2.5 Managing soils for irrigation

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Key points

- Farm management affects soil structure, which in turn affects plant available water.
- Good soil structure is essential in maximising water use efficiency.
- Soil pit observations, chemical testing and visual inspection will help soil management decisions.
- Irrigation system construction efficiency will be influenced by soil type.

Soil water availability depends on a number of soil properties, including texture and structure.

Soil texture is determined by the particle sizes that a soil is made up of. The proportion and type of the smallest particle, clay, is most important in determining how the soil behaves. Different clays and the cations found within clays affect:

- nutrient-holding capacity
- the capacity of the soil to regenerate, and
- the likelihood of soil problems when subjected to application of water.

Texture and clay type also influence how much of the irrigation water applied to a soil can be stored for use by the plant (Table 2.5.1).

A thorough introduction to soil water is included in WATERpak Chapter 2.1.

Steps for determining plant available water content are well covered in SOILpak and therefore are not repeated here.

Table 2.5.1. Soil type and amount of water available to plants between field capacity and permanent wilting point for well-structured soil (top metre)

Soil type	Plant available water capacity (mm)
Sand	70
Sandy loam	140
Clay loam	140
Heavy clay	150
Well structured clay	200

Source: *Irrigation scheduling of cotton*, CRC information sheet

Soil structure, which is strongly affected by farm management, further influences the amount of water available to plants. The history of tillage, compaction, wetting and drying, plant growth and soil biology and chemistry influence soil structure.

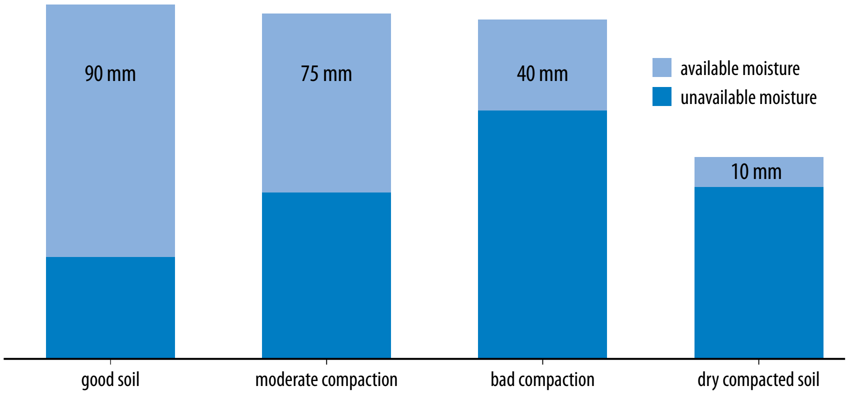
Pores, compaction and plant available water

An interconnected network of macropores is required for good water and oxygen entry to the depth of the root zone.

Disruption to the interconnectivity of pores and reduction of the total pore space by compaction from farm implements and dispersion in unstable soils affects the amount of water that is available to plants between irrigation events.

Compaction is more about loss of root pathways than lowered soil water storage. This is why a compacted soil shows only a small decrease in the total amount of water actually stored in the profile when measured with a sensing probe, but water available to plants is much reduced (Figure 2.5.1).

Figure 2.5.1. Changes to plant available moisture with compaction (cracking clay example, top 60 cm)

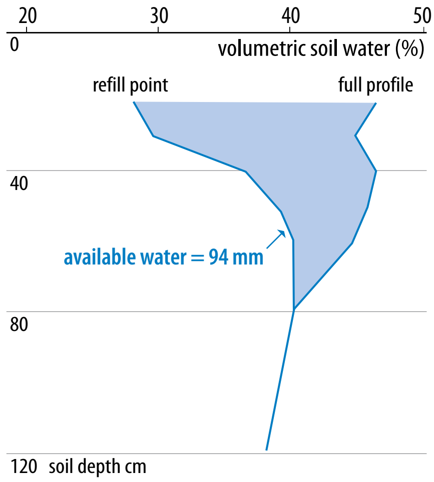


Source: from *Cotton production during drought* 1995

Normally roots follow the path of least resistance when exploring the soil for nutrients or water — the path generally follows natural crack lines, especially in cracking clay soils or biopores (old root channels, faunal tunnels, and so on). As soil compaction increases, there are fewer pores, and roots have to push through soil where pores have been destroyed. There is a maximum force that roots can exert on a soil, and as the soil dries and its strength increases it becomes impermeable to roots. If the soil is well structured with numerous pores, plant roots can still explore a large area of soil by following these cracks or pores.

