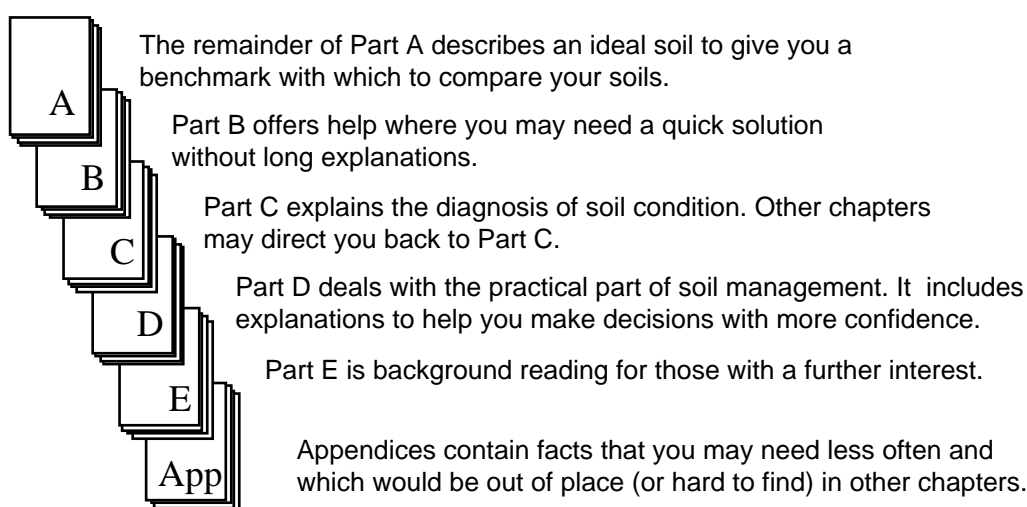


# A1 About this manual

Northern Wheat-belt SOILpak is a soil management manual. It applies to cropping areas with summer-dominant rainfall, in Queensland and Northern New South Wales. The manual aims to help dryland farmers manage their soil for sustainable and profitable production.

**Figure A1-1** Overview of contents.

The manual is divided into parts:



**Soil management** Dryland productivity depends on many factors. Where soil is concerned, there are three factors that we can influence strongly: soil erosion control, effective water use, and soil fertility management.

1. *Controlling soil erosion.* This manual emphasises good management of crops and soil, hand-in-hand with earthworks, to control erosion.

Erosion is influenced by surface cover, the stability of soil aggregates and infiltration rate. Infiltration rate, in turn, varies with soil water content. A soil profile full of water can not store any more, and further rain runs off.

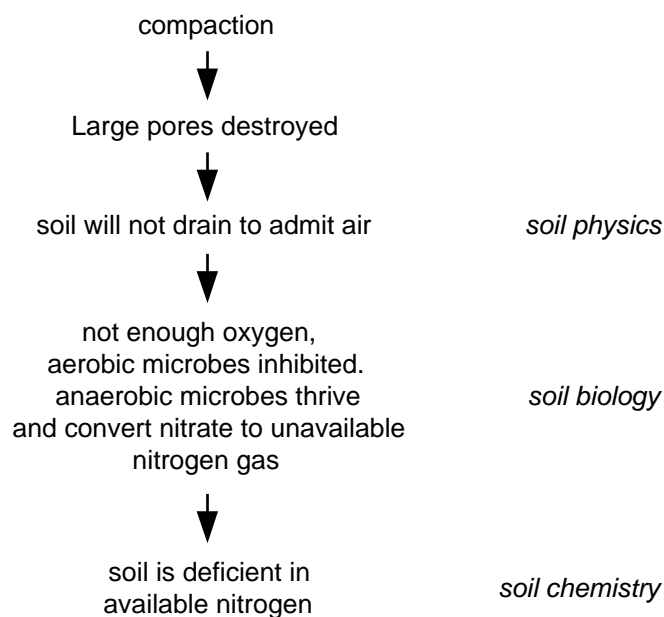
2. *Effective water use.* This manual emphasises good soil management to make the most of rain: allowing better infiltration to store more water during fallow, and allowing better uptake of soil water by crops.

In this region, most of the year's rain falls in summer. Usually, rain falling during the growing season is insufficient for winter crops; they need a good base of stored water from the previous summer's rain.

3. *Managing soil fertility.* This manual emphasises good soil management to maintain all aspects of soil fertility: chemical, biological and physical fertility. Of these aspects of fertility, the single most important for north-western dryland cropping is soil chemical fertility, especially nitrogen fertility.

