gypsum in small, regular amounts to maintain slight (tolerable) salinity and to replace sodium with calcium.

On severe scalds where it is too difficult to establish plants, an alternative strategy is to begin the leaching first. Earthworks can detain water and allow it to enter the soil. The earthworks may be small scale, such as low banks to form small ponds. Stubble brought in from outside the scald will help reduce run-off and erosion and increase infiltration. When the soil surface has leached sufficiently, establish plants to continue the repair.

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