



## **SOILpak – northern wheat belt - Readers' Note**

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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>

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# C1. Examining the soil profile.

Purpose of this chapter

To explain how you can assess a soil's structure.

Chapter overview

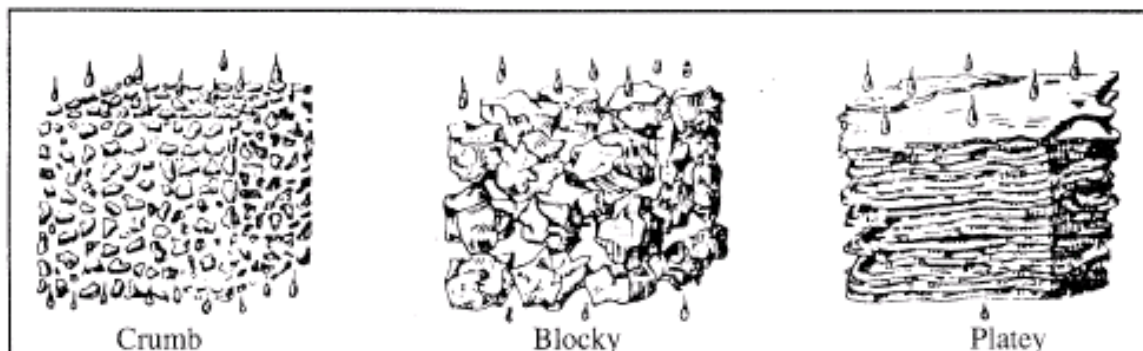
This chapter deals with the soil surface, topsoil and subsoil. The main contents are:

	Page
What to examine first	C1-3
Section 1: Farm and paddock	C1-4
Section 2: Surface soil	C1-6
Section 3: Soil structural form	C1-17
Section 5: Conclusions	C1-33
Section 6: Soil management options	C1-36

Associated chapters

You may need to refer to the following chapters:

- C2: Chemical tests and soil structure
- C3: Alternatives to the spade
- C4: Measuring soil water
- D-s2: Maintaining and improving soil structure
- E1: Soils of the northern wheatbelt



# C1

## Examining the soil profile.

### Why examine soil?

Examining soil and assessing its condition is a management aid. Knowing the condition of a soil helps you to make a better decision on the use of that soil, and what it needs. You can decide land use, crop rotation, what tillage (if any) is necessary and whether the soil will benefit from such tillage.

The main source of information about a soil's condition is field observation, backed up by laboratory testing. This chapter deals with the field observations. Most laboratory testing is for chemical properties, and there is information about them in **Chapter C2**.

Soil management decisions fall into one of two categories:

- long term strategies: for example, the length of cropping and pasture phases;
- short term tactical decisions: for example, whether the soil is at the right moisture content for a planned operation.

### Soil features

This chapter deals mainly with soil structure. Soil structure is the arrangement of soil particles and the pore spaces between them, and the stability of that arrangement. Soil structure influences plant growth by controlling the movement of water and air, and root penetration.

In addition to soil structure, this chapter covers other features - of the soil or of the paddock - that affect soil management decisions. These other features are paddock history, ground cover, soil colour and soil texture (guides to soil type), soil moisture, bleached or cemented layers, and natural deposits of lime or gypsum.

This chapter deals with these aspects of soil structure:

- structural **form** (the shape and size of aggregates, the nature of their faces, their porosity and their friability). Roots are good indicators of structural form;
- structural **stability** (the ability of a soil to maintain its structural form). Soils that resist slaking and dispersion, and aggregates that resist remoulding (reshaping) have high structural stability.

There is a third aspect of soil structure: structural **resiliency** (the ability of a soil to recover its structural form after disturbance). This chapter does not deal with the assessment of structural resiliency. However, structural resiliency, deduced from soil type, affects your choice of soil management options after you have assessed soil condition.

A silty or fine-sandy topsoil, low in organic matter, has both a low structural stability and a low structural resiliency. It is easily degraded (low structural stability), even by raindrops, to form a crust or hard-set layer. Once formed, a crust or hard-set layer persists (low structural resiliency) until mechanical operations loosen the soil.

Cracking clays also have a low structural stability. Quick wetting can make them slake and possibly form a crust, traffic can compact them, and tillage can remould or smear them if they are wet.. However, cracking clays have a high structural resiliency: drying can crack a crust and form a self-mulched surface; cycles of wetting and drying can restore a compacted or smeared cracking clay to a well-structured condition.

**How important is the outcome?**

The kind of observations you need to make depends on the importance of the outcome. For example, you should give much attention to a decision on whether to deep till. Deep tillage is expensive, it may not be necessary and it can damage soil structure - not improve it - if the soil is wet. Such a decision would deserve a full examination of the soil profile.

**What do you know already?**

A full examination of the soil is not necessary every time you examine a paddock. Some qualities change extremely slowly. For example, soil texture may not alter in a thousand years (unless erosion removes a surface layer). Soil organic matter may not show an appreciable increase or decrease until several years after a change in soil management.

Tip: Start with the easy observations. You don't always have to examine everything.

However, qualities such as soil structure can change rapidly. For example, one pass of an implement through wet soil may create a plough pan immediately. Root growth may open up and improve a compacted soil significantly in as little as a few months.


Because soil structure can alter so rapidly in response to management, assess soil structure before making a management decision if you think soil structure may have changed.

The pocket at the back of this manual contains blank soil description sheets. The sheet is a place to record what you find when you examine soil. It also acts as a prompt for what to examine, and it leads you towards an appropriate management option.

Each section of this chapter contains an example of how you might enter notes in the relevant section of the soil description sheet.

**Figure C1-1** gives a guide to which soil features to examine for different reasons.

Figure C1-1 A guide to soil observations

What to examine: 		Paddock history	Surface cover	Colour	Texture	Staking	Dispersion	Surface structure	Profile structure	Moisture	Collect soil for lab tests
When:	Possible decision:	Page:	7, 28	7, 28	7, 28	9	9	14	17	C4-1	B10-6
First assessment	Potential problems?	4	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pasture	Suitable for a cropping phase?	✓		?	?	✓			✓		?
Before sowing	Moisture for seed? Potential crusting?							✓	✓	✓	
Before deep till	Is deep tillage needed?				?		✓		✓	✓	
After deep till	Has tillage worked? Dispersive subsoil brought up?						✓		✓	✓	
After wet harvest	Serious compaction?							✓	✓	✓	
After stock	Trampling damage?		✓					✓	?		
Crop failure	Is it a soil problem?	✓	?	?	?	✓	✓	✓	✓	✓	✓
Crusting surface	Can the crusting be managed?		✓			✓	✓	✓			✓
Long crop history	Time for pasture to restore soil condition?	✓				✓	✓	✓	✓		✓


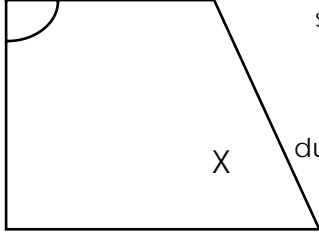
<input checked="" type="checkbox"/>	?	<input type="checkbox"/>
Definitely check	This information will help to finalise a decision	Not useful now

## Section 1: farm and paddock information

Before you examine the soil profile, spend a little time describing the paddock. Such background information will help you to place in context the features that you find on and beneath the soil surface.

**Figure C1-2** shows an example of how you would fill in details for section 1 of the sheet.

**Figure C1-2** Example of section 1 of the soil description sheet - farm and paddock information

1. farm & paddock information	
farmer: John Smith property: The Brigalows paddock: East 4 reason for inspection: Poor growth and low yield of last wheat crop inspected by: PK date: 10 Jan 95	paddock history: crops, yields, protein, fertiliser, lime, gypsum, herbicide, disease? 10 years wheat/long fallow anticipated management: 4 years lucerne, then wheat
sketch map of site, extra notes etc. <div style="display: flex; align-items: center;"> <div style="margin-right: 20px;"> <p>N</p>  </div> <div style="margin-right: 20px;"> <p>sand</p>  </div> <div> <p>soil reasonably uniform, except for small patch of sand in NW corner</p> <p>dug hole 200 paces in from SE corner</p> </div> </div>	

**Farmer, property, paddock** Record the location of the inspection. If this is your own property, the name of the farmer may seem unnecessary, but an agronomist using the sheet may visit many farms and will need a record of the location.

**Reason for inspection** Clarify why you are examining a soil. The reason for inspection often suggests a cause of the current paddock condition, and that in turn suggests which features to examine first. After examining those features, you can reassess your first impression.

The example in **Figure C1-2** gives the reason for inspection as 'poor growth and low yield of last wheat crop'.

### **Paddock history**

Accurate and detailed records are a great help in determining the cause of poor crop growth. From your farm diary (if possible, for the last five years) note:

crops grown;  
their yields;  
if applicable, their protein content;  
plant diseases;  
monthly rainfall for the same period;  
lime or gypsum applications; and  
fertiliser applications.

The example in **Figure C1-2** shows paddock history as a long period of continuous wheat on long fallow. There is no mention of fertiliser.

Sometimes the first sign of a soil structural problem is poor crop growth. Seedling emergence may be sparse; seedlings may be slower to emerge and develop; plants may be shorter than plants in other paddocks or there may be variation in plant height within one paddock. A crop may appear to run out of soil moisture because its roots can not penetrate a hard layer to reach moisture lower down. In wet weather, crops on compacted soil may appear yellow due to waterlogging.

Of course, poor growth may be due to many factors other than a degraded soil structure: cold weather, disease, inadequate soil water, poor nutrition, waterlogging and so on.

Take into account the effect that the previous crop may have had on soil fertility. For example, a previous crop may have depleted the soil nitrogen. Did you apply enough fertiliser? If you didn't use fertiliser, was the bare fallow long enough to mineralise organic nitrogen? How many cereal crops since a legume phase? Was soil moisture adequate? Was the ground compacted during harvest?

### **Anticipated management**

Here you can record what management is anticipated for this paddock. Such information is useful in deciding which features to examine first. The example in **Figure C1-2** shows '4 years lucerne, then wheat'. In this case you might consider whether the soil is low in nitrogen, and would benefit from a legume-based pasture phase (see **Chapter B10** for help in estimating plant nutrient requirements). Pasture also benefits soil structure; it would be useful to examine current soil structure with a view to its need for improvement by a pasture. Current structure also acts as a benchmark to assess the benefits gained by the pasture.

### **Sketch map**

Make a sketch of the site as a record: you may want to go back to the same site and investigate further.

## Section 2: surface soil

The **soil surface** is the soil and surface cover that you see without digging. Surface cover (vegetation and plant residues) can be considered to be part of the soil surface, because surface cover influences soil surface properties. You may need to separate the components of the soil surface by removing surface cover to see the actual soil at the surface.

The **surface soil** includes the soil surface and the upper part of the soil profile that has a structure **in common with the soil surface**. 'Surface soil' and 'surface layer' mean the same. To examine the surface soil, you may need a screwdriver or blunt knife to prise pieces out.

The surface soil may take one of the following forms:

- the tilled layer in a recently cultivated soil that has not had rain to settle it. Such a surface layer may consist of fine aggregates or coarse clods. However, if rain on a cultivated soil creates a crust, then the **crust** is the surface soil because its structure is different from the soil below. The soil below is then referred to as **subsurface** soil.
- the loose material above a firm (not recently tilled) topsoil. Such a layer may consist of loose, fine aggregates on a self-mulching soil, or a layer of separate grains of sand;
- compacted, crusted or hard-set soil, before you come to better-structured soil. If the thickness is up to 1 cm, it is a crust. If the thickness is much greater, possibly the full depth of the topsoil, it may be a hard-setting soil;

These categories can be further divided, as explained later under 'Surface soil structure'.

**Figure C1-3** Section 2 of the soil description sheet - surface soil

<b>2. surface soil</b>	cover % (crop, 30% loose stubble, weeds): stubble	slaking (0-4): 2	dispersion (0-4): 2 on wetting, 4 after remoulding
colour: (black, grey, brown, red)	grey	structure (grains, aggregates, cloddy, crusted, hard-set, cracked): weak, thin (0.5 cm) crust, aggregates below. Known to crack when dry.	
texture (sand, silt, loam, clay):	medium clay		

**Cover %**

*Significance of surface cover:* surface cover reduces the impact of raindrops thereby protecting surface structure. Cover also slows down water running over the surface, thereby increasing the intake of rain to the soil and reducing erosion. Large amounts of surface cover at sowing time can pose a problem to some planting implements.



Go to Part D-s1, for pictures of stubble cover.

Note whether the surface is bare, or covered by a crop, weeds or stubble. Note whether stubble is standing or loose. The example in **Figure C1-3** shows '30% loose stubble'.

**Colour**

*Significance of soil colour:* Soil colour is a valuable guide to soil type.

Surface soil colour may vary slightly from the true colour of the topsoil (as assessed by looking at a moist aggregate from below the surface). Dead plant material, moss, dispersed sand or evaporation deposits may mask, or apparently change, the colour of the surface. Nevertheless, surface soil colour is quick and easy to assess, even from a distance! Follow with a closer inspection to assess soil colour beneath the surface. Together with soil texture, soil colour is a good indicator of soil type.

**Texture**

*Significance of soil texture:* Soil texture is a measure of the behaviour of a small handful of soil when moistened and kneaded into a ball and then pressed out between thumb and forefinger. It depends mainly upon the proportions of gravel, coarse sand, fine sand, silt and clay in the soil.

**Surface** soil texture affects the surface soil structure: clay soils (non-sodic) develop a porous, crumbly surface; some fine sands and silts form surface crusts or set hard through the whole topsoil depth. Thus surface soil texture affects both the intake of water to the soil, and seedling emergence.

*When to assess surface soil texture:* Texture is a basic property of a soil. It changes extremely slowly (over thousands of years). However, operations such as deep tillage may bring up subsoil, and earthworks may expose subsoil, changing surface soil texture.

Texture varies from place to place. Many paddocks are not uniform, and it is wise to check texture in several places within a paddock. Texture variation may help to explain differences in plant growth between parts of a paddock or between different paddocks. Compare a sample of soil from one sampling place with soil from another place, to help you to gauge relative differences in texture. Gauging relative differences in texture is easier if two soil samples are assessed at the same time - one in each hand.