For all soil types, good management is concerned with providing the right chemical, biological and physical conditions for plant growth. Soil chemistry, biology and physics are all inter-related. See **Figure A1-2** for an example of this inter-relationship.

**Figure A1-2** An example of the inter-relationships between soil chemistry, soil biology and soil physics.



Managing soil *chemical fertility* includes the use of fertilisers to supply plant nutrients, legumes to fix nitrogen from the air, lime to raise soil pH, and gypsum to treat sodic clay soils.

Managing soil *biological fertility* means providing the chemical and physical conditions to encourage the right soil organisms. For example, a well-structured soil provides aerated conditions. These conditions encourage microbes that mineralise nitrogen from organic matter, and discourage those microbes which convert plant-available nitrate into unavailable nitrogen gas.

The term biological fertility includes the activities of earthworms.

Managing soil *physical fertility* includes avoiding damage to soil structure, and repairing damaged soil structure. For example, minimum tillage reduces soil disturbance; tillage at an appropriate soil moisture content maintains and improves soil structure.

Good soil management has economic benefits. **Inappropriate soil management can lead to large yield losses** (depending on the season, yield loss can be total crop failure). As well as reducing yield and increasing production costs, **inappropriate soil management leads to lost opportunities in cropping**. Worse, it can lead to **loss of soil**.

Good soil management improves your chances of getting good crop yields. There is no guarantee that a certain action will increase yield, because yield is influenced strongly by the season. In a favourable season, with the right amount of rain at the right time, even a poorly structured soil can produce a good crop. In a poor season, good soil structure maintains better growing conditions and gives a better chance of a good yield. For example, in a dry season, a well-structured soil allows more rain to infiltrate and allows plant roots better access to stored water.

### **The aim of this manual**

This manual is designed to:

- provide help with identifying soil condition;
- help extension officers, consultants and farmers with soil management decisions; and
- provide teaching-support materials for use at seminars and field days.

The manual is not meant to be read from cover to cover. Turn to the part that interests you. **Chapter B1** contains a trouble-shooting guide that will direct you to relevant chapters.

### **You choose**

The manual gives you relevant information, not a set of answers. Those chapters that contain a list of options will follow a step-by-step format to guide you towards a decision. It is up to you to decide which option best suits your needs.

Your resources, the weather and your personal goals will influence your soil management decision. Similarly, insect, disease and weed control will limit the range of options.

### **Soils covered in this manual**

The Queensland and Northern New South Wales wheat-belt includes a complex range of soils. This manual groups them into two broad management classes:

- cracking clays, which can repair damaged structure through wetting and drying; and
- non-cracking soils, which rely largely on organic matter for a stable structure.

*Cracking clays* have two features that are most important in their management:

- when wet, clay soils are soft and are easily damaged by traffic or tillage;
- cracking clays, because they swell and shrink as they wet and dry, have the capacity to restore their structure.



Go to Chapter E2 for an explanation of swelling and shrinking.

For cracking soils, these two features are the key to their successful management.

*Non-cracking soils* do not naturally repair their structure through shrinking and swelling. Their behaviour depends on:

- texture, or the proportions of different-sized mineral particles in the soil;
- the amount of organic matter, and
- the balance of cations.

Cracking clays are sometimes called "black soils" even if they are not truly black. They may be grey or brown, but look black when compared with red soils. Moreover, this description is often a reflection of the soils' behaviour: all "black soils" crack when dry, and most of them self mulch; "black soil roads" are slippery after rain.

### The future

The aim is to keep the information simple, relevant and accessible. **The emphasis is on a system that is useful in the field.**

The manual is in loose-leaf format to make it easy to update. Researchers can use this manual to identify areas requiring further research. New editions of the manual will include results of that research.

### Other related publications

This manual is one of several SOILpaks aimed at different industries, and all built from contributions by many people working in those industries. The first manual was the irrigated cotton SOILpak. Other manuals in development or being planned will cover the southern wheat-belt, the southern irrigation area, semi-arid cropping, pastures on acid soils, vegetables and perennial horticulture.

An Agfact by NSW Agriculture: number P5.3.6, 'Soil management for irrigated cotton' contains colour photographs of various forms of soil structure. Not all of the management principles are applicable to dryland farming, but the photographs are applicable. The Agfact is available through any NSW Agriculture office and costs \$5.00.

