NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – cotton growers - Readers' Note

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

http://www.dpi.nsw.gov.au/agriculture/resources/soils/guides/soilpak/cotton

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

PART A. INTRODUCTION

A1. The aim of this manual

SOILpak for cotton growers, third edition, is a ‘Best Practice’ soil management manual for the Australian cotton industry. It focuses on irrigated cotton production, but contains a supplement for dryland growers.

Grey and brown cracking clays (sometimes referred to as Vertisols or Vertosols) are the most common of the soil types used by Australian cotton growers, so they receive the most attention in this manual. However, other soil types such as hardsetting red soil are important in some districts.

This SOILpak concentrates on the skills needed to:

- assess the condition of a soil, with emphasis on soil structure
- understand the management options for maintaining or improving soil condition.

The package does not aim to make the final decision for cotton growers. Instead, it provides options which can assist growers to develop successful soil management strategies.

Good soil management has economic benefits. Poor soil management can lead to large yield losses (up to one-half of the potential yield) and/or unnecessary input costs.

Sensible soil management also improves the condition of the surrounding environment by reducing erosion, deep drainage and emission of harmful gases.

The information in this manual was collated from a wide variety of sources, many of which are not easily accessible. Being in loose-leaf format, SOILpak can easily be updated.

SOILpak should be read in conjunction with:

- NUTRIpak, a companion manual dealing with cotton nutrition issues
- MACHINEpak, which describes the machinery available for land preparation
- Australian cotton industry *Best management practices manual* for minimising the impact of pesticides on the environment.

A companion manual, *SOILpak Pocket Notes*, provides a summary of field methods, laboratory procedures, critical limits and management options that are described in SOILpak:

- *SOILpak Pocket Notes* is a small, robust document that is very portable.
- The bulkier SOILpak manual is best kept in the office.

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See *SOILpak Pocket Notes*

INTENDED AUDIENCE

SOILpak is intended for the following groups within the Australian cotton industry:

- growers who want to learn more about how to manage their soil
- consultants and extension officers who wish to become more skilled in advising their clients on soil management.

The manual caters for two distinct types of cotton growers:

- users wanting an overview and/or quick help
- ‘best management practice’ users wanting measures of soil condition, and details of options for overcoming soil management problems.

Examples of pathways through the manual, and likely entry and exit points, are shown in Figure A1-1. To deal with a specific problem, refer to the index to find the relevant information—it is not necessary to work through the whole manual.

YOU CHOOSE

Those chapters that contain a list of management options have a step-by-step procedure to guide you towards a decision. You will be asked which of several circumstances best describes your situation. Each circumstance is matched with a list of possible options.

It will be up to you to decide, given your resources and economic situation, which option best suits your needs. Your decision must take account of insect, disease and weed management and equipment availability. You will have to decide how much time you have and what the risk of unfavourable weather is likely to be.

The weather is an over-riding factor in all farming operations. *Remember, when following any plans or guidelines, that the weather may not allow them to be realised.*