**Table C1-1** Guide to determining soil texture

<i>Field texture groups</i>	Coherence	Feel	Other features	Ribbon length	Texture grade
<i>The Sands</i>	Nil	Sandy	Single sand grains stick to fingers	Nil	<b>Sand (S)</b>
	Slight	Sandy	Discolours fingers with an organic stain	5	<b>Loamy sand (LS)</b>
	Slight	Sticky	Sand grains stick to fingers and discolour with a clay stain	5-15	<b>Clayey sand (CS)</b>
<i>The Sandy Loams</i>	Just coherent	Sandy	Medium sand readily visible	15-25	<b>Sandy loam (SL)</b>
	Just coherent	Sandy	Fine sand can be felt and heard	15-25	<b>Fine sandy loam</b>
<i>The Loams</i>	Coherent	Spongy and greasy	No obvious sandiness or silkiness	25	<b>Loam (L)</b>
	Coherent	Smooth	Silky; very smooth when manipulated	25	<b>Silt loam (SiL)</b>
<i>The Clay Loams</i>	Strong	Sandy	Medium sand in a fine matrix	25-40	<b>Sandy clay loam (SCL)</b>
	Coherent	Smooth and sandy	Fine sand can be felt and heard	40-50	<b>Fine sandy clay loam (FSCL)</b>
	Strong	Smooth	No obvious sand grains	40-50	<b>Clay loam (CL)</b>
	Coherent	Smooth	Silky	40-50	<b>Silty clay loam (SiCL)</b>
<i>The Light Clays</i>	Coherent	Plastic	Fine to medium sand	50-75	<b>Sandy clay (SC)</b>
	Coherent	Plastic	Smooth and silky	50-75	<b>Silty clay (SiC)</b>
	Coherent	Plastic	Smooth with <b>slight</b> resistance to shearing	50-75	<b>Light clay (LC)</b>
<i>The Medium and Heavy Clays</i>	Coherent	Plastic	Smooth; handles like plasticine; <b>moderate</b> resistance to shearing	75+	<b>Medium clay (MC)</b>
	Coherent	Plastic	Smooth; handles like plasticine; <b>firm</b> resistance to shearing	75+	<b>Heavy clay (HC)</b>

Source: Australian Soil and Land Survey Field Handbook.

*Caution:* Do not rely solely on the length of the ribbon to assess texture.

Some of the terms in **Table C1-1**:

- *Coherence*: the ball holding together.
- *Sandy*: feels gritty, and you can see coarser sand grains. Very fine sand grains (too small to see and feel a bit like silt) make a grating sound as you rub the soil between your fingers.
- *Spongy*: typical of loams; also, a high organic matter content creates a spongy feel.
- *Silky*: the smooth, soapy, slippery feel of silt.
- *Plastic*: the ball can be deformed and it holds its new shape strongly. Typical of clays.
- *Resistance to shearing*: how firm the soil feels as you form a ribbon. (place the ball of soil between your thumb and forefinger and squeeze, sliding your thumb across the soil). The firmness is a good way to distinguish light, medium and heavy clays. A light clay is easy to shear; a medium clay is stiff, a heavy clay is very stiff and it usually takes two hands to form a ribbon.

**Tip:** Surface soil texture can be a good guide to the texture of the whole topsoil, especially if tillage has mixed the soil. An exception would be a soil that has experienced sheet erosion, where coarse sand may remain on the surface after finer material has washed away.

*How to assess texture:* Take a sample of soil sufficient to fit comfortably into the palm of the hand. Moisten the soil with a little water, and knead it until the ball of soil no longer sticks to your fingers. Add more soil or water to attain this condition. Continue kneading and moistening until there is no apparent change in the feel of the soil ball, usually working for one to two minutes. The ball of soil is now ready for you to assess texture, using **Table C1-1**.

### **Slaking and dispersion**

This test is a measure of soil structural stability and shows the behaviour of dry soil when it is wet quickly. **Slaking** is the breakdown of a lump of soil into smaller fragments on wetting and is caused by the swelling of clay and the bursting out of entrapped air. Organic matter reduces slaking by binding mineral particles and by slowing the rate of wetting.

*Significance of slaking:* Most cultivated soils in Australia are prone to slaking. The results can be either good or bad, depending on the size of the fragments produced.

Slaking is involved in the process of self-mulching, which occurs in many cracking clays. Self-mulching produces a loose surface layer of granular aggregates. Sometimes a thin, fragile crust caps the layer, but the crust is not strong enough to affect seedling emergence.

Crusting or hard-setting soils slake into very small fragments which run together and then set hard on drying. The slaking test allows you to identify such problem soils.

**Dispersion** (the separation of soil into single particles) is governed by soil texture, clay type, soil organic matter, soil salinity, and exchangeable cations. See **Chapter E2** for an explanation of how dispersion occurs. The test described here is for dispersion on wetting. A further test (dispersion after remoulding) is described later in this chapter.

*Significance of dispersion on wetting:* A soil that disperses on wetting has a very unstable structure. It can form a surface crust or hard clods on drying. Pores below the surface can become blocked by dispersed soil particles. Dispersion of the **surface** soil slows down the intake of rain to the root zone and therefore increases run-off.

*When to test for dispersion:* this is a very simple test that gives you important information about your soil's behaviour. We suggest you do it routinely, and particularly the first time that you assess a soil.

Do this test if you are considering deep tillage. Tillage that brings up dispersive subsoil will create a dispersive soil surface which may crust. Similarly, be cautious of operations that remove topsoil and expose the subsoil, such as when forming erosion control banks. Carry out the test using a sample from the depth of the proposed tillage or earthworks.

*What to do to assess slaking and dispersion:* This test requires air-dry crumbs of soil. If the soil is moist you can not assess slaking, and dispersion occurs more rapidly. It is better to take a lump of soil and air dry it (overnight) before testing.

*Caution:* Do not dry the soil in an oven or its properties will change.

Take several small (3-5 mm) crumbs of dry surface soil and place them in a dish or saucer of rain water (or distilled water). Make sure the water is deep enough to completely cover the samples. Cover the dish to prevent wind from disturbing the water. Because dispersion takes some time to develop, start the tests and leave them while you examine something else.

**Tip:** You may find it easier to assess slaking if the lumps are a little larger (10-20 mm). However, this means doing two separate tests: the dispersion test requires small (3-5 mm) lumps of soil. As you gain experience, you will find it simpler and quicker to assess both slaking and dispersion on the same small lumps of soil.



**Scoring slaking**

After five minutes, score slaking as follows:

- Score **0** if the lump remains intact.
- Score **1** if the lump collapses around the edges but remains mainly intact.
- Score **2** if the lump collapses into angular pieces.
- Score **3** if the lump collapses into small (less than 2 mm) rounded pieces, forming a cone.
- Score **4** if the lump collapses into single grains (you can see sand grains).

*Decisions to make in relation to slaking:* A score of 0 or 1 means that the soil is stable to wetting. This is typical of pasture soils, rich in organic matter. No action is needed.

A score of 2 is typical of self-mulching soils. They form a loose, granular surface layer with perhaps a thin, fragile crust. Do the dispersion test (see below). If the soil does not disperse, no action is needed.

A score of 3 suggests that the soil may form a surface crust. A pasture phase to increase organic matter will improve the soil.

A score of 4 indicates a soil that may crust or hard-set. It is not a good soil to cultivate and is probably better suited to pasture.

Combine the results of this test with the results of the dispersion test (see below). **Figure C1-4** will help you interpret these results.

**Scoring dispersion on wetting**

Look for **dispersion** of the soil - where the soil breaks down to individual particles. A milky halo of clay particles around the remains of the soil crumb indicates dispersion.

Very unstable soils begin to show dispersion within about 10 minutes. Within 2 hours a very unstable soil may have dispersed completely into a cloudy suspension of single particles, with just sand grains remaining. More stable (less dispersive) soil may show no milky halo or only a slight halo (hard to see) after 2 hours. Extremely stable soils will not show dispersion even by the next day.

Record dispersion on wetting as follows:

- Score **0** for no dispersion within 2 hours.
- Score **1** for slight dispersion within 2 hours.
- Score **2** for slight dispersion within 10 minutes or strong dispersion within 2 hours.
- Score **3** for strong dispersion within 10 minutes or complete dispersion within 2 hours.
- Score **4** for complete dispersion within 10 minutes.



*Caution:* Do not disturb the dish once the crumbs are in the water. Water movement may increase dispersion. Always put the water in the dish first and then add the crumbs.

*Decisions to make in relation to dispersion on wetting:* A score of 0 means that the soil does not disperse on wetting. If, as well, the score for slaking is 2 or less, it is unlikely to form a crust or hard blocks on drying.

A score of 1 or 2 indicates a possible need for gypsum. Investigate further with laboratory testing.

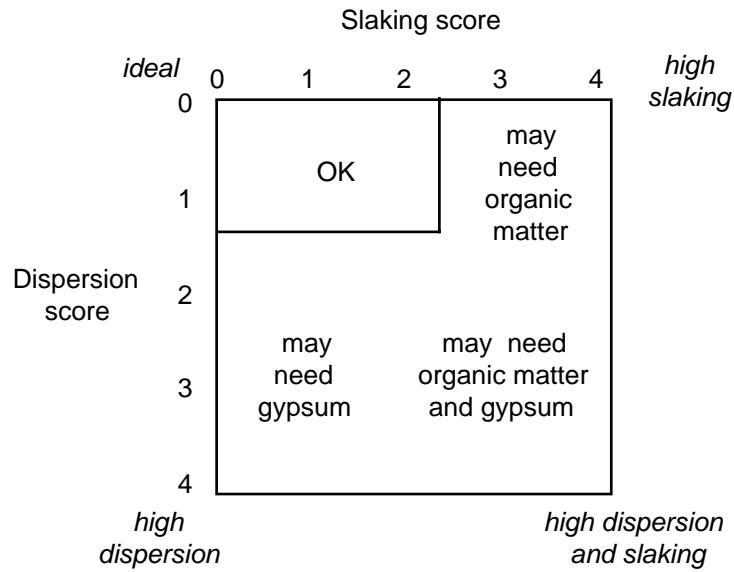
A score of 3 or 4 means that the clay disperses easily when the soil is wetted. As the soil dries, it forms either a surface crust or sets into hard blocks. Gypsum and/or lime will reduce clay dispersion and improve surface soil structure. Investigate further with laboratory testing to determine how much gypsum or lime is required. See **Chapter C2:** Chemical tests and soil structure.

Dispersion on wetting is a good in-field test which points to the likely need for gypsum to prevent surface dispersion. Repeat the test with additional samples of soil from other areas of the paddock to confirm the results; don't assume that one crumb of soil is typical of a whole paddock! It is a good practice to try test strips of gypsum (see **Chapter B8**) before treating the whole paddock. If you do decide to treat a whole paddock, leave an untreated strip to show the benefits.

**Figure C1-4** combines the results of the slaking and dispersion tests:

- A soil with a dispersion score above 1 may benefit from gypsum.
- A soil with a slaking score above 2 may need more organic matter. A pasture phase is advisable.

**Figure C1-4** Management decisions from the results of slaking and dispersion tests



**Dispersion after remoulding**

*Significance of dispersion after remoulding:* Some problem soils do not disperse spontaneously on wetting, but do disperse after remoulding. Tillage when the soil is wetter than the plastic limit causes remoulding. Also, raindrop impact has a similar effect to remoulding. A soil that disperses on remoulding requires (more than ever!) a cover of plants or stubble to protect its surface structure from raindrop damage.



Go to Chapter C4 for the method of determining the plastic limit.

*What to do to test for dispersion after remoulding:* If the soil does not disperse on wetting, repeat the test using soil that you have remoulded. The idea is to duplicate the state of the soil after tillage. Mix some soil with rain water to a plastic consistency and remould (knead) it with a knife for one minute. Alternatively, you may use the texture sample after kneading (See 'Texture' earlier in this section). Place small lumps of the remoulded soil in a dish of rain water.

Record dispersion after remoulding in the same way as dispersion on wetting, on Section 2 of the soil description sheet.

*Decisions to make in relation to dispersion after remoulding:* A score of 0 means that the clay is bound strongly enough to resist dispersion by wet tillage. However, this does **not** mean that the soil structure is immune to damage caused by smearing, remoulding or compaction.

A score of 1 indicates a soil that disperses to some degree if tilled wet and its management deserves caution.

A high score (2, 3 or 4) indicates that the soil is very prone to dispersion if tilled moist. Such a soil may be suited to no-tillage cropping or pasture.

Remoulding damages the structure of any soil by closing off or destroying large pores; if compounded by dispersion, the damage is extreme. The soil sets into hard intractable blocks on drying. Take extra care to avoid tillage when wet.

## Structure

*Significance of surface soil structure:* The structural form of surface soil influences water infiltration, run-off of water and therefore soil erosion, and seedling emergence.

Some soils can appear very well structured, but still have infiltration problems. This is why it is important to do the slaking and dispersion tests, and to note whether the soil shrinks and swells. A soil that disperses is likely to form a surface crust and may also set hard on drying. A soil that slakes badly may do the same. A soil that shrinks and swells is able to repair its structure.

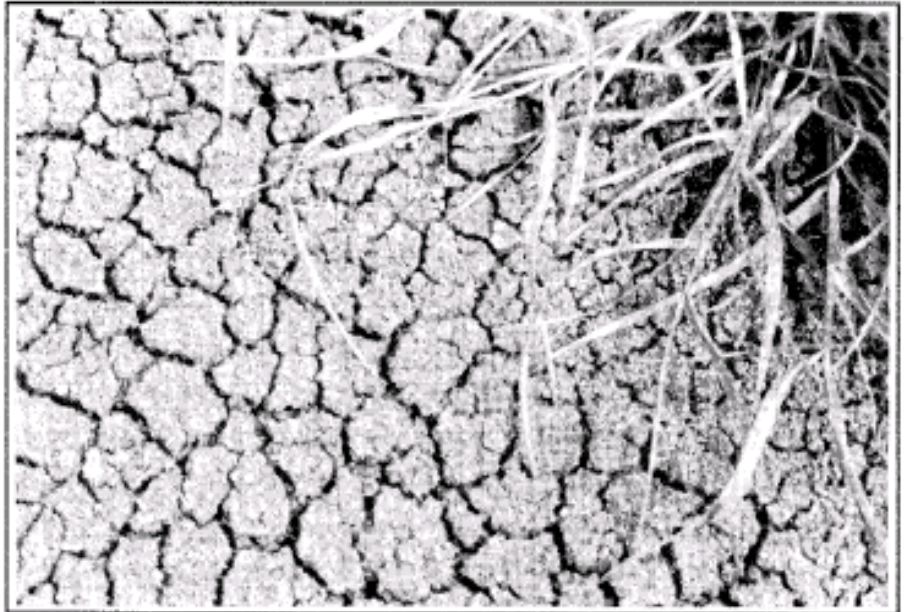
*How to assess surface soil structure:* Dig until you come to soil that has a different structure from the surface. Note the depth of the surface soil. The surface soil may be a 1 cm thick crust above better structured soil, or it may be a recently cultivated layer 10 cm thick above uncultivated soil. Record the following features that apply (the surface soil may have more than one of these features):

- hard-set (hard surface layer more than 1 cm thick. Sometimes the full depth of topsoil is hard-set);
- crusted (crust up to 1 cm thick
- poached (trampled when wet by stock);
- cracked;
- self-mulched;
- cloddy;
- friable;
- dispersive.