SOILpak

# A2 Ideal soil for farming

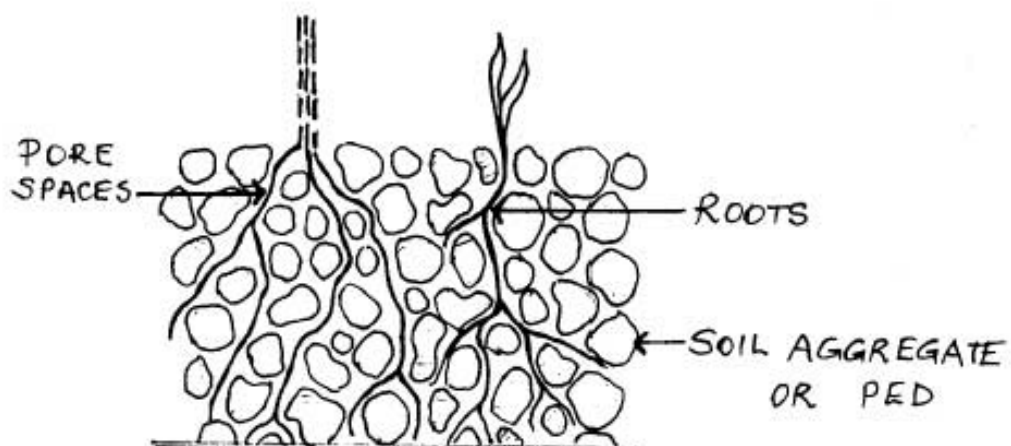
Purpose of this chapter To give a benchmark with which to compare soils normally found in farm paddocks.

Chapter contents

- plant available water capacity (PAWC)
- infiltration
- internal drainage
- nutrition
- seedbed condition
- surface slope
- soil uniformity
- salinity
- sodicity.

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

- E1: Soils of the northern wheatbelt
- E6: Managing the moisture budget for increased water use efficiency
- D-s8: Sodicity
- D-s9: Salinity
- E3: Crusting and hard-setting
- E4: Organic matter
- E5: Plant nutrients



GOOD SOIL STRUCTURE ALLOWS WATER, AIR AND ROOTS EASY ENTRY INTO THE SOIL

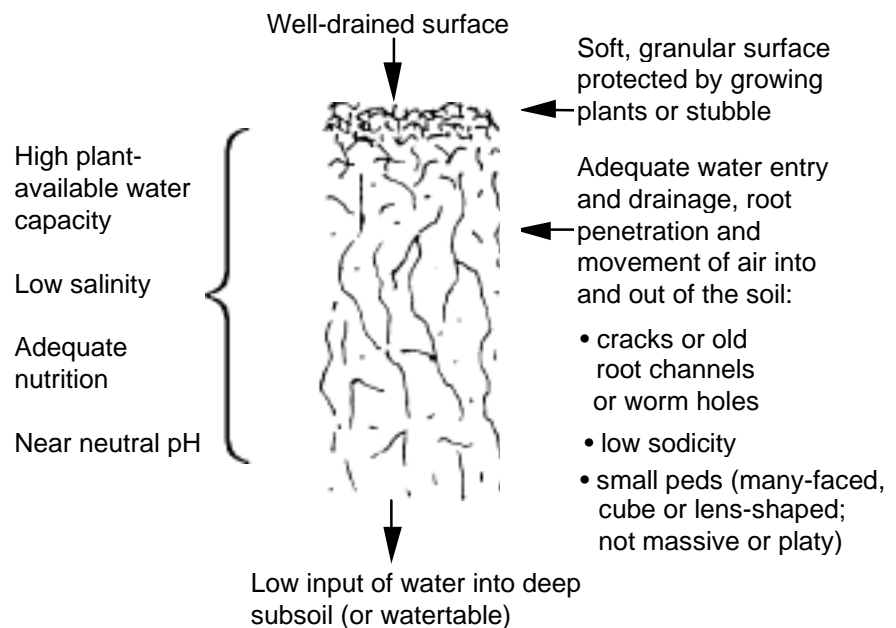
## A2

# Ideal soil for farming

**What soil provides** Soil should provide plants with water, air, nutrients and physical support. Few, if any, soils are ideal in all the aspects shown in **Figure A2-1**. However, soils that have most (but not necessarily all) of the ideal features can grow very good crops.

Good soil caters for these plant needs and in addition buffers plant roots against extremes of, or sudden changes in, temperature, pH or nutrient concentration. Hydroponic ('soil-less') culture caters for these plant needs, but lacks the buffering capacity of soil; it therefore requires constant monitoring and adjustment of the nutrient solution.