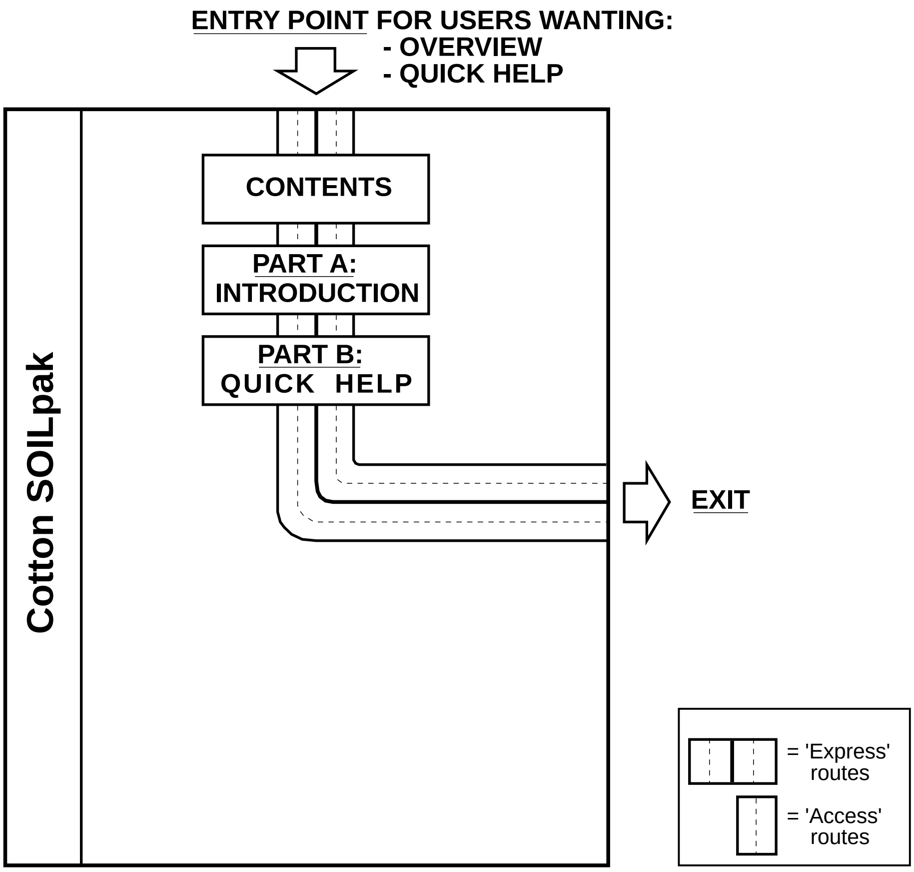
There is no doubt about the value of soil assessment—it is recommended strongly. However, the final decision about which soil management option to select is the responsibility of the growers and their advisers.

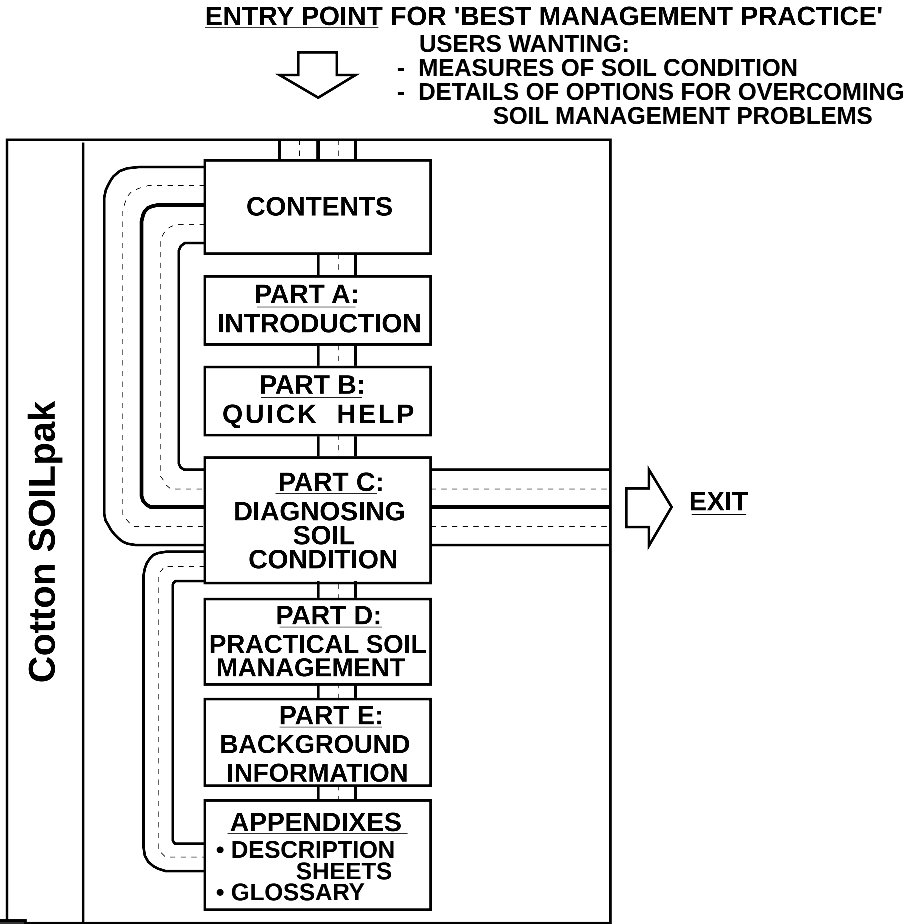
OVERVIEW OF CONTENTS:

The manual is divided into parts and chapters:

- The remainder of Part A describes an ideal soil so that you can form a picture of what to aim for.
- Part B offers help for a range of situations where you may need a quick solution without long explanations.
- Part C concentrates on the diagnosis of soil condition, with emphasis on soil structure and information from the field and laboratory. Other chapters may refer you back to Part C.
- Part D deals with the practical aspects of soil management (the ‘how’) following soil diagnosis, but includes some background information (the ‘why’) to help you make decisions with more confidence.
- Part E contains background reading. It has a more theoretical tone and focuses on soil processes.
- The appendixes include a glossary of soil management terminology, the description sheets and a further reading list.

Figure A1-1. Pathways to finding information in this manual





Each chapter starts with a summary outlining the contents of that chapter. *SOILpak Pocket Notes* provides a brief summary of the entire SOILpak manual.

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See SOILpak Pocket Notes

HOW TO USE THE SOILpak MANUAL– SOME EXAMPLES

To illustrate how the SOILpak manual can be used by cotton growers and their consultants, consider the following four examples:

Example 1

An entire cotton field near Warren had poor growth and disappointing yields during the previous summer. The following pathway was used to diagnose and overcome the problems:

Trouble-shooting guide

- Figure B1-1.
- Figure B1-3.

Field signs

Hard, dense subsoil; dispersion.

Soil pit digging: where, how and when?

- Chapter C1.

Diagnosis of soil condition; comparison with critical limits

- *Green* description sheet (Appendix 6).
- Chapters C2, C3 and C4.

Conclusion

Serious compaction caused by land development under wet conditions; sodic topsoil.

Management options

- Soil drying with a well-fertilised wheat crop (Chapter D2).
- Gypsum application (D2).
- Deep tillage (D2).
- Assess structure after deep tillage (C5).
- Controlled traffic (D1).
- Ongoing monitoring of soil condition (C10).

Example 2

Yield mapping of a cotton field near Wee Waa indicated a 250% difference in lint yield between the best and worst sections, even though a controlled traffic farming system had been introduced two years earlier. The following pathway was used to see if problems in the poor area were soil related:

Trouble-shooting guide

- Quick help (see Chapter B8).

Soil pit digging: where, how and when?

- Chapter C1.

Diagnosis of soil condition; comparison with critical limits

- *Green* description sheet (Appendix 6).
- Inspections in both the good and poor sections of the field.
- Chapters C2, C3 and C4.

Conclusion

Sodic subsurface and subsoil in areas with poor yield.

Management options

- Gypsum application; variable rate (see Chapter D2).
- Ongoing monitoring of soil condition (see Chapter C10).

Example 3

One hundred and twenty millimetres of rain fell half-way through harvest of a cotton crop near Dalby. Attempts to continue harvesting caused large ruts in the furrows. The following pathway was used to develop a soil management plan for the next cotton crop.

Trouble-shooting guide

- Quick help (see Chapters B3 and B4).

Soil pit digging: where, how and when?

- Chapter C1.

Diagnosis of soil condition; comparison with critical limits

- *Green* description sheet (Appendix 6).
- Inspections in both the damaged and undamaged sections of the field.
- Chapters C2, C3 and C4.

Conclusion

Encroachment of compacted wheel tracks into beds where wet picking occurred.

Management options

- Dry damaged soil with a rotation crop (Chapter D2).
- Assess structure after soil drying and cracking (Chapter C5); and deep plough if necessary.
- Use controlled traffic with narrow wheeled machinery (Chapter D1).
- Ongoing monitoring of soil condition (Chapter C10).

Example 4

A new cotton development was proposed in the lower Macintyre Valley. Recently published soil maps of the district suggested that salinity and sodicity were potential problems. The following pathway was used to produce a soil management plan for the development project.

Trouble-shooting guide

- Quick help: Soil survey for development or redevelopment (see Chapter B9).

Soil pit digging: where, how and when?

- Chapter C1.