Note whether or not any of the above are also cracked. **An important feature in determining soil management strategy is whether or not a soil cracks appreciably on drying.**

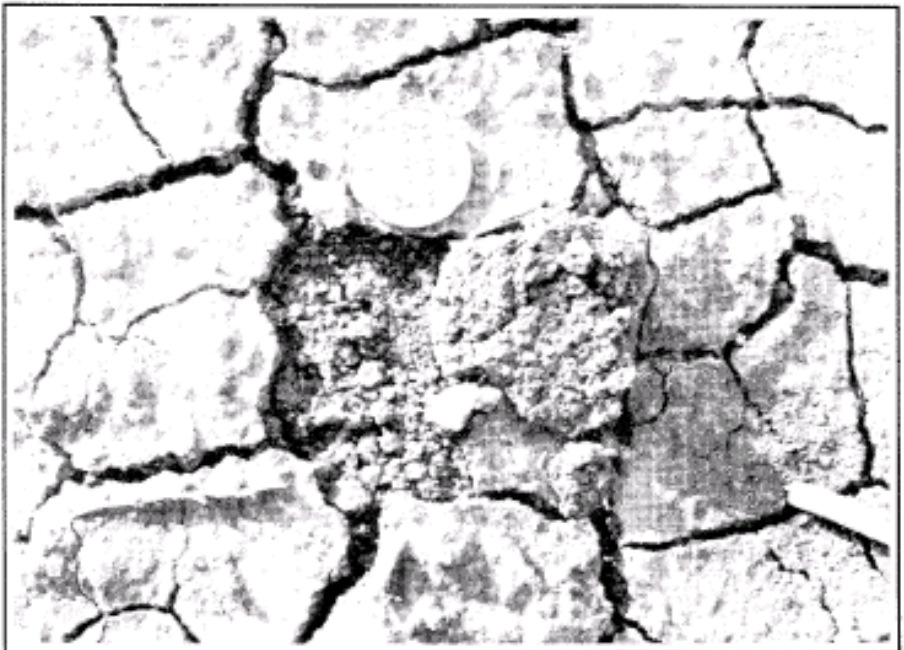
The example (**Figure C1-3**) shows 'weak, thin (0.5 cm) crust, aggregates below. Known to crack when dry'. **Figure C1-5** shows such a soil surface.

**Figure C1-5:** A fragile crust of weakly adhering granules on a self mulching soil.



Photograph: Ian Daniells

**Figure C1-6** A thin, cracked crust with well structured soil below. Seedlings would be able to emerge through this crust. The well-structured soil below the crust would enable seedlings to establish



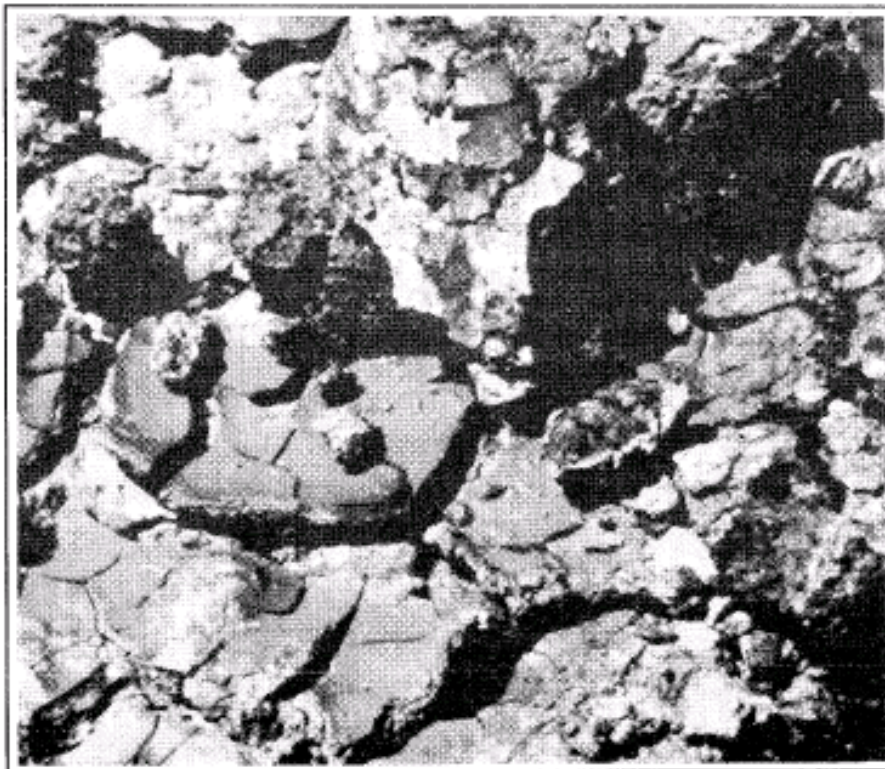
Photograph: Ian Daniells

**Figure C1-7** A crusted soil showing a footprint. Soft soil below the crust has compressed and allowed the crust to break and sink. A hard-set soil (provided it was dry) would not show a footprint



Photograph: Ian Daniells

**Figure C1-8** A crust on a dispersive clay soil



Photograph: Tony Bernardi

## Section 3: subsurface and subsoil: soil structural form

Figure C1-9 Section 3 of the soil description sheet - soil structural form

3. subsurface and subsoil: soil structural form									
depth, (cm)	aggregate size (cm)	ease of fracture	new roots	aggregate shape	fracture faces	peds within aggregates (%)	porosity (0-2)	colour of smallest aggregates	structure score (0-2)
0.5-10	0.5	crumbly		many-faced	shiny	90%	2	dark grey	L1.8
10-15	2	doughy	branch at 10 cm	massive	dull	nil	0	dark grey	F0.2
15+	5	parts easily		lens	shiny	70%	1	dark grey	F1.9

*Significance of soil structural form:* The **form** of soil structure is a description of the arrangement of soil particles into larger units, and of the pore spaces between the units. It affects the movement of water through the soil, the movement of air into and out of the soil, and the ease of penetration by roots. Soil structural form is distinct from other aspects of soil structure: structural stability and structural resiliency. In common usage, 'soil structural form' is often referred to simply as 'soil structure'.

*When to assess soil structure:* It is possible to record differences due to a single cultivation, as well as long term changes. Use your assessment as a systematic way to check past decisions and plan future management. For example, before deciding to deep till, examine the soil to see if there is a real need for that operation. If there is a hardpan, measure its depth so that you can set the depth of the cultivation tines to break the pan. Check again after a short run with the machine to see if it is doing the job.

*Decisions to make in relation to soil structure:* Of a number of paddocks with similar soil texture, those paddocks with good soil structure are more versatile than those with poor soil structure. You have a greater range of options when the soil structure is good.

Poor soil structure indicates the need for different management strategies: perhaps deep tillage, a change from cropping to pasture, or reduced stocking rate on pasture.

*How to assess soil structure:* Examine the soil profile by digging a hole with a spade. Usually there is no need to dig deeper than 50 cm to examine the relevant features of the soil profile. Often a 30 cm depth will tell you all you need to know. Hire a backhoe if you want to dig a deep pit and make observations on the **undisturbed** subsoil profile. A post hole borer will allow you to sample **disturbed** soil from depth to assess colour and texture. (See **Chapter C3**: Alternatives to the spade.) For normal soil examination, a spade (and perhaps a mattock) will do to dig a hole to 30 cm (or 50 cm) deep.

Note the way the soil breaks as you dig it. Horizontal breaks may indicate compacted layers, platiness, crusting or hard-setting. Examine pieces of soil that have not been compacted by the spade.

Section 3 of the soil description sheet (**Figure C1-9**) has columns for recording your assessments of several soil structural features. These assessments are used to form structure scores for individual zones in the soil profile.

The features, from left to right on the soil description sheet, are in priority order. They start with aggregate size, the feature that has the most influence upon the suitability for plant growth, and end with the colour of the smallest aggregates.

After assessing and recording the following features, use **Table C1-2** to decide on structure scores.

### **Depth**

Enter depths on the sheet for zones in the soil profile that you identify as being distinctive. In the example, (**Figure C1-9**) there are three zones: 0-10 cm, 10-15 cm and deeper than 15 cm (15+). Identification of zones often entails assessing some structural features first.

### **Aggregate size**

*Significance of aggregate size:* Small aggregates indicate a good tilth; large aggregates indicate cloddiness.

*How to assess aggregate size:* Break a lump of soil into smaller and smaller pieces, using moderate hand pressure. Take note of the size of the lump just before you begin tearing through the fabric of the soil, leaving a fine grainy surface. This is the point at which you are no longer breaking the soil along natural fracture planes: you are tearing the aggregate apart.

Note the most common size or note size differences where you have aggregates of widely varying size. For example, in a cloddy tilled layer, some clods may be larger than 4 cm with the remainder of the soil made up of clods smaller than 1 cm or dust.

*Moderating factors:* When examining wet soil, it can be difficult to determine the natural fracture plane between aggregates and hence their size. Very dry soil can have high strength because of interlocking

aggregates. Use enough force to expose natural faces; hitting a dry lump with an implement may be the best technique.

### **Ease of fracture**

*Significance of ease of fracture:* Well-structured soil parts along natural faces (the aggregates 'part' from one another). Poorly-structured soil breaks where you apply the force: rather than along natural faces.

*What to look for:* When examining dry soil, distinguishing between 'parting' and 'breaking' requires some experience. Think of dry, poorly-structured soil as 'snapping apart'. Dry, well structured soil crumbles into small aggregates: it is friable.

When examining wet soil, parting of aggregates from one another is easier to detect. Don't squash the soil, but tease it apart. If it fractures easily, it is well-structured. If it will not part but stretches like dough or plasticine, or tears apart, it is tearing through the fabric of the soil; such a piece of soil is poorly-structured.

### **New roots**

*Significance of new roots:* Roots, where present, are the best indicators of soil structure. **New** roots are indicators of current structure. Roots grow where they can - along the easiest path. A prolific growth of new roots throughout the soil indicates good soil structure. Where roots follow cracks and grow around aggregates rather than penetrating them, the soil structure is poor. Good soil structure allows roots to grow straight. Roots may bend or branch above a compacted layer. Unrestricted roots are round in cross section, whereas roots in compacted soil may show flattening or bulging.

*How to assess roots:* Follow some plant roots as you dig through the soil. Note any abrupt change of direction. This is a good way to detect a hardpan. If the soil is too hard for plant roots to grow vertically, they may turn and grow horizontally. Check also that roots growing vertically are not deformed. If there is evidence of healthy root growth well below the plough layer, there is no need to dig further.



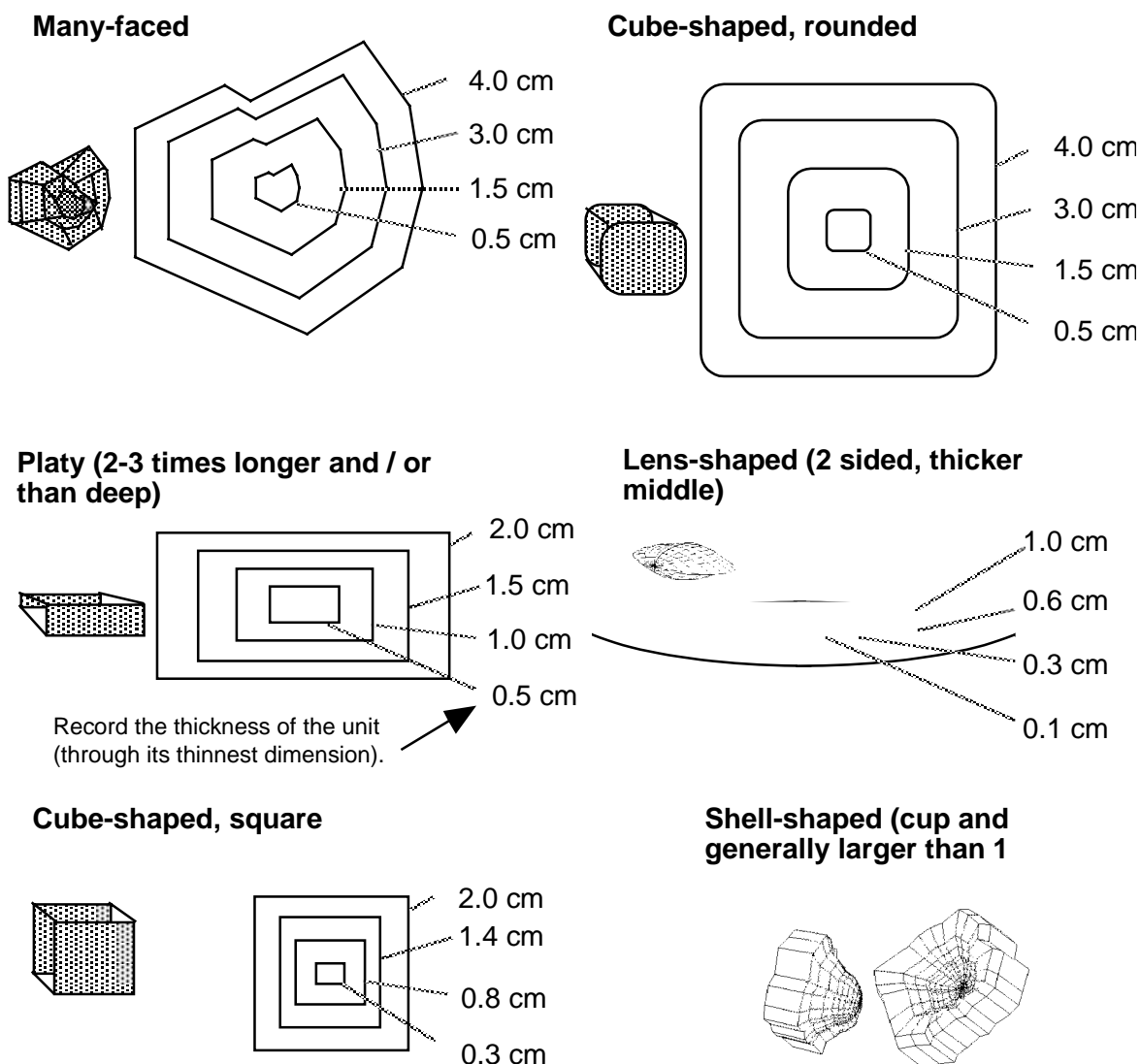
*Caution:* roots bend for reasons other than a restricting soil layer. Herbicide damage, soil diseases or 'root pruning' by tilling close to plants can cause roots to bend or branch. Do not confuse branching due to compacted soil with proliferation of lateral roots in well structured soil.