**Figure A2-1** Ideal soil.



### **Plant available water capacity (PAWC)**

PAWC is a measure of the maximum amount of water that a soil can store, and later release to plant roots. It is expressed as millimetres of plant-available water in the whole root zone.

If a soil could store enough water to last a crop through the entire growing season it would be an extremely valuable resource. In reality, stored water is never enough for maximum yield: in-crop rainfall is also needed. Nevertheless, management of stored soil water in northern wheat-belt cropping is very important.

PAWC is related to soil texture (the proportions of sand, silt and clay). High values of PAWC (up to 230 mm of water) occur in some clay-rich alluvial soils and deep black earths. In sandy soils PAWC may be as low as 50 mm. In all types of soil, it is important to manage the stored water with fallowing, stubble cover and weed control.

Rooting depth affects PAWC. In shallow soils over bedrock and in soils with dense sodic subsoils, PAWC may be between 80 mm and 130 mm of water.

Structural damage can reduce PAWC. For example, crusting can restrict water entry; a plough pan can restrict root and water penetration.

**Infiltration capacity**

Infiltration is the downward movement of water through the soil surface. A soil with a large infiltration capacity allows more rain to enter the soil, hence less rain runs off the surface compared with a soil that has a smaller infiltration capacity.



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

Black earths, and the better structured grey and brown clays - with their extensive cracking - allow easy entry of water when they are dry. As they become saturated, the cracks close and water entry is slower.

Sands and loams also have good surface infiltration if they do not set hard or form an impermeable crust. Pasture or retained stubble will reduce the tendency of the soil to set hard or crust.

When a soil is full of water (and obviously there is no room for any more water) rain runs off. However, the soil does not need to be full of water before run-off starts. Run-off can occur at any time that the rainfall rate exceeds the infiltration capacity of the soil; and the infiltration capacity becomes lower as the soil becomes wetter. For this reason, 'fallow efficiency' (the proportion of rain that the soil stores) declines gradually over the fallow period.

The impact of raindrops on a bare soil surface can damage the surface structure and seal the soil. Stubble cover protects the soil from raindrop impact.



Go to Chapter E6 for information on entry and storage of rainfall.

When the intensity of rain exceeds the infiltration capacity of a soil, water will run off. However, stubble on the soil surface can detain

water and allow more to infiltrate. Hence zero tilled, stubble-mulched paddocks refill with moisture sooner than conventionally tilled paddocks.

Compaction of the soil by traffic or stock will reduce infiltration capacity. Sodlicity has a similar effect.

A rough surface provides hollows that trap rain water. However, if infiltration capacity is low, much of the water will be lost as evaporation before it can soak in. Stubble cover is more effective than a rough surface.

### Internal drainage

The redistribution of water within the soil following infiltration depends upon the internal drainage of the whole soil profile. Good internal drainage allows water to move away from the surface so that air can enter. Air-filled pores allow exchange of gases with the atmosphere: the replenishment of oxygen used by root respiration, and the elimination of carbon dioxide so produced.

Soils with dense, sodic<sup>1</sup> subsoils have poor internal drainage. A sodic subsoil can be present in any soil type, but is more common in grey and brown cracking clays and red-brown earths.



Go to Chapter D-s8 for information on sodicity.

Some soils have a clay subsoil that is far less permeable than the sand or loam that lies above it (these are 'duplex' or 'texture-contrast' soils). Water lying on top of the less permeable subsoil may lead to poor aeration (waterlogging) within the root zone.



Go to Chapter D-s2 for advice on improving subsoil permeability.

### Nutrition

A soil should have sufficient nutrients to ensure that crop growth is not limited.

The pH of a soil is very important for plant nutrition because pH affects the availability of nutrients to plants. Most plants grow best when soil pH (measured in calcium chloride solution) is between 5.0 and 7.0. Below pH 5.0, aluminium and manganese become more soluble and may reach concentrations which are toxic to plants.



Go to Chapter B6 for information on liming.

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<sup>1</sup>Sodic soils are those with greater than 5% exchangeable sodium and low salinity. The sodicity predisposes them to disperse on wetting.

Other nutrients such as phosphorus and molybdenum may be less available to plants. Above pH 7.0 manganese, iron, copper, zinc and boron become less available to plants.