Diagnosis of soil condition; comparison with critical limits

- *Orange* description sheet (Appendix 6).
- Pit inspection on a 150 m grid; EM survey.
- Chapters C2, C3, C4, C7 and C8.

Conclusion

Topsoil and sub-surface wetter than the plastic limit; sodic subsoil.

Management options before landforming

- Dry soil with a well-fertilised wheat crop (Chapter D2).
- Develop fields by using landforming contractors.

Management options after landforming

- Quick help (see Chapter B10).
- Chapter C1.

Diagnosis of soil condition; comparison with critical limits

- *Yellow* description sheet (Appendix 6).
- Inspection of three representative pits.
- Chapter C4.

Conclusion

Exposure of sodic subsoil; compacted sub-surface and subsoil.

Management options

Options to deal with problems identified during the grid survey and post-landforming inspection:

- Gypsum application (D2).
- Avoiding salinity problems (D4).
- Deep tillage (D2).
- Assess structure after deep tillage (C5).
- Controlled traffic (D1).
- Ongoing monitoring of soil condition (C10).

THE FUTURE

The producers of this edition of *SOILpak* have worked hard to keep its contents simple, relevant and accessible. The emphasis is on a system which is useful in the field and easily updated.

As research workers and farm managers develop and refine improved methods of diagnosing and improving soil condition, the new methods will be incorporated into *SOILpak* via updates.

We reserve the right to update or change this information at any time without notice. Your local agronomist can provide the latest list of updated pages. If you have access to the Internet, updates will be provided through the Technology Resource Centre, Cooperative Research Centre for Sustainable Cotton Production, Narrabri. Their Home Page, *Oz cotton on line,* is at http://www.cotton.pi.csiro.au.

Soil management training courses (Figure A1-2) are being held in several regions through 1998–99 to demonstrate the use and application of the manual in the field.

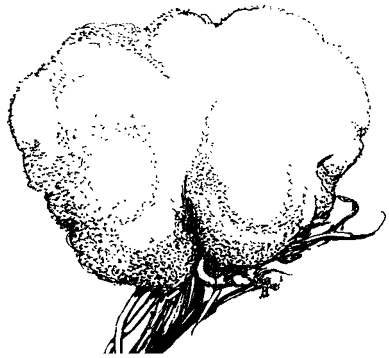
IDENTIFYING RESEARCH NEEDS

Compilation of this edition of *SOILpak* has highlighted several gaps in our knowledge, some of which are mentioned throughout the manual. Further research is needed, despite excellent progress over the last 15 years. Research leaders and the funding bodies have been given details of these problems.

On-farm trials are most important for testing new ideas and fine-tuning existing recommendations (see Appendix 3).

Figure A1-2. Participants in a soil management training course

A2. The ideal soil for cotton



PURPOSE OF THIS CHAPTER

A benchmark is provided against which irrigated and dryland cotton soil types can be compared.

CHAPTER OVERVIEW

This chapter covers the following points:

- infiltration and internal drainage
- plant available water capacity (PAWC)
- slope, surface drainage, waterlogging and flooding
- suitability of soil structure for seedling establishment
- suitability of soil structure for root growth
- salinity
- pH
- nutrition
- erosion control
- soil variability and micro-relief
- technical specifications (at the end of this chapter).

Other chapters to refer to:

- Chapter E3: ‘Effects of sodicity and salinity on soil structure’
- Chapter E5: ‘Organic matter and soil biota’
- Chapter E6: ‘How soil structure and temperature affect plant growth’.

FEATURES OF AN IDEAL SOIL FOR COTTON- AN OVERVIEW

The ideal soil condition for high-yielding, low-cost cotton production is shown in Figure A2-1. The features mentioned in this diagram are explained in the following text.

Infiltration and internal drainage

Cotton has poor tolerance of waterlogging. To allow adequate water entry, and to encourage root exploration by quickly re-establishing aeration after irrigation and rainfall, cotton soil needs to have good porosity for infiltration and internal drainage.

The alluvial soil types, black earths and the better structured grey and brown clays—with their extensive cracking and vigorous root growth—provide favourable conditions. Soil types with dense, sodic subsoils have poor profile permeability and drainage.