### **Aggregate shape**

*Significance of aggregate shape:* The shape of aggregates depends upon the forces acting on the soil. Tillage and traffic can change the shape from what is considered 'natural'.

Soils that contain appreciable amounts of clay become plastic when moist or wet; they are particularly vulnerable to reshaping. Therefore in clays and clay loams, aggregate shape is an excellent indicator of soil structural form. In other, less clayey soils such as loams or silty or sandy soils, aggregate shape is less indicative of structural form.

**Figure C1-10** Common aggregate shapes and sizes

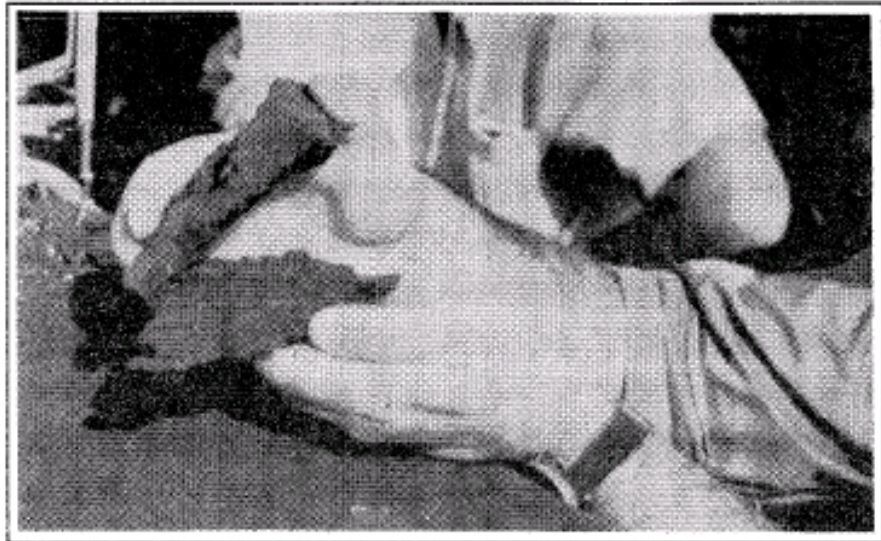


*How to assess aggregate shape:* Look at undisturbed lumps of soil from the side of the hole that you dug, or from middle of a new spadeful. Refer to the diagrams of natural and damaged aggregates in **Figure C1-10**.

*Natural shapes:* many-faced, lens, wedge, cube-with-rounded-corners, (and cube-with-square-corners if small and faces are shiny).

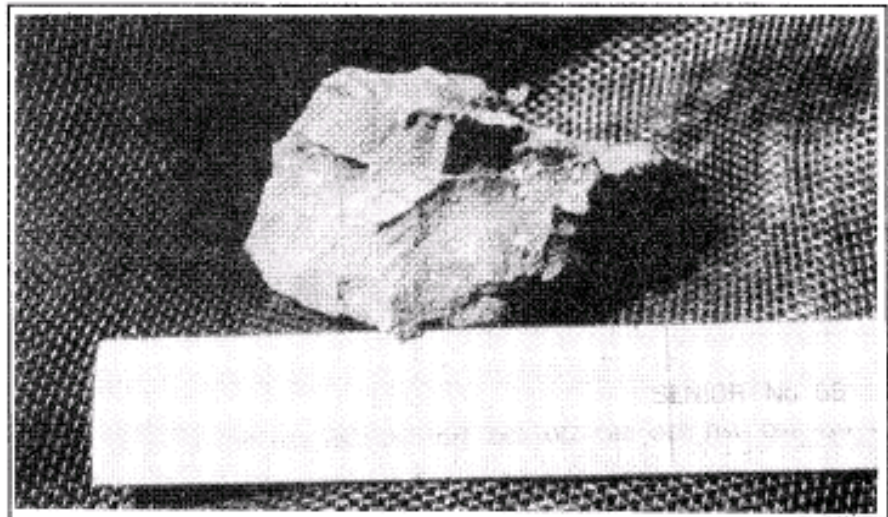
*Signs of damage:* platy, shell-shaped, massive (and cube-with-square-corners if large and faces are dull).

**Many-faced** aggregates are a sign of good structure. They may be loosely joined as a thin, fragile crust (not usually strong enough to inhibit seedling emergence) or bound into very porous, crumbly aggregates.

**Figure C1-11:** Platy aggregates showing horizontal breaks.

Photograph: Ian Daniells.

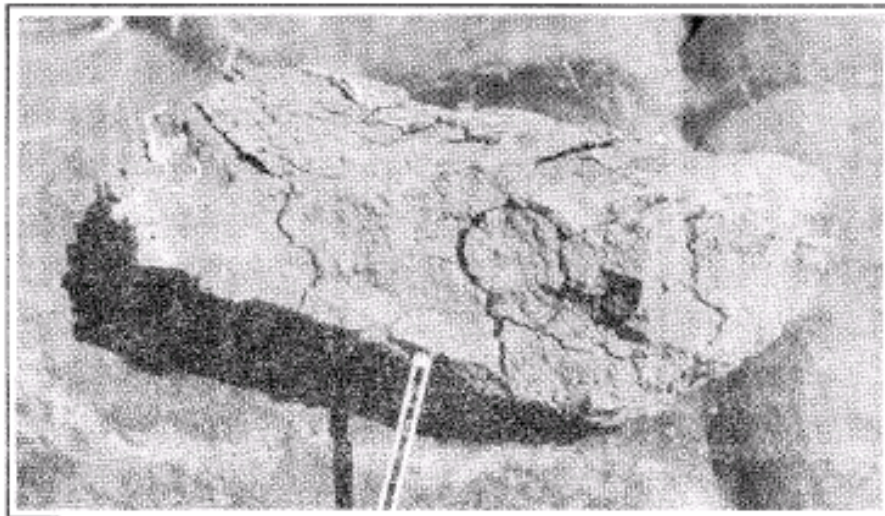
**Platy** aggregates (**Figure C1-11**) show as obvious horizontal layering in the soil profile, or may show in the way a lump of soil parts. Prise a lump from the soil and remember its orientation. Break it into smaller pieces by forcing in different directions. If it parts more easily along horizontal fractures than in other directions, and produces flat plates, it is platy. Platiness is a sign of poor soil structure. A thick platy layer is worse than a thin one. Platiness is common under wheel tracks and does not usually extend deeper than 30 cm below the surface.

**Figure C1-12:** Massive aggregates are dense and have few pores.

Photograph: David Larsen.

**Massive** aggregates (**Figure C1-12**) are dense and have few pores. They appear dull. 'Featureless' would be an apt description. Massiveness is a sign of poor structure.

**Figure C1-13:** This massive aggregate shows a cup-and-ball fracture (shell-shaped) above and to the right of the pencil.



Photograph: David Larsen.

**Shell-shaped** aggregates (**Figure C1-13**) are another sign of degradation in clays. You may find clods that separate along a **cup-and-ball** shaped fracture, suggesting that one clod has been pressed into another. This is a sign of poor soil structure. Shell-shaped is distinct from lens or wedge: shell-shaped is tightly curved and has dull faces.

**Cube with square corners:** these aggregates occur naturally in non-self-mulching clays, but may also be the products of a massive block fractured by drying. Knowledge of similar soils in the area helps here: look under trees or pasture to see if that soil type naturally has aggregates with square corners.

**Cube with rounded corners:** these aggregates occur naturally, together with many-faced aggregates, below the surface. They may fit together in larger aggregates.

**Lens-shaped** aggregates occur naturally in clay subsoils and are a sign of good structure. Such aggregates may be hard to find because often we see only part of a large lens-shaped aggregate (half a lens appears as **wedge-shaped**). Lens or wedge-shaped aggregates usually part into smaller aggregates. They occur at all angles in the soil although larger aggregates typically have a face at  $45^{\circ}$  to the horizontal.

### Fracture faces

*Significance of fracture faces:* In clays, the fracture faces may be **shiny**, indicating a natural fracture plane between aggregates, or **dull**, indicating that the soil has been remoulded. In loams, rough faces with many pores indicate good structure.

*What to look for:* Examine the faces of a lump of soil removed from the side of a hole. Break the lump apart to reveal faces between aggregates. A good way to learn to recognise the different kinds of fracture face is to

compare soils that have been treated differently: for example, compare soil from a pasture with soil from a wheel track; or soil from a plough pan with soil from below the pan.

*Moderating factors:* Do not confuse natural shiny faces with shiny smeared layers made by tillage implements.

**Peds within aggregates** *Significance of proportion of small aggregates:* This observation refines the observation of aggregate size by demonstrating the internal structure of larger aggregates. It confirms other observations such as ease of fracture, aggregate shape and fracture faces.

*How to assess proportion of smallest aggregates:* Roll an aggregate gently between thumb and forefinger to break it down. Record the proportion of the breakdown products that are shiny faced (in clays) or that are more than single-grained in loams.

*Moderating factors:* Moisture content has a large influence on the soil's behaviour in this test. However, it is possible to distinguish soil that are puggy when wet, or brittle when dry from those that are friable.

The example in **Figure C1-9** shows high proportions (90% and 70%) of natural peds within aggregates except for the degraded layer, 10-15 cm. This agrees with the assessment of other structural features for this degraded layer.

### **Porosity**

*Significance of porosity:* Pores large enough to see are the means by which water, nutrients and air are able to move into and through the soil. Root growth is sparse within non-porous clods, consequently limiting nutrient and moisture extraction.

*What to look for:* **Look** at the soil and **feel** how it breaks. Attempt to break a lump into smaller and smaller pieces. The feel of the soil (crumbly for good structure; doughy, flinty or powdery for poor structure) also tells you if the soil is porous. Rate porosity by the potential pathways for root penetration. Score porosity as 0 (no visible pores), 1 (moderate number of pores) or 2 (many pores).

*Moderating factors:* In dry soils it is more difficult to feel porosity because even well-structured soils are hard when dry. It is best to assess the soil when it is moderately moist.

### **Colour of smallest aggregates**

*Significance of colour of smallest aggregates:* Well structured soils generally have strong colours because of high organic matter content. Thus dark grey or reddish brown colours indicate good structure. Pale colours such as light grey or slightly brown indicate less well structured soil. Bluish colours indicate a tendency to waterlogging. Note that this observation is the **lowest** priority in scoring the over all structure.

**Table C1-2** A numerical system for classifying soil structure. Features listed in descending order of importance

Features	Score		
	Firm 0 (F0) Poor structure	Firm 1 (F1) Moderate structure	Firm 2 (F2) Good structure
Aggregate size: width of natural sub-units produced by moderate hand pressure	Mostly more than 50 mm wide	5 mm - 50 mm wide	Mostly less than 50 mm wide
Ease of fracture	Difficult for spade or knife to penetrate; soil made up of large, tightly fitting blocks; breaks like heavy dough or plasticine	Moderate hand pressure needed to part the blocks	Parts readily into porous sub-units
New roots	Very few new roots	Medium number of new roots, but concentrated between the aggregates	Prolific growth of new roots throughout the sample
Aggregate shape	Massive, platy or shell-shaped	Mixed shapes	Many-faced, cube-with-rounded-corners, lens or wedge
Fracture faces	Soil breaks along the line of force applied in any direction, into units with sharp corners; internal faces have no protruding sub aggregates	Some natural separation planes with shiny faces, but most fracturing is along the line of applied force, to produce angular corners and smooth, dull internal faces	Natural fracture planes dominate; most of the faces are smooth and shiny, although often there are protruding, many-faced, round-cornered aggregates
Peds within aggregates: proportion of smaller aggregates within aggregates, revealed by rolling the sub-units between thumb and forefinger	Less than 10% of the breakdown products are shiny-faced aggregates	50% of the breakdown products are shiny-faced aggregates	More than 90% of the breakdown products are shiny-faced aggregates
Porosity: internal porosity of smallest aggregates	Porosity rating mostly 0 (no pores)	Porosity rating mostly 1 (moderate number of pores)	Porosity rating mostly 2 (many pores)
colour of smallest aggregates	Bluish	Light grey or slightly brown	Dark grey or reddish brown
<b>extra notes for dry soil</b>	Requires a very strong blow with an implement to break the blocks, revealing smooth, dull faces with sharp corners; flinty	Hard hand pressure required to part the blocks	Falls apart with light hand pressure to produce small, natural aggregates

Loose soil, moist Features	Score		
	Loose 0 (L0) Poor structure	Loose 1 (L1) Moderate structure	Loose 2 (L2) Good structure
Aggregate size	Diameter of the dominant fraction usually more than 20 mm	Diameter of the dominant fraction usually between 5 mm and 20 mm	Diameter of the dominant fraction usually less than 5 mm
Ease of fracture into constituent natural sub-units, if present	At least half the soil mass is large, dense and massive clods; dull and smooth fracture faces	At least half of the clods are larger compound aggregates which can be parted by moderate hand pressure into their constituent natural aggregates	Comprised wholly of natural aggregates that may be separate or compound (very easily parted by hand into their constituent natural aggregates). When broken, the aggregates separate along many-angled, often shiny faces. If shiny faces are not evident, the soil has many, obvious pores and is friable
Aggregate shape	Cube-shaped with square, sharp edges, or shell-shaped	Mixed shapes	Many-faced, or cube-shaped with rounded-edges
Porosity: internal porosity of smallest aggregates	Porosity rating mostly 0	Porosity rating mostly 1	Porosity rating mostly 2
<b>extra notes for dry soil</b>	A large proportion of large, hard, flinty clods with sharp edges	As above, but compound aggregates are firmer; some are flinty	As above

Reference: SOILpak structure score as modified by David McKenzie and Sue Greenhalgh. In: Final Report to Cotton Research and Development Corporation.