The three major plant nutrients are nitrogen, phosphorus and potassium. Plants need moderate amounts of calcium, magnesium and sulphur. Trace elements include iron, manganese, zinc, copper and boron.



Go to Chapter B10, D-s3 or E5 for more information on plant nutrition.

The balance of exchangeable calcium to exchangeable magnesium used to be considered important in plant nutrition. However, research has shown no differences in plant growth over a wide range of calcium:magnesium ratios. A low calcium:magnesium ratio (less than 2) may aggravate the tendency of a sodic soil to disperse. To prevent dispersion, apply frequent small doses of gypsum.



Go to Chapter C2, D-s8 or E2 for more information on clay dispersion.

Many soils that have been cropped for a number of years are nitrogen deficient, unless the crop rotation included **significant** legume phases. Nitrogen management includes stubble management, legume or pasture rotations, and the timing of fertiliser applications.

### Seedbed condition

A friable surface tilth provides good conditions for seedlings to emerge and establish.

On cracking clays there is often a self-mulching surface (fragments produced by wetting and drying). However, silty or fine-sandy topsoils, and even some clays, may, if left bare, set hard throughout the surface layer or form a surface crust. This hard-set layer or crust may need to be mechanically broken to allow seedling emergence.



Go to Chapter B4 or E3 for more information on crusting and hard-setting.

The best way to prevent hard-setting or crusting is to add organic matter to the surface, either by stubble retention or through a pasture phase.

### Slope

A gentle slope is desirable; this assists surface drainage without a high risk of erosion. However, steeper slopes can also have a low erosion risk, provided that they have at least 70% surface cover (plants or stubble).

The greater the slope that you are farming, the higher the risk of erosion under heavy rainfall. Erosion control banks and the careful management of surface cover reduce the erosion risk. If you are cropping a fairly steep area, choose a crop that will hold the soil (for example a fibrous rooted rather than tap rooted crop) and retain the stubble for as long as you can.



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

On a level surface (especially with clay soil) ponding or flooding can occur. This results in poor air flow through the soil to the crop roots. Ideally, a soil should have enough slope to drain excess water before waterlogging affects the crop. Raised beds can help surface drainage.



Go to Chapter D-s7 for more information on bed farming.

### Soil uniformity

A paddock is easier to manage if the soil type is the same over the whole area. All parts of the paddock then respond similarly. Decisions about tillage, fertilising or planting can be applied to the whole paddock.

Where patches of different types of soil occur, consider separate management. A map of soil types will help you to divide your property into management units. Alternatively, be aware of the differences in a paddock when planning tillage and fertiliser requirements.

Gilgai (natural mounds and depressions on some clay soils) can also lead to variable crop performance and can be difficult to manage.

However, non-uniformity (diversity) in soil type can be an advantage. Different seasons will suit different soil types. For example, a wet season may waterlog a clay soil, but crops on lighter country will do well. In a dry season, the opposite will be true. Thus the yield over the whole farm can be more stable from year to year, with less danger of a complete failure.

### Salinity

Salinity is a measure of the **total** soluble salts in the soil, not just sodium chloride. An ideal soil has low salinity. This does not mean **zero** salinity: a soil with zero salinity would not have any dissolved salts in the soil water. With no dissolved salts, clay (even a non-sodic clay) may disperse, making the soil structure unstable. A soil with zero salinity would not provide plant nutrients (plants absorb nutrients as dissolved salts).

Most grain crops are fairly tolerant of salinity. However, if the soil is highly saline, expect a yield loss or crop failure. Crops that are particularly sensitive to salinity include most of the legumes (peas, beans, clovers and medics), horticultural crops (vegetables and fruit) and maize.



Go to Chapter D-s9 for more information on salinity.

### **Sodicity**

Sodicity (the proportion of exchangeable sodium in the total exchangeable cations) should be low. High sodicity causes excessive swelling and clay dispersion, leading to structural breakdown.

At the surface, structural breakdown can cause crusting. A crust can limit seedling emergence and reduce water entry. Surface crusting is more serious in the non-cracking soils, as these soils do not have the capacity to break the crust through shrinkage.

A sodic subsoil swells excessively when wet. The swelling closes pores and restricts drainage. Subsoil sodicity often causes problems with air and water movement through the soil, one of the results being waterlogging.



Go to Chapter D-s8 for more information on sodicity.

In cases where a porous topsoil overlies an impermeable subsoil, the soil may become "spewy". Where topsoil is eroded to expose a sodic subsoil, that subsoil is very prone to further erosion.