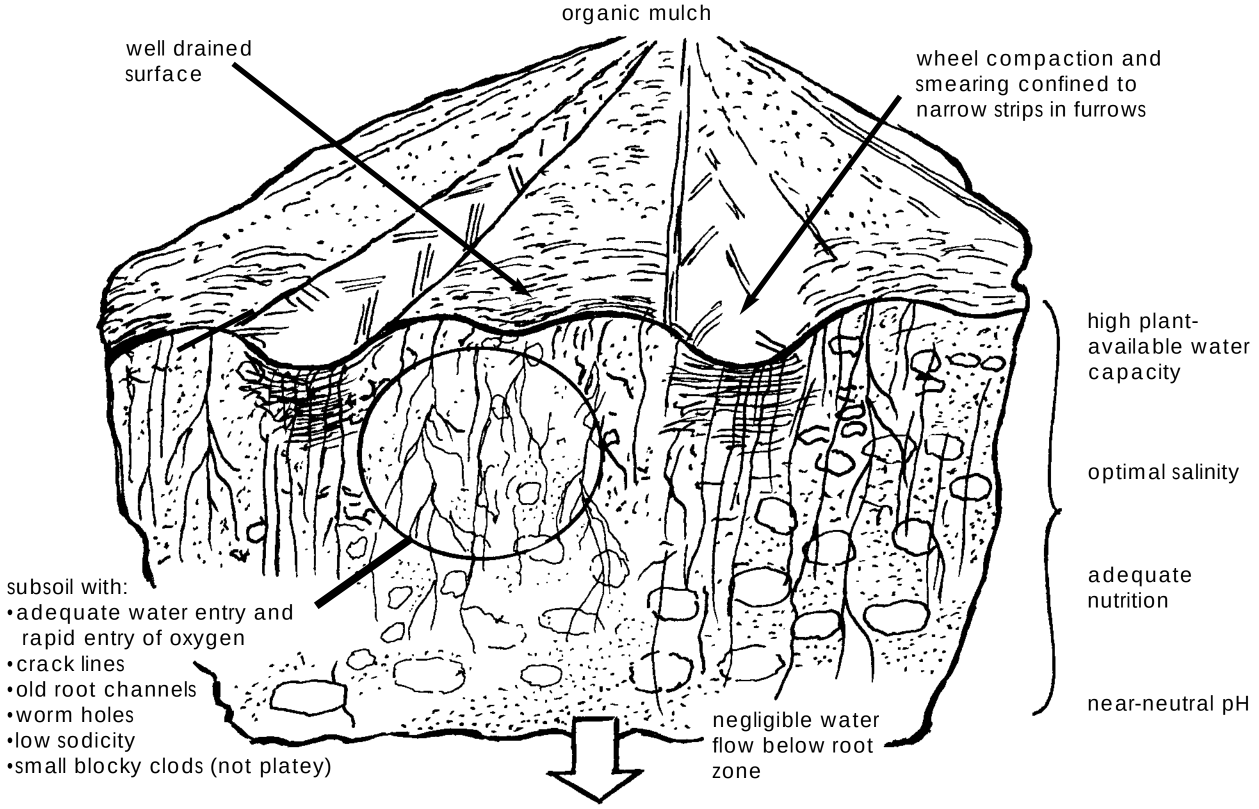
Structural damage, due to excessive traffic or tillage at incorrect moisture contents, may create large platey clods in any cotton soil. Such damage restricts permeability.

While the root zone should be permeable, the deep subsoil should be almost impermeable; excessive deep drainage may cause water tables to rise. Irrigation management and crop rotation should aim to minimise the amount of water draining to the deep subsoil.

Plant available water capacity (PAWC)

Large values of PAWC, which are found in some clay-rich alluvial soil types and deep black earths, allow a longer interval between furrow irrigations. Under dryland conditions, large values of PAWC delay the onset of drought stress in crops.

Figure A2-1. Features of an 'ideal' cotton soil



Total PAWC is poor in shallow soil over bedrock, in sandy soil, and in soil with dense sodic subsoil. The ability of crop roots to access the available soil moisture is reduced by structural damage. Compaction may also reduce the ability of a soil to allow water entry.