### Structure score

This final column in Section 3 of the soil description sheet is for you to record your overall assessment of soil structure from the various observations. Give single values for individual zones within the soil.

Use **Table C1-2** (above) to choose a structure score. The Table shows three scores for firm soil (F0, F1 and F2), and three scores for loose soil (L0, L1 and L2).

The scores are 0 (poor structure, 1 (moderate structure) and 2 (good structure). These scores can be subdivided (the example in **Figure C1-9** shows scores of L1.8, for loose soil that is not quite a perfect 2, F0.2 for the degraded layer that is not quite as bad as F0, and F1.9 for an almost-perfect deeper layer).

Loose soil is soil that can be removed by scraping with the hand, a trowel or a spade (not digging). It may be a loose seedbed, a loose tilled layer (even if cloddy) or a self-mulched layer. Very loose soil may be found at depth in association with salinity, which promotes fine aggregation.

Firm soil is soil below the depth of tillage, or below a natural loose self-mulched layer. It has aggregates that fit together along faces, and which require at least gentle hand force to lever them apart. Firm soil is not necessarily compacted. Firmness is a natural state of the soil at depth, but surface soil may be firm if compacted, crusted or hard-set.

When assessing a soil dominated by silt and fine sand (a soil that does not develop shiny faces) ignore all references to shiny faces.



## Section 4: subsurface and subsoil: other features

Figure C1-14 Section 4 of the soil description sheet - other features

4. subsurface and subsoil: other features							
depth, (cm)	dispersion (0-4)	moisture	intact soil colour	texture	bleaching?	cementing?	Lime, gypsum?
0.5-10	2	mod. moist	dark grey	medium clay	none	none	few small
10-15	2	moist	dark grey	medium clay			lime nodules
15+	2	moist	dark grey	medium clay			at 30 cm

### Dispersion

*Significance of dispersion in the subsurface or subsoil:* A subsurface soil that disperses sets into hard blocks on drying. A subsoil that shows dispersion in this test will swell strongly when wet, closing large pores. The result is poor permeability which can be a cause of waterlogging. Subsoils don't usually disperse when in place, but this test shows their **tendency** to disperse, which indicates their tendency to swell.

*How to test for dispersion in the subsurface or subsoil removed from the profile:* the method is the same as for testing dispersion of surface soil (Section 2). Ensure that the sample is dry: a moist sample disperses more easily, possibly leading to a false assessment.

*Decisions to make:* Beware of bringing dispersive soil to the surface by deep tillage, or allowing erosion or earthworks to expose it. Apply gypsum to a dispersive topsoil. It is difficult and expensive to get gypsum down to the subsoil.

### Moisture

*Significance of soil moisture content:* Tillage at the wrong soil moisture content can degrade soil structure. **Chapter D-s6** gives a full explanation. You can also assess moisture for sowing. Having dug a hole to examine the subsoil, you can get some idea of stored moisture (to the depth of the hole) for the next crop. If contemplating deep tillage, a knowledge of subsoil moisture will help you decide on the likely effect.



Go to Chapter C4 for advice on how to assess soil moisture.

Check various depths, as moisture content often varies down the soil profile.

**Intact soil colour**

*Significance of intact soil colour:* This assessment is for the colour of intact aggregates, as distinct from the smallest aggregates (Section 3). Colour may be useful for distinguishing between soil horizons. Red colours usually indicate a freely drained soil. Yellow, greenish or bluish colours may indicate poor drainage. Plant residues buried in wet soil may induce a bluish colour in the surrounding soil; decomposition of the organic matter uses up oxygen and creates an anaerobic zone for a short time. Mottling (blotches of colour different from the main soil colour) indicate that the soil may have been periodically waterlogged in the past, but not necessarily now.

*How to assess intact soil colour:* Break a moist aggregate and judge the colour. Use broad categories.

Moderating factors: Judging a colour without a colour chart can be misleading; It is difficult to remember fine differences, and colour perception is affected by contrasts in the surroundings. Therefore it is best to judge colours against standards; a simple standard is a piece of soil from another paddock.

**Texture**

*Significance of soil texture:* Section 2 deals with surface soil texture and its significance in water intake and seedling emergence. It is also important to repeat the assessment at various depths. Texture at various depths is, together with soil colour, an indicator of soil type. Soil type is important in determining soil management.

Texture affects the ease of working a soil (compare the ease of ploughing a light, sandy loam with the heavy ploughing of a clay soil). Texture affects water-holding capacity (loams hold more plant-available water than clays or sands). Texture affects the retention of nutrients and their availability (for example, sandy soils are 'hungry' and need frequent, but small, amounts of fertiliser).

A clay subsoil under a sand, silt or loam topsoil can reduce infiltration or plant root growth. If you are having these problems, check for an abrupt texture change under the topsoil. As you dig down, look for any changes in the soil (such as a change in colour, or harder digging). Test the texture and compare it with the topsoil.

*How to assess soil texture:* Take samples of soil from various depths, particularly those depths that show a different colour from other layers. Follow the method described under 'Surface soil texture' in Section 2, using **Table C1-1**.

**Bleaching**

*Significance of a bleached soil layer:* Some soils have a bleached layer in the lower part of the topsoil. This bleached layer is paler in colour than the upper part of the topsoil, but is still part of the topsoil.

The bleaching is caused by waterlogging, usually because a poorly permeable subsoil prevents the topsoil draining.

*What to look for:* Look for a layer that is paler than the upper part of the topsoil. It need not be white, just a paler colour. It may be a continuous layer, or occur as scattered patches across a paddock.

*Decisions to make in relation to a bleached soil layer:* A bleached layer alerts you to past waterlogging. The subsoil may be restricting drainage from the topsoil, as well as restricting root growth. See **Chapter D-s2:** for information on deep tillage.

**Cementing**

*Significance of a cemented layer:* Sometimes soils have a layer of naturally hard material. The layer is chemically cemented and may consist of lime, iron or silica. Such a layer impedes drainage and root growth.

*What to look for:* Look for a hard layer. You can distinguish a cemented layer from a plough pan (compacted layer) as follows. A cemented layer does not slake when a dry piece is placed in water, and it does not soften when it is wet. The opposite is true of a plough pan.

*Decisions to make in relation to a cemented layer:* Deep tillage is the accepted way to break the layer. See **Chapter D-s2:** Maintaining and improving soil structure.

**Lime, gypsum?**

*Significance of lime and gypsum:* Both lime and gypsum are sources of calcium. Lime is calcium carbonate; gypsum is calcium sulphate. Lime may occur in neutral or alkaline soils. It is a good sign if high in the profile as it helps to promote structural stability. Gypsum high in the profile **may** be an indicator of salinity; if deep in the profile, it is not a problem. Gypsum also helps to flocculate clay and so promote structural stability.

Free lime or gypsum can give false values for exchangeable calcium in a chemical test. See **Chapter C2:** Chemical tests.

The presence of lime in one part of the soil profile does not mean it is present throughout the soil. The surface may still be deficient in calcium through leaching.

*How to distinguish lime from gypsum:* Lime occurs as fine particles, too small to see, or as white nodules usually up to pea-size but sometimes as large as 5 cm across. Test with dilute acid (dilute hydrochloric acid or vinegar). Fizzing indicates lime.

Gypsum occurs as crystals: colourless, white or tinged pink. The crystals are usually needle-shaped but occasionally are shaped like whole finger nails. Gypsum does not fizz with acid, but a mixture of lime and gypsum does fizz.

*Decisions to make in relation to observations of lime and gypsum:* This may temper decisions on applying lime to raise pH, or gypsum to reduce clay dispersion. If gypsum is found high in the soil profile, send soil samples for laboratory testing to determine the salinity level.



Figure C1-15 Example of completed soil description sheet - side 1

**1. farm & paddock information**

farmer:	John Smith
property:	The Brigalows
paddock:	East 4
reason for inspection:	Poor growth and low yield of last wheat crop
inspected by:	PK
date:	10 Jan 95

paddock history: crops, yields, protein, fertiliser, lime, gypsum, herbicide, disease?

10 years wheat/long fallow

anticipated management: 4 years lucerne, then wheat

sketch map of site, extra notes etc.

N

sand

soil reasonably uniform, except for small patch of sand in NW corner

dug hole 200 paces in from SE corner

**2. surface soil**

cover % (crop, stubble, weeds):	30% loose stubble	slaking (0-4):	2	dispersion (0-4):	2 on wetting, 4 after remoulding
colour: (black, grey, brown, red):	grey	structure (grains, aggregates, cloddy, crusted, hard-set, cracked):	weak, thin (0.5 cm) crust, aggregates below. Known to crack when dry.		
texture (sand, silt, loam, clay):	medium clay				

**3. subsurface and subsoil: soil structural form**

depth, (cm)	aggregate size (cm)	ease of fracture	new roots	aggregate shape	fracture faces	peds within aggregates (%)	porosity (0-2)	colour of smallest aggregates	structure score (0-2)
0.5-10	0.5	crumbly		many-faced	shiny	90%	2	dark grey	L1.8
10-15	2	doughy	branch at 10 cm	massive	dull	nil	0	dark grey	F0.2
15+	5	parts easily		lens	shiny	70%	1	dark grey	F1.9

Figure C1-16 Example of completed soil description sheet - side 2

**4. subsurface and subsoil: other features**

depth, (cm)	dispersion (0-4)	moisture	intact soil colour	texture	bleaching?	cementing?	Lime, gypsum?
0.5-10	2	mod. moist	dark grey	medium clay	none	none	few small lime nodules at 30 cm
10-15	2	moist	dark grey	medium clay			
15+	2	moist	dark grey	medium clay			

**5. conclusions**

**broad soil type**

cracking clay

texture-contrast loam

uniform-textured loam

	<b>soil structural features</b>	For each feature, enter notes or simply tick. Enter soil structure score where appropriate.
<b>surface soil</b>	hard-set	
	crusted	weak, thin crust
	poached	
	cracked	cracks when dry
	self-mulched	crust breaks to fine aggregates
	cloddy	
<b>subsurface and subsoil</b>	friable	
	dispersive	slight dispersion
	continuous pan	
	discontinuous pan	F0.2 pan at 10-15 cm
	no root-restricting layer	

**6. management options**

no-tillage

slight disturbance

surface pitting

chisel

deep rip  after a drying crop

gypsum

lime

crop

pasture

**notes**

Plough pan requires breaking. Try natural cracking first, as soil dries under a crop. Check again to see if drying has cracked the pan - if not, deep rip when dry.

Gypsum may be required to overcome surface dispersion. Confirm with soil testing.

Lucerne-based pasture for a few years is required to build up organic nitrogen.

## Section 5: conclusions

This section of the soil description sheet is where you record your conclusions about the state of the soil., based on your observations in Sections 2, 3 and 4. These conclusions, combined with farm and paddock information (Section 1), will help you choose a soil management option for that paddock.

**Figure C1-17** Section 5 of the soil description sheet - conclusions

5. conclusions		<i>soil structural features</i>		For each feature, enter notes or simply tick. Enter soil structure score where appropriate.
<b><i>broad soil type</i></b>		<b>surface soil</b>	hard-set	
cracking clay <input checked="" type="checkbox"/>	crusted		weak, thin crust	
texture-contrast loam <input type="checkbox"/>	poached			
uniform-textured loam <input type="checkbox"/>	cracked		cracks when dry	
	self-mulched		crust breaks to fine aggregates	
	cloddy			
	friable			
	dispersive	slight dispersion		
	continuous pan			
	discontinuous pan	F0.2 pan at 10-15 cm		
	no root-restricting layer			

## Broad soil type

*Significance of broad soil type:* Soil type determines the overall soil management strategy for a paddock. There is no need to be a soil classification expert: the aim is to fit the soil into a broad type only.

**Figures C1-15** and **C1-16** show all of the examples of the description sheet from the various sections of this chapter. The example soil illustrates the procedure for determining a broad soil type.

Soil texture and soil colour are the main observations to determine soil type. Together with surface slaking and surface soil structure, they will allow you to assign a soil to a broad soil type. Refer to **Table C1-3**.

**Table C1-3** Broad soil types

Main features		Other features to help confirm type	Broad soil type
Soil texture	Soil colour		
clay topsoil over clay subsoil	black, grey, brown or red	usually self mulching, strongly cracking	cracking clays
clay loam, fine sandy loam or silty loam with marked change to clay subsoil	brown or red	often hard-setting, non-cracking	texture-contrast loams
wide range of clay content, from clay loam to sandy loam; little variation down the profile	brown or red	wide range of surface properties	uniform textured loams (recent alluvium)

**Texture**

The first feature to consider is soil texture. From **Section 2** of the soil description sheet, note surface soil texture. From **Section 4** of the soil description sheet, note soil texture of the various depths of the soil profile. In the example, the soil has a texture of medium clay all the way down the profile.

**Colour**

From **Section 2** of the soil description sheet, note the colour of the surface soil.

In the example, the colour is grey. The texture and colour information takes us to the first soil type: 'cracking clays'.

**Surface slaking**

From **Section 2** of the soil description sheet, note the slaking score of the surface soil. In the example, we have a slaking score of 2 (the lump collapses into angular pieces on wetting). A score of 2 is typical of a self-mulching soil, confirming that we are following the correct line in **Table C1-3**.

**Surface soil structure**

From **Section 2** of the soil description sheet, note the surface soil structure. In the example, we have 'weak, thin (0.5 cm) crust with aggregates below. Known to crack when dry'. Although this description is not 'self-mulching' as in **Table C1-3** it is close to that description (self-mulching soils sometimes form a weak crust which then breaks up to form a mulch). Furthermore, the cracking noted in the example fits this soil type.

## Characteristics of the broad soil groups

### Cracking clays

Cracking clays are prone to compaction, smearing and remoulding. However, they can restore and maintain good structure under wetting and drying. Black earths are strongly cracking, and repair their structure easily. Grey, brown and red cracking clays are less strongly cracking. The surfaces of all these soils are usually self-mulching; if not, the surface may be dispersive and gypsum may be required.



Go to Chapter E1 for more information on soil types.

### Texture contrast loams

Texture contrast loams include the red-brown earths, solodized solonetz and solodics. They are prone to crusting or hard-setting under cultivation, but are more stable under pasture. They may need judicious tillage, and practices to increase their organic matter content.

### Uniform textured loams

Uniform textured loams have a wide range of clay contents, but the texture varies little down the soil profile. Their management requirements depend upon their tendency to crust, hard-set or crack.

Any of these broad soil types may have other features, such as compaction, that require management attention. The different soil types require different management approaches.