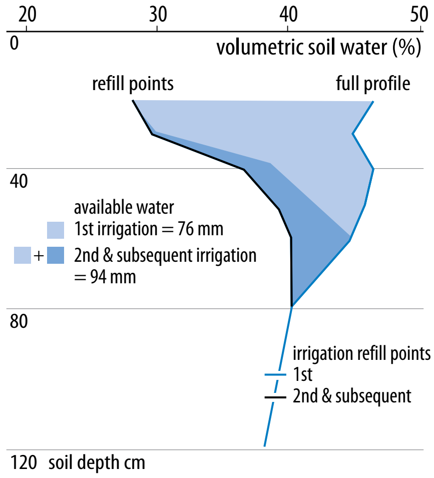
The next three diagrams (Figures 2.5.2, 2.5.3 and 2.5.4) from the SOILpak manual show patterns of water extraction from a well- structured cracking clay soil, a soil with a moderately compacted layer and a heavily compacted soil. Note that the availability of water within the profile can change between irrigation events. As the soil is wet, strength decreases, and there is opportunity for roots to penetrate compacted zones: the extent to which they do this is related to the degree of compaction. Heavily compacted soils may show marginal increases in extraction between each irrigation event.

Figure 2.5.2. Well-structured soil, extraction pattern



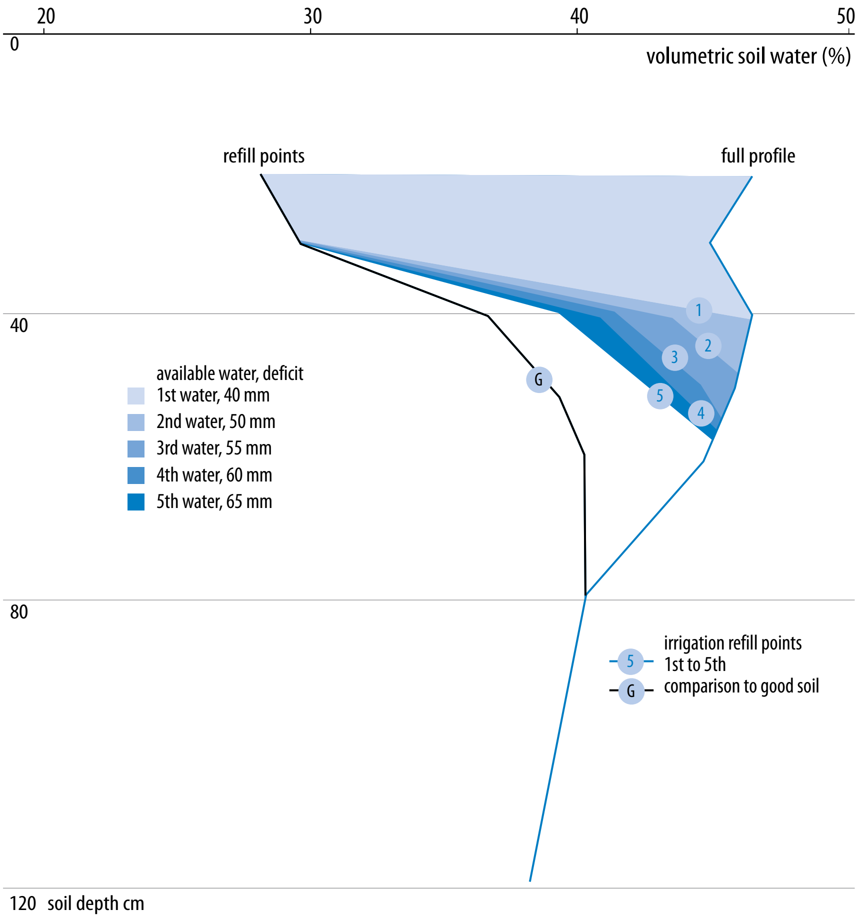
The soil water profiles in Figure 2.5.2 show typical extraction pattern from a well-structured soil. The soil is able to provide the plant with 94 mm of water. Extraction has taken place down to 80 cm. The right-hand line is the amount of water in the profile after irrigation, the line on the left being the amount in the soil when the plants are starting to show signs of requiring water.

Figure 2.5.3 Moderately compacted soil, extraction pattern



This profile in Figure 2.5.3 shows what can happen in a soil that has a light compaction layer that roots are able to penetrate