Slope, surface drainage, waterlogging and flooding

An appropriate slope and field length, in combination with furrows and hills/beds, will ensure good surface drainage and reduce waterlogging. Land forming using laser grading usually is needed to provide the required slope across all parts of a field, particularly under irrigation. Surface drainage and tail drains must be designed to minimise flooding during heavy rain, the consequences of which may be disastrous during the seedling stage.

Furrow-edge compaction and water application rates need to be matched so that the root zone does not become waterlogged due to excessive water intake.

Slopes that are too steep create erosion hazards.

Suitability of soil structure for seedling establishment

Rapid and uniform seedling emergence is most likely to occur where the surface tilth is friable and has fine water-stable clods. Those clay soil types with a surface structure that regenerates by swelling and shrinking as the soil is wetted and dried (self-mulching); e.g. black earths, and most grey and brown clays; provide ideal seedbed conditions if protected from mechanical compaction.

In some soil types, the surface may slake and disperse (collapse) and become waterlogged following irrigation and/or rain, then set hard when dry. This restricts water infiltration and seedling emergence. Soil types with low clay contents (less than about 35% clay) and insufficient organic matter (less than 2% organic matter) and poor biological activity are particularly prone, for example red-brown earths, solodized solonetz and solodics.

Even in soil that swells and shrinks strongly, an excess of sodium attached to the clay particles (sodicity) makes the seedbed dispersive and more prone to waterlogging, hard when dry and too cloddy when tilled.

Organic mulches (e.g. cereal straw) on top of the seedbed protect it from the damaging effects of raindrop impact, and may help to reduce slaking and dispersion when the soil is wet. Mulches encourage earthworms, which regenerate soil structure by producing burrows and stabilising soil aggregates.

Suitability of soil structure for root growth

Crops are more likely to produce high yields when their roots are able to grow freely.

Root growth is retarded by the same factors that restrict water entry and seedling growth (see the previous sections ‘Infiltration and internal drainage’ and ‘Suitability of soil structure for seedling establishment’). Subsoil sodicity tends, however, to cause waterlogging by the process of excessive swelling rather than dispersion of clay particles.

Salinity

Cotton is more tolerant of salinity than most other crops, although some crops grown in rotation with it are sensitive. Cotton grown on ‘very highly saline’ soil types will suffer yield loss. It is only semi-tolerant to boron salts.

A ‘very highly saline’ soil would have a root zone with an $EC_{1:5}$ greater then 1.33 dS/m for a medium clay, or greater than 1.72 dS/m for a heavy clay.

pH

The optimum pH range (measured in 0.01M $CaCl_2$) for cotton lies between 5.5 and 7.0. Acidic conditions, or extreme alkalinity caused by an accumulation of sodium carbonate, do not suit cotton crops. Their roots are very sensitive to soluble aluminium—concentrations of 0.5 ppm, which may develop when pH is less than 5.0, greatly reduce the root development of cotton seedlings.

Nutrition

Fertility status, other than for nitrogen, is generally medium to high in soil types used for cotton production in Australia. Total and available nitrogen levels are usually low (especially after several cotton crops) and satisfactory yields require applications of nitrogen fertiliser.

An ideal soil for cotton would contain sufficient plant nutrients for the crop’s growth. Refer to *NUTRIpak* for further details.

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See NUTRIpak for more information on cotton nutrition.

For cations, the balance between the various elements is as important as their concentrations. Expressed as a percentage of the soil’s cation exchange capacity, the desirable ranges are:

- calcium 65–80%
- magnesium 10–15%
- potassium 1–5%
- sodium 0–1%
- aluminium <5%.

Values of exchangeable magnesium percentage greater than 20 may induce potassium deficiency. Conversely, values of exchangeable potassium percentage above 10 may result in magnesium deficiency.

The desirable level of exchangeable sodium percentage (0–1%) is well below the danger level (5%) for clay dispersion. The desirable levels of calcium (65–80%) and magnesium (10–15%), besides providing adequate nutrition, also discourage clay dispersion.

Erosion control

The risk of soil loss by water and wind erosion is reduced if the soil surface is protected by a straw mulch. Coverage should be at least 30%, preferably anchored.

Soil variability and microrelief

To allow efficient management of each crop area as a single unit, it is highly desirable that the soil of the area be fairly uniform. A complex distribution of soil types with differing tillage and irrigation requirements, for example, cannot be managed optimally.