You may encounter another soil type, **krasnozems**. These have a clay loam or light clay topsoil grading to more clayey subsoil. They have a brown or red porous surface, are non-slaking, non-dispersive and non-cracking. They are relatively resistant to compaction and smearing.

## Conclusions on soil structural features

In **Section 5** of the soil description sheet, tick the box that matches your broad soil type.

From **Section 2** of the sheet, enter notes in **Section 5** against the listed surface soil features. In the example, (**Figure C1-17**) we can note that the soil has a weak, thin crust, slight dispersion, and is self mulching (the crust breaks to fine aggregates).

From **Sections 3** and **4** of the sheet, enter notes against the listed subsurface and subsoil features. Enter the soil structure score where applicable. In the example, we can note that there is a **continuous** pan (structure score of F 0.2) at 10-15 cm depth. This pan is compacted soil. A cemented layer is also a pan. A **discontinuous** pan limits root penetration to some degree, but there are zones where roots can grow through the layer.

## Section 6: soil management options

Figure C1-18 Section 6 of the soil description sheet management options

6. management options	notes
no-tillage <input type="checkbox"/>	<p>Plough pan requires breaking. Try natural cracking first, as soil dries under a crop. Check again to see if drying has cracked the pan - if not, deep rip when dry.</p> <p>Gypsum may be required to overcome surface dispersion. Confirm with soil testing.</p> <p>Lucerne-based pasture for a few years is required to build up organic nitrogen.</p>
slight disturbance <input type="checkbox"/>	
surface pitting <input type="checkbox"/>	
chisel <input type="checkbox"/>	
deep rip <input checked="" type="checkbox"/> after a drying crop	
gypsum <input checked="" type="checkbox"/>	
lime <input type="checkbox"/>	
crop <input type="checkbox"/>	
pasture <input checked="" type="checkbox"/>	

### Management options

The broad soil types and soil structural features in **Section 5** of the sheet determine soil management options. Tillage options include **no-tillage** when the soil is well structured, **slight disturbance** for example by a planter or by harrows to disrupt a thin crust, **surface pitting** to increase surface roughness to reduce run-off, and the more disruptive options of **chisel** ploughing or **deep ripping** to break a pan.

The aim should always be to minimise tillage operations, particularly those involving disc implements because of their damaging effects on soil structure.

Other options are applications of gypsum and/or lime. The final decision is to choose between crop and pasture. This decision depends upon soil requirements, but economics will have an influence.

Management options for cracking clays and loams are explained below, under the various soil structural features as determined in Section 5. Check that soil moisture content (**Section 4** of the sheet) is appropriate for a tillage operation.



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

## Surface soil

### Hard-set

*Cracking clays* do not hard-set. A hard surface layer may be due to poaching or dispersion.

*Loams* may hard-set when organic matter content is low. Refer to paddock history (**Section 1**). A long history of cropping, with little or no pasture may be the cause. Retain stubble or sow pasture to protect the soil surface from raindrop impact, and to improve organic matter content.



Go to Chapter C4 for the method of determining the plastic limit.

Tillage to break the hard-set layer may be required to establish plants, but till when the soil is close to the plastic limit to avoid dust formation, compaction or smearing. Minimum tillage or no-till is of most benefit after the soil has been restored to good structure.

### Poached

*Cracking clays* recover from poaching as they dry and crack. Poaching damage on a cropping paddock can be alleviated by tillage when the soil is dry. Poaching damage to a cracking clay under pasture is probably best left to repair itself.

*Loams* under heavy grazing poach when wet and pulverise when dry. Till a poached cropping paddock when the soil is at the plastic limit (see **Chapter C4**). A poached loam pasture will improve in time. Reduce grazing pressure and allow root growth and earthworms to open up the soil.

### Crusted

*Cracking clays*: Refer to the results of the slaking and dispersion test. The soil may respond to gypsum.

*Loams*: A crust may be due to low organic matter content, particularly in a fine-sandy loam or a silty loam. If this is a cropping paddock, refer to paddock history (**Section 1**) to see how long since pasture. Have there been seedling emergence problems? Surface cover may reduce the tendency to crust. Increase surface roughness to form hollows that will detain water and assist infiltration. Harrows will break a thin crust and may assist seedling emergence.

### Dispersive

Link information on clay dispersion to other features recorded in **Section 5** of the sheet. It may help to determine whether gypsum will improve a crusted or hard-set soil.

### Cracked

The degree of cracking was a factor in determining the broad soil type in **Section 5**. It may influence your decision on the appropriate action for other features. You can employ wetting and drying to improve a cracking soil.

**Self-mulched**

A self-mulched surface requires no remedial action to improve soil structure. However, the loose nature of the surface makes it prone to rill erosion. Sloping ground requires surface cover.



Go to Chapter D-s1 for more information on erosion control.

**Cloddy**

*Cracking clays:* A cloddy tilled layer will mellow (improve in structure with wetting and drying, or frost). Further tillage before mellowing is unlikely to improve soil structure. After the soil structure has mellowed, till only the depth of dry soil.

*Loams:* A cloddy layer requires further tillage when the soil is close to the plastic limit.

**Friable**

A friable surface is well structured. Provided that there are no root-restricting layers in the soil profile, this is a suitable soil for no-tillage.

## Subsurface and subsoil

**Continuous pan**

A continuous pan in the subsurface or subsoil may be due to tillage, traffic or cementing.

*Cracking clays* respond to wetting and drying. Subsequent deep tillage may be required when the pan is dry. The example in **Figure C1-17** illustrates a cracking clay with a continuous pan. The structure score of F 0.2 means that this soil layer is seriously degraded and requires remedy.



Go to Chapter B5 for more information on deep tillage.

*Loams* respond to pasture and tap rooted crops. Deep till when the soil is dry enough not to smear, but has enough moisture to prevent powdering.

**Discontinuous pan**

A discontinuous pan may be due to wheel compaction or sporadic areas of cementing. Consider the severity of the pan before deciding whether it requires remedial action. If the pan covers only small, isolated areas, it may not have much effect on plant growth. Base your decision upon observations of pathways for roots to reach soil below the pan. If you decide that a remedy is required, follow the management described under 'Continuous pan'.

**No root restricting layer**

If this soil also has a well structured surface, it is suitable for no-tillage.

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## C2 Chemical tests

Purpose of this chapter

This chapter explains how to interpret the results of some chemical soil tests.

Chapter contents

- pH
- organic matter
- soil nitrogen
- electrical conductivity
- exchangeable cations
- converting units.

Associated chapters

You may need to refer to the following chapters:

- Chapter C1: Examining the soil profile



## C2

# Chemical tests.

Several commercial laboratories offer a soil chemical testing service to describe the nutrient status of soil and give fertiliser recommendations. These services usually do not include direct measurements of soil structure. However, chemical testing, as well as providing valuable information about the chemical fertility of the soil, can also give some **indirect** information about a soil's physical condition.

## Soil pH

The standard method of measuring soil pH is with a suspension of 1 part air-dry soil by weight to 5 parts liquid by volume. The recommended liquid is 0.01M CaCl<sub>2</sub> (calcium chloride). Results in this case are reported as *pH (CaCl<sub>2</sub>)*. Distilled water is sometimes used in place of calcium chloride, in which case results are reported as *pH (water)*. Soil tested in CaCl<sub>2</sub> solution gives pH values about 0.5-0.8 lower than the same soil tested in water.

**Interpreting soil pH** The pH (CaCl<sub>2</sub>) of northern wheat-belt soils can vary down the profile and between sites, from strongly acid (less than 5) through to strongly alkaline (greater than 8). Values of pH between 5 and 8 are very common.

A low pH (less than 5) is detrimental to plant growth, not because of the acidity itself, but because of imbalances in nutrient levels. Phosphate is poorly available; aluminium and/or manganese may be present in toxic concentrations. Lime is needed to raise the pH.

A pH greater than 8 indicates possible high levels of exchangeable sodium or magnesium, and therefore a tendency for the clay to disperse (producing poor soil structure). Phosphate, iron, zinc and manganese are poorly available.

A desirable pH (CaCl<sub>2</sub>) range for plant production is 5.5 to 7.5.

## Organic matter

Changes in organic matter levels over time (several years) will indicate the effects of a management system on soil condition. A high level of organic matter generally indicates better soil structure. In cracking clays, organic matter may not be quite as important to soil structure as it is in other soils.

Laboratory methods for estimating soil organic matter include:

- *loss on ignition* (the loss in weight of a soil sample when it is heated to 400° C). This method assumes that only organic matter is lost. However, in a calcareous soil (one with free lime, common in cracking clays and western red-brown earths) inorganic carbon is also lost as carbonates decompose at that temperature. Loss on ignition must be corrected by measuring carbonate separately.
- *carbon dioxide analyser*. This method is similar to loss on ignition in that soil is heated to oxidise the organic matter. The carbon dioxide produced is a measure of soil carbon content. As with loss on ignition, inorganic carbon (if present) will contribute to the total carbon measured.
- *wet oxidation* by the Walkley-Black method measures only organic carbon and is the recommended method for calcareous soils. Assume that any soil is calcareous unless proved otherwise, and **be wary of reported organic matter contents that do not state the method used.**

#### **Converting organic matter values**

The average carbon content of soil organic matter is approximately 57%. Multiply values for organic carbon % by 1.75 to convert to organic matter %.

#### **Interpreting organic matter values**

Most soils in Australia, even in their natural state, are low in organic matter compared with soils in other parts of the world. Cultivation history, sample depth and soil type affect organic matter levels markedly. The following ranges are only a guide and individual values could lie outside these ranges.

A virgin grey or brown cracking clay could have an organic matter content anywhere between 1.4% and 4.0% in the surface 0.1 m. The lower value is for a coolabah soil and the higher value is for a brigalow soil.

Typically, the red-brown earths and solonized brown soils have organic matter levels around 1.75% in the topsoil.

In the broad context of various soil types, regard below 1% organic matter as very low, 1-2% as low, 2-4% generally satisfactory, and greater than 4% as high. As with much soil data, information on organic matter content becomes more useful when compared over different locations, management histories and times.

## Soil nitrogen

**Total nitrogen** Soil nitrogen occurs in many forms. Total nitrogen is a measure of all those forms, some available to plants immediately and some becoming available only as organic matter is mineralised. It is a measure of the potential long-term chemical fertility. Total nitrogen in % by weight varies from less than 0.05 (very low), 0.05-0.15 (low), 0.15-0.25 (moderate), 0.25-0.5 (high) to greater than 0.5% (very high).

**Carbon nitrogen ratio** Calculate this ratio by dividing organic carbon percentage by total nitrogen percentage.

Plant residues contain more carbon than nitrogen. As the residues decompose, carbon is oxidised to carbon dioxide gas and so the carbon content declines. The nitrogen content rises as a consequence (it is less diluted by the carbon). The carbon:nitrogen ratio in 'raw' plant residues may be as high as 60:1 (in wheat straw, for example). A figure of 25:1 is very high for a soil, indicating the presence of undecomposed residues. A figure of 15 or 20:1 indicates a slowing in the decomposition process. A figure of 10 or 12:1 is normal for a cropped soil.

**Nitrate** Nitrate is a form of nitrogen that is immediately available to plants. Nitrate content of soil varies, both over time and with soil depth. Interpretation of soil testing results can be difficult, because soil nitrate levels depend on:

- rainfall, which leaches nitrate from the topsoil;
- waterlogging, which promotes conversion of nitrate to nitrogen gas (denitrification);
- time of year when soil is sampled (warm, moist aerobic conditions encourage mineralisation of soil organic matter to nitrate);
- sampling depth (most of the nitrate is at shallow depths; deep sampling dilutes it. However, deep sampling - perhaps to 60 cm at increments of 15 cm - may be desirable to determine the total nitrate in the root zone);
- treatment of the samples before they reach the laboratory. For example, leaving moist soil samples in warm conditions changes their nitrate levels. Air-dry the samples before sending them to the laboratory. Do not dry the samples above 40°C.

Local agronomic experience is needed to reliably interpret soil nitrate levels. Tests on soil from shallow depths are poor indicators of nitrate status. Soil samples covering the main root zone (from the surface to at least 30 cm and preferably 60 cm) give a much better indication of fertiliser requirements. However, the following is a guide to the meaning

of nitrate contents of shallow (0-15 cm) soil samples. Greater than 30 mg kg<sup>-1</sup> (ppm) nitrate generally indicates a high level. A value of less than 10 mg kg<sup>-1</sup> indicates that plants will probably respond to increased soil nitrogen.

Nitrogen response varies with rainfall: in a wet year, there is sufficient soil moisture to make use of more nitrogen. A nitrate content above 30 mg kg<sup>-1</sup> is then no longer 'high' (as above); plants will likely respond to increased soil nitrogen. In a dry year, plants are not able to make full use of available soil nitrogen; they will not respond to increased soil nitrogen.

## Electrical conductivity (salinity)

Electrical conductivity (EC) is a measure of the ability of a liquid to pass an electric current. EC increases as the **salinity** (salt concentration) of the liquid increases. The units are dS/m (decisiemens/metre).

EC<sub>e</sub> is the electrical conductivity of a saturated soil/water extract. The water is removed from a just-saturated soil sample by centrifuge or vacuum pump and the water extract is tested for its electrical conductivity. EC<sub>e</sub> is the preferred method of estimating soil salinity because it best reflects how salinity will affect plant growth. However, it is very time consuming and is not a routine method.

EC<sub>1:5</sub> is the electrical conductivity of a suspension of 1 part air-dry soil by weight to 5 parts water by weight, as for pH (water). This is the most common method because it is easy to do. However, it is difficult to interpret. EC<sub>1:5</sub> values need to be converted to EC<sub>e</sub> values to allow interpretation.

Total soluble salts (TSS) used to be a popular way of expressing soil salinity and is still used by a few laboratories. TSS is not recommended because it can not be easily related to plant growth.

### Converting EC values

Tables of salt tolerance use values of EC<sub>e</sub>. If your result sheet shows TSS, first convert values to EC<sub>1:5</sub> and then to EC<sub>e</sub>.

### Step 1: convert TSS to EC<sub>1:5</sub>, if necessary

TSS units are mg kg<sup>-1</sup> (ppm) or g/100 g (%). The following two formulae approximately relate EC<sub>1:5</sub> and TSS:

$$\begin{aligned} \text{EC}_{1:5} \text{ (dS/m)} &= \text{TSS (mg kg}^{-1}\text{)} \times 0.00031 \\ \text{EC}_{1:5} \text{ (dS/m)} &= \text{TSS (g/100g)} \times 3.1 \end{aligned}$$

**Example:** TSS % of 0.015 g/100 g:

$$\begin{aligned} EC_{1:5} &= 0.015 \times 3.1 \\ &= 0.047 \text{ (dS/m) (approx.).} \end{aligned}$$

**Step 2: convert  $EC_{1:5}$  to  $EC_e$**  To obtain an approximate value for  $EC_e$  multiply  $EC_{1:5}$  by a factor which depends on soil texture (**Table C2-1**).