In some cotton growing locations cracking clays are intimately associated with hard-setting soil types. The latter, with poor intake of water, require more frequent irrigation than the former, and often there are different fertiliser and herbicide requirements.

Gilgai micro-relief, once levelled, can also provide a complex mosaic with former mound and depression sites giving differing crop performance which may persist for many years.

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See Chapters C1 to C10 for more information on the tests mentioned in the tables.

FEATURES OF AN IDEAL SOIL FOR COTTON- TECHNICAL SPECIFICATIONS

Part C of this manual describes how to measure and interpret soil properties that influence the growth of cotton.

A summary of target values is shown in Tables A2-1 and A2-2. A

Table A2-1. Key soil properties influencing the growth of cotton

Process	Key soil properties	Targets
Water movement	**SOILpak score**	**>1.5 (depth = 0.0–1.0 m)**
		<0.5 (depth >1.0 m)
	ASWAT score*	**<6; preferably = 0**
		(depth = 0.0–1.0 m)
		>6 (depth >1.0 m)
Water storage	Plant Available Water Capacity	
	(PAWC)	maximise
Seed germination	**SOILpak score**	**>1.5 (topsoil; 0.0–0.1 m)**
	ASWAT score*	**<6; preferably = 0**
		(depth = 0.01–0.1 m)
	Soil temperature	18–31°C (diurnal range)
	Electrical conductivity (EC_e)	<6.8 dS/m
	pH (0.01 M $CaCl_2$)	5.5–7.0
	Nutrients	see Table A2-3
Root growth	**SOILpak score**	**>1.5 (depth = 0.0–1.0 m)**
	ASWAT score*	**<6; preferably = 0**
		(depth = 0.0–1.0 m)
	Temperature	18–31°C (diurnal range)
	Electrical conductivity (EC_e)	<7.7 dS/m
	pH (0.01 M $CaCl_2$)	5.5–7.0
	Nutrients	see Table A2-2
Erosion control	Organic residues	> 30% cover
	Field slope	0.01–0.05%
		(1:750–1:1500)

> = greater than, < = less than

* associated soil chemical factors (of relevance to soil structural stability in water) are summarised in Table A2-2

Table A2-2. Summary of chemical factors affecting soil structural stability in water

Soil factor	Values associated with stability (low ASWAT scores)	Values associated with instability (high ASWAT scores)
Exchangeable sodium percentage (ESP)	<2	>2 (low EC) >15 (high EC)
Electrochemical stability index ($EC_{1:5}$/ESP)(ESI)	>0.05	<0.05
Ratio of exchangeable calcium to exchangeable magnesium (Ca/Mg ratio)	>2.0	<2.0 (particularly <1.0)
Calcium carbonate ($CaCO_3$) content, %	>0.3	<0.3
Organic matter —total, %	*	*
Organic matter —labile, %	*	*

> = greater than, < = less than

* critical limits for organic matter (OM) content have not yet been established for different types of cotton soil. However, in terms of soil structural condition, the more OM there is (particularly labile OM) the better, if accompanied by an adequate supply of calcium ions.

Table A2-3. Soil-test values below which nutrients may be deficient

	Nutrient		Extraction method*	Critical level (mg/kg)
**	nitrogen	NO_3	aqueous buffer	20–25
	phosphorus	P	bicarbonate	10–20
**	sulfur	S	Ca dihydrogen orthophosphate	5–10
***	iron	Fe	DTPA EDTA	2 80
	manganese	Mn	DTPA	2
***	zinc	Zn	DTPA EDTA	0.5 4.0
***	copper	Cu	DTPA EDTA	2 2
***	boron	B	magnesium chloride calcium chloride/mannitol hot water	1.5 0.4 0.15
				(cmol+/kg)
	calcium	Ca	ammonium chloride	20–35
	magnesium	Mg	ammonium chloride	10–12
	potassium	K	ammonium chloride	0.38 (150 ppm)

* Different laboratories may use different extraction methods.

** Nitrogen and sulfur are both dynamic nutrients. Their values can vary through the year, depending on such factors as soil temperature and moisture.