**Table C2-1** Multipliers for converting  $EC_{1:5}$  (dS/m) to an approximate value of  $EC_e$  (dS/m).

Soil texture	Multiply $EC_{1:5}$ (dS/m) by this number
Sand, loamy sand, clayey sand	23
Sandy loam, fine sandy loam, light sandy clay loam	14
Loam, loam fine sandy, silt loam, sandy clay loam	9.5
Clay loam, silty clay loam, fine sandy clay loam, sandy clay, silty clay, light clay, light medium clay	8.6
Medium clay	7.5
Heavy clay	5.8

Source: Slavich and Petterson

**Example:** a medium clay has an  $EC_{1:5}$  of 0.4 dS/m.

$$\begin{aligned} EC_e &= 0.4 \times 7.5 \text{ dS/m} \\ &= 3 \text{ dS/m (approx.).} \end{aligned}$$

**Miscellaneous units for electrical conductivity**

1 dS/m (decisiemens/metre) equals:

- 1 mS/cm (millisiemens/centimetre)
- 1 mmho/cm (millimho/centimetre)

**Interpreting  $EC_e$**

Conventionally, saline soils are defined as those having an  $EC_e$  value greater than 4 dS/m. However, much lower levels of salinity than this can affect the growth and yield of sensitive plants such as maize, most legumes (beans, peas, clovers and to some degree lucerne) and some grasses

Saline soils are often friable because the high salt concentration allows the clay particles to flocculate (form clusters) even when the soil has high exchangeable sodium percentage.



Go to Chapter D-s8 or E2 for more information on flocculation of clay.

## Exchangeable cations

A few laboratories report exchangeable cations as  $\text{mg kg}^{-1}$  (ppm). It is more useful to express them as **centimoles of positive charge per kilogram of soil** ( $\text{cmol (+) kg}^{-1}$ ), numerically equal to milliequivalents per 100 g of soil ( $\text{me}/100\text{g}$ ). This takes account of the different cations' valencies and atomic weights. Use the numbers in **Table C2-2** to convert the units.

**Table C2-2** Converting  $\text{mg kg}^{-1}$  to  $\text{cmol (+) kg}^{-1}$

**Step 1: Convert  $\text{mg kg}^{-1}$  to  $\text{cmol (+) kg}^{-1}$ , if necessary**

Cation Divide  $\text{mg kg}^{-1}$  by this number:

calcium (Ca)	200
magnesium (Mg)	120
potassium (K)	390
sodium (Na)	230
aluminium (Al)	90

**Step 2: calculate cation exchange capacity**

After converting the cation concentrations to  $\text{cmol (+) kg}^{-1}$ , add them to give an approximate value for the cation exchange capacity (the 'effective' CEC). Express each cation as a % of the effective CEC, as in the example (**Table C2-3**).



*Caution:* Never add values expressed as  $\text{mg kg}^{-1}$  or ppm. The result is meaningless.

**Table C2-3** Example of calculating exchangeable cations as % of effective CEC.

Cation	$\text{mg kg}^{-1}$	$\text{cmol (+) kg}^{-1}$	% of effective CEC
calcium (Ca)	3000	$3000/200 = 15.0$	$100 \times 15.0/34.9 = 43.0$
magnesium (Mg)	2020	$2020/120 = 16.8$	$100 \times 16.8/34.9 = 48.1$
potassium (K)	351	$351/390 = 0.9$	$100 \times 0.9/34.9 = 2.6$
sodium (Na)	512	$512/230 = 2.2$	$100 \times 2.2/34.9 = 6.3$
aluminium (Al)	nil	0.0	0.0
Total (effective CEC)		34.9	

Other cations (manganese, iron, copper and zinc) are usually present in only trace amounts and so do not contribute significantly to the total. In addition, soils with pH ( $\text{CaCl}_2$ ) above 5 contain very little exchangeable aluminium and so the effective CEC is the sum of the four cations calcium, magnesium, potassium and sodium. In the example, the effective CEC is 34.9.

**Step 3: note ESP**

The exchangeable sodium percentage (ESP) in the above example is 6.3. This value gives a guide to the potential for clay dispersion. A clay soil with ESP greater than 5 is prone to dispersion on wetting if its salinity is low.

**Step 4: calculate Ca/Mg**

Calculate the ratio of exchangeable calcium to exchangeable magnesium (Ca/Mg ratio) after converting units to  $\text{cmol (+) kg}^{-1}$ .

Using the example in **Table C2-3**:

$$\text{Ca/Mg ratio} = \frac{15.0}{16.8} = 0.89 \text{ (no units)}$$

**Exchangeable cations and clay dispersion**

The balance between the various exchangeable cations and the concentration of total salts (salinity, measured by electrical conductivity) interact to determine whether clay will disperse in water (see **Chapter E2: clay minerals**).

In general, non-saline soils with an exchangeable sodium percentage (ESP) above 5 are liable to disperse in water. The soil in the example above has an ESP of 6.3 and may disperse.

A Ca/Mg ratio of less than 2 (particularly, less than 1) also indicates a tendency to disperse. The soil in the example above has a Ca/Mg ratio of 0.89. Combined with its ESP of 6.3, it is likely that such a soil would disperse if non-saline.

Free lime or gypsum can give false values for exchangeable calcium (overestimated by as much as 50%). Laboratories should use the Tucker method for exchangeable cations (ammonium chloride leaching solution at pH 8.5, and measurement of the sulphate and carbonate content) to minimise this error.

# C3 Alternatives to the spade

Purpose of this chapter To show different ways of examining the soil profile.

Chapter contents

- post-hole digger
- auger
- coring tube
- backhoe

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

- C1: Examining the soil profile
- C4: Measuring soil water



## C3

# Alternatives to the spade

A spade (and perhaps a mattock or crowbar) are useful to dig small holes to examine soils to a depth of about 30 cm. To examine soils to a greater depth, there are easier methods than using a spade.

### Post-hole digger

A powered post-hole digger brings up disturbed soil. Consequently, it can not be relied on to show undisturbed soil structure. However, you can examine soil colour, texture and moisture. A post-hole digger is an easy way to obtain soil from depth, but there is some mixing of soil from different depths. It is suitable only for a coarse examination.

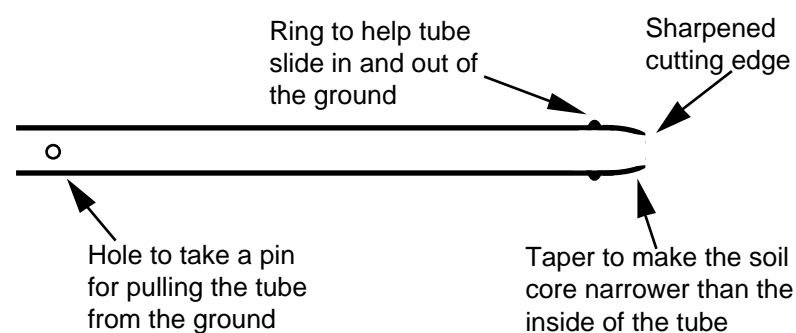
### Auger

A soil auger also brings up disturbed soil. It is slower than a post-hole digger, but allows more accurate measurement of the depth of each auger-full. If loose soil falls down the hole, it will become mixed with soil from the next depth. Prevent surface soil from falling down the hole by clearing away loose soil around the hole. Measure depth from the surface of the undisturbed soil away from the auger hole.

### Coring tube

A coring tube takes a slightly disturbed soil sample. The tube smears the outside of the core, and there is some distortion of the sample. However, the centre of the core usually retains its structure reasonably well. A soil core shows the soil layers and plant roots.

**Figure C3-1:** Section through a coring tube.



A coring tube can be made from thin-walled steel tube, such as car exhaust pipe. Shape the cutting end as shown in **Figure C3-1**. Heat the end of tube to dull-red heat and hammer it into a tapered metal dolly. A reducing joiner (as used to join different sizes of water pipe) may be suitable as a dolly. Better, make a dolly on a lathe.

A ring on the outside of the tube enlarges the hole and helps to ensure that the tube does not stick in the ground. A ring of braze will do.

Wipe a film of oil inside and outside the tube to stop soil sticking. If the soil samples are for an estimate of soil moisture, a thin film of oil will not greatly affect the result. However, if the soil samples are for chemical testing, oil may contaminate the samples. Phosphate-free and nitrogen-free oils are available but are expensive.

Hammer the tube into the ground using a heavy wooden mallet. Withdraw the tube using a lever on the principle of a fence post puller. Lay the tube in a tray (such as a plastic pipe cut in half lengthways). Insert a stake inside the cutting end to push the soil core out of the tube and into the tray.

Photograph: Ian Daniells



## Backhoe

A backhoe pit shows the soil profile over the depth of the root zone, and is useful for examining the effect of wheel tracks.

Dig a pit up to 1.5 m deep, and as long as one reach of the backhoe arm. The pit should be wide enough to stand in it to examine the exposed soil profile. Dig steps or a ramp at one end of the pit.

Don't drive the backhoe over the pit site as the backhoe wheels will compact the soil. Reverse the backhoe up to the site, dig the pit and drive away forwards.

If you are interested in examining the effect of wheel tracks, you may wish to dig a long pit across the direction of traffic. If the pit is to be longer than the reach of the backhoe arm, reverse the backhoe up to each end of the pit. As before, drive away forwards after digging.

The backhoe bucket will smear the sides of the pit, so use a knife, spatula or screwdriver to flick out the smeared soil and reveal undisturbed soil behind.

**Caution: Do not dig pits in sandy soil, and not deeper than 1.5 m in any soil or they may cave in.**



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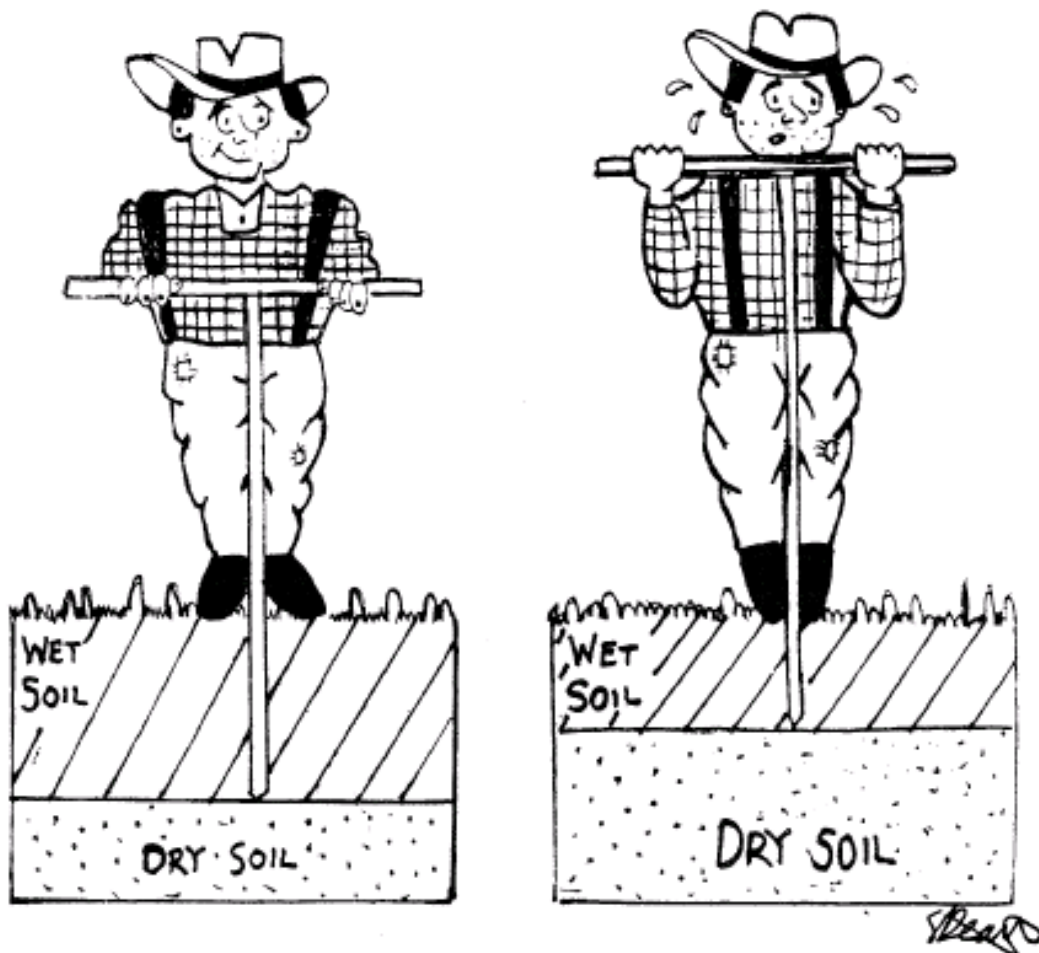
# C4 Measuring soil water

Purpose of this chapter To show the different ways of judging the soil moisture content before tillage or sowing.

- Chapter contents
- plant symptoms
  - push probe
  - testing by hand
  - weighed samples

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

- C1: Examining the soil profile
- C3: Alternatives to the spade



# C4 Measuring soil water

## Why measure soil water?

Dryland farming involves the management of soil water; such management is made more effective by estimates of soil moisture status.

Water is fundamental to plant growth. Decisions on sowing depend upon estimates of the amount of water stored in the soil, as much as upon the expectation of rain after sowing.

Soil water content determines the additional amount of rain that the soil can accept before run-off occurs. As the soil profile fills with water, run-off occurs more and more frequently. The erosion hazard increases and a fallow becomes less and less efficient at storing rain. Once a soil profile is more than three-quarters full of water, it is time to sow a crop to make use of that water!

Soil water greatly affects soil strength and determines the way a soil responds to external forces. Such external forces include disturbance by tillage, and loads on the soil surface (wheels can compact a wet subsoil, even though the surface is dry).

When you are considering tillage, estimate soil water content through and below the depth of intended tillage.

Following sections describe ways of estimating soil water content.

## Plant symptoms and weather

Simple observations of plants and weather will give you some idea of the water content of your soil. If a crop has a dry finish, the soil may be close to permanent wilting point at harvest. Provided there hasn't been any rain since harvest, your soil will be dry **to the depth of the root zone**.



Go to Chapter B5 or D-s2 for more information on using crops to dry soil.

Permanent wilting point is the soil water content at which plants wilt, and do not recover when evaporative stress lessens (at night) or when the soil becomes moist again.

Permanent wilting point is slightly drier than the plastic limit: the water content of a soil above which it can be remoulded (is plastic) and below which it cannot be remoulded (is brittle).

When plant symptoms show a soil to be at permanent wilting point, it is very likely that the root zone is slightly **drier** than the plastic limit. Such water content is suitable for tilling clay soils.



*Caution:* Where there is a compacted layer, the root zone may be quite shallow; soil below the root zone may be too moist to till without smearing.

Where the subsoil is well structured, considerable depth. Maize and soybeans generally dry the soil to 80 cm; cereals, sunflower and safflower can dry the soil to below 120 cm; deep-rooting pasture (particularly lucerne) may dry the soil to 2 m or more.

On sodic cracking clay soils, plant symptoms such as wilting may suggest that the soil is dry. The same is true of any saline soil. However, the soil may still be wetter than wilting point, even though the water is not available to plants. Hence such a soil may be moist enough to smear if tilled. Beware of deep tillage in those circumstances.

*When using plant symptoms and weather:*

**Advantages:**

- Simple observations.

**Cautions:**

- Rain after crop ripening makes this method unreliable.

## Push probe

A piece of rod with a pointed end and a T-bar to push down on can be a useful way of judging the depth of wetting in a soil. After some practice, it can also be used to estimate the water content of a soil. Soil moisture content varies from point to point, and a push probe is a quick way of assessing soil moisture at many points over a paddock.

An agricultural consultant may be able to calibrate your soil for push probe readings. Depth of wet soil will then translate into millimetres of plant-available water.

*The push probe:*

**Advantages:**

- You can assess water content at depth without digging.

**Cautions:**

- Rain after crop ripening makes this method unreliable.

## Moisture test by hand

A simple and very effective way to determine suitability for tillage is to mould some soil in your hand. See if it will form a ball, try to form a ribbon, then try to roll it into a thin rod.

This method is reliable and there are several 'exit points' where it is obvious that there is no need to continue. For example, if a soil **easily** forms a ribbon, then it is much wetter than the plastic limit and would smear if tilled. There is then, no point in doing the rod test. **Table C4-1** gives the full method. **Figure C4-1** summarises the method.

**Table C4-1** Guide for assessing soil water content - complete description of method

Soil Water Status	Sands, Silts, Sandy Loams	Loams	Clay Loams, Clays
<b>DRY</b>	Flows through fingers or fragments break to powder.	Does not form a ball when squeezed in hand. Fragments break to powder.	Does not form a ball. Fragments break to smaller fragments or peds.
<b>PLASTIC LIMIT</b>	Does not form a ball or rod. Fragments do not powder.	Does not form a ball or rod. Fragments do not powder.	Forms a ball. Does not ribbon. <b>Just</b> makes a 3 mm rod.
<b>MODERATELY MOIST</b>	Appears dry. Ball does not hold together.	Forms crumbly ball on squeezing in hand.	Forms a ball. Does not ribbon. Forms a rod to 3 mm.
<b>MOIST</b>	Forms weak ball but breaks easily.	Forms a ball. Does not ribbon.	Forms a ball. Ribbons easily.
<b>WET</b>	Ball leaves wet outline on hand when squeezed.	Ball leaves wet outline on hand when squeezed. Sticky.	Ball leaves wet outline on hand when squeezed. Sticky.

Source: Australian Soil and Land Survey Field Handbook.

**Does the soil form a ball?** Take a handful of soil - it could be one lump or some loose soil - and try to squeeze it into a ball with your hand.

A dry soil will not form a ball but will break into smaller fragments or powder. (A very compact lump will not break, of course.) The soil is drier than the plastic limit. You can safely till a clay soil at this water content: it will shatter, not smear. A silty or sandy soil is too dry to till: it will pulverise.

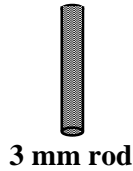
**Does the soil ribbon?** If the soil forms a ball, place the ball between your thumb and forefinger and squeeze, sliding your thumb across the soil. If a ribbon forms, the soil is much wetter than the plastic limit. Tillage will smear a clay soil at this water content.

**Rod test for clays**

This test applies to clay soils. Not all soils form a rod. A soil requires a high clay content to make it plastic enough for remoulding into a rod. The rod test is a useful way to further test the water content of a clay soil that crumbles but does not powder

(see **Figure C4-1**).

If the soil forms a ball, roll it on a flat surface to form a rod of 3 mm thickness. If it is **just** possible to form a rod, the soil is at the plastic limit. If the soil crumbles in the process it is drier than the plastic limit. If you can form a rod easily, the soil is wetter than the plastic limit.



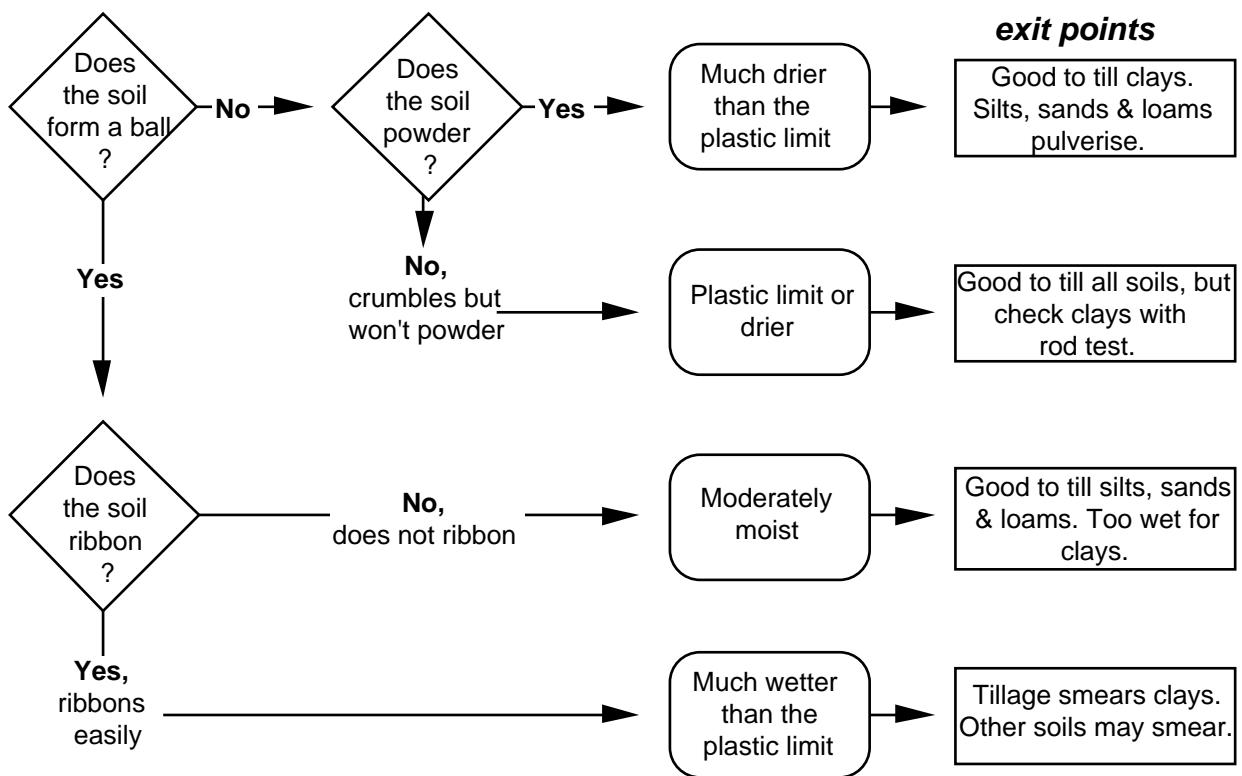
**Tip:** The plastic limit is quite dry: you will need considerable force to form the soil into a rod.

A suitable flat surface could be the cover of this manual or the **back** of a shovel - the concave front of the shovel will not allow the soil to roll without bending (and crumbling) the rod.

When rolling the soil into a rod, don't stretch it by moving your hands apart; that will make it appear to be crumbling (drier than the plastic limit) when, in fact, it could be a little wetter than the plastic limit

**Figure C4-1**

Guide for assessing soil water content by hand - summary of method



*Moisture test by hand:***Advantages:**

- If you check relevant depths of soil, this test shows suitability for tillage, and suitability for sowing.

**Cautions:**

- Do this test quickly to avoid soil drying in your hands.

## Soil water content by weighing

A soil sample, weighed fresh and after drying, gives a measure of soil water content by weight. The conversion of water content by weight to water content in millimetres requires a measured value, or an assumed value, of soil bulk density.

However, even when using assumed values for soil bulk density, water content by weighing is a useful measure.



*Caution:* The soil water content measured by this method is not all available to plants. This method measures the **total** soil water content; some of this total water content remains in the soil after plants have extracted the available water. To estimate the **available** soil water content, subtract the water content of a soil profile at permanent wilting point (for example, after a dry harvest). The difference is a measure of plant-available water.

**Tip:** Water content by weighing is easier to interpret when you compare measurements taken at different times on the same site.

Once you know the values (for a given soil) that relate to a soil profile full of water, to permanent wilting point, or to the plastic limit, you can begin to make management decisions that depend upon soil water content.

Management decisions may relate to the sowing of an opportunity crop to make use of plentiful soil water; or to the necessity to sow a crop to use soil water and reduce the risk of run-off and erosion, or the possible risk of deep drainage to groundwater. You may need to make decisions relating to the appropriate soil water content for effective tillage.



Go to Chapter B11 for more information on choosing a suitable rotation.

A coring tube allows you to sample to depth. Cut the soil core into sections, say every 150 mm depth. Alternatively, dig a hole and take soil samples from the side of the hole at measured depths.



Go to Chapter C3 for information on how to sample deep soil.

**Tip:** Calculations are easier if all depth intervals are the same (in this example, the core is cut into equal depth intervals of 150 mm).

Place each sample of soil into a watertight container (for example, a plastic tub with a sealing lid) and weigh it together with its container soon (preferably the same day). Write the weights on the record sheet (Column 2 in the example, **Figure C4-2**).

Dry the samples and weigh them in their containers again. Write the weights down in Column 3. Weigh each empty container, and write the weights down in Column 4 (in the example, **Figure C4-2**, the container weights are all 30 g)

Drying the sample requires some care. Laboratories use fan-forced, temperature-controlled ovens at 105°C to dry soil samples overnight. You could crumble the samples, spread them out in separate trays and leave them in a well-ventilated place to air-dry (for at least 48 hours, but preferably longer).

**Figure C4-2** Example of calculating soil water content by weighing

Soil water content. Paddock No. 4 Core No. 1 Date 5 November 2000								
Depth interval (D) = 150 mm								
1 Depth, mm	2 Weight of moist soil with tub, g	3 Weight of dry soil with tub, g	4 Weight of empty tub, g	5 Weight of water in soil, g	6 Weight of dry soil, g	7 Bulk density, g/cm <sup>3</sup>	8 Water content by volume	9 mm of water
				= 2 - 3	= 3 - 4		= 5 x 7 / 6	= 8 x D
0-150	156	114	30	42	84	1.0	0.50	75
150-300	144	103	30	41	73	1.1	0.62	93
300-450	178	134	30	44	104	1.3	0.55	82
450-600	158	119	30	39	89	1.3	0.57	86
600-750	153	120	30	33	90	1.3	0.48	72
750-900	158	124	30	34	94	1.5	0.54	81
Total soil water (mm) over depth of core (sum of Column 9)								489

**Tip:** Air-dry is not oven-dry. Precise estimates of soil water content require oven-dry weights, or else require a correction factor to convert air-dry weights to oven-dry weights.

In practice, the correction makes little difference.

*Calculations:* Calculate the weight of water in each sample as the difference between entries in Column 2 and Column 3. Enter the results in Column 5

Calculate the weight of dry soil in each sample as the difference between entries in Column 3 and Column 4. Enter the results in Column 6

Bulk densities for samples from various depths have to be assumed in this method. Column 7 shows typical values. Enter your own values for bulk density, or use the suggested values in Column 7.

Calculate soil water content by volume (mm of water per mm of soil) by dividing entries in Column 5 by entries in Column 6, and multiplying by entries in Column 7. Enter the results in Column 8.

Calculate mm of water in each depth sampled by multiplying Column 8 by the sampling depth interval (in this example, samples were taken every 150 mm; therefore the depth interval is 150 mm). Enter results in Column 9.

Finally, add all the entries in Column 9 to get the total mm of water to the total depth sampled. In the example (**Figure C4-2**) the soil core contains 489 mm of water in the sampling depth of 0-900 mm. **Not all of this water is available to plants**; some of this 489 mm is unavailable.

#### *Soil water content by weighing:*

##### **Advantages:**

- Gives an objective value for soil water content.

##### **Cautions:**

- Oven-drying: do not exceed 105 degrees C.
- Take several samples from an area.
  - Measure soil water at permanent wilting point to estimate unavailable water content in wetter samples.

## Neutron probe

A neutron probe (neutron moisture meter) provides a quick way of measuring soil water **by volume** over a range of depths. Ideally, you should calibrate a neutron probe for each soil type. However, the supplier of the neutron probe usually provides a calibration that is close enough for general purposes. Experience with a particular neutron probe can substitute for an exact calibration. The readings will not relate to precise millimetres of soil water, but they will, with your experience, tell you if the soil profile is wet enough for sowing.

Neutron probe readings are the most informative when you compare readings on different dates at the one site. For example, the readings will tell you the depth from which plants are drawing water. Poor water extraction from a particular depth may indicate poor root activity due to a hard pan at that depth. Check by digging a hole - away from the access tube to avoid disturbing your reading site - and examine soil structure.

Neutron moisture meters are expensive. Ask your District Agronomist, Extension Agronomist or Soil Conservationist whether a neutron probe is available in your district. Landcare groups may consider the purchase of a shared probe.

*Neutron moisture meter:*

**Advantages:**

- Quick. You can measure soil water at several depths and times without making a new hole each time.

**Cautions:**

- Expensive to buy. See if a probe is available in your area.
- Requires access tubes in the ground: possible nuisance.
- Check soil by the hand test (in relation to the plastic limit) before tillage.

SOILpak