*** Soil tests for trace elements are unreliable. This table gives only a rough guide to critical levels.

A3. District soil management problems

Emerald
Theodore
Biloela
Dalby
Goondiwindi
St George
Mungindi
Moree
Collarenebri
Gunnedah
Narrabri
Wee Waa
Walgett
Trangie
Warren
Bourke

PURPOSE OF THIS CHAPTER

Some soil management problems under irrigated and dryland cotton—e.g. subsoil compaction—have been observed in all cotton growing districts. Other problems are more specific—e.g. erosion on steep fields at Emerald, and poor seedling emergence on hardsetting loam soil at Trangie.

This chapter describes the main soil management problems highlighted by extension leaders across the various districts.

Other chapters to refer to:

- Chapter E1: 'Australian cotton soil'.

summary of nutrient ‘critical limits’ is presented in Table A2-3.

DISTRICT PROBLEMS

Emerald

- On sloping black earths, considerable soil movement may occur when there is high intensity rainfall early in the season. With depth to the underlying bedrock usually less than 150 cm, such erosion losses are of concern.
- Watertable salinity has affected some areas, but drainage schemes have been installed to deal with the problem.
- 2 m wide permanent beds are not functional; the slope prevents adequate wetting-up.
- Poor trash breakdown during dry winters.
- Small blocks make rotation uneconomical.

Theodore/Biloela

- Small fields, mixed soil types, variable grades.
- Not much rotation.
- Seedling disease incidence increasing.

Darling Downs

- Most of the dryland area is subject to overland flow, with subsequent soil erosion problems.
- Soil-borne diseases are a big concern, particularly in the cooler areas.
- Very dry winters; problems with wetting up the soil and decomposing trash, but soil compaction problems are not severe.
- Legumes in rotation have fared poorly.
- Controlled traffic through fallow and rotation crops—problems with machinery compatibility.

St George

- Grey/brown clays which are quite variable across fields.
- No 2 m wide beds, because of subbing problems.
- Soil condition thought to be improving under irrigation, relative to pristine areas.

Macintyre Valley

- Problems in some areas with sodic soil.
- Long fallow disorder.

Northern New South Wales

- Some machinery tends to become heavier with the introduction of new models, e.g. cotton pickers.
- Compaction due to incompatible wheel track centres.
- Poor lateral subbing of irrigation water into beds, particularly on the lighter textured soil near Trangie.
- An excessive number of passes is required to manage permanent beds.

- Dryland salinity problems upstream of irrigation districts.
- Excessive soil movement with through-the-bank irrigation pipes.
- A small percentage of land in the Macquarie Valley and Bourke district is affected by salinity.
- Concern about weed control under reduced tillage.
- Herbicide incorporation is difficult where thick mulches are present.
- Possible adverse affect of agrochemicals on microorganisms that are required to break down organic residues.

All cotton growing districts:

- Poor subbing of irrigation water into permanent beds, particularly on lighter-textured soil.
- How to deal with furrow-edge compaction.
- Tractors often are too big, and their tyres are too wide, for bed farming (particularly during wet periods when the soil is most compactible).
- Guidance systems are needed to overcome 'guess row' variation.
- Uncertainty about when a topsoil is sufficiently disturbed by cultivation to destroy Heliothis pupae.
- How finely divided and incorporated should the stubble be?
- Under dryland conditions, an apparent conflict between Heliothis control and efficient intake of rainwater.
- Salt addition to soil through the use of bore water.

GETTING HELP

All of the problems identified above can be overcome, or at least eased, by good land management.

For assistance with any of the soil management problems that relate to the following issues, refer to Chapter B1:

- Poor seedling establishment.
- Disappointing yields and profitability.
- Excessive costs due to too much cultivation, N application and irrigation.
- Too much erosion.

Also in Part B are 'Quick help' sections to deal with specific on-farm soil management problems.

The apparent conflict between *Heliothis pupae control*, and the avoidance of soil structure problems, is discussed in Chapters B2, B4 and D1.

For specific questions about *red soil management*, refer to Chapter D10.

Questions about *stubble management* are dealt with in detail in Chapter E5.

Salinity hazards associated with the use of *bore water* are discussed in Chapter D4.

Correct *matching of farm machinery and bed architecture* is covered in Chapter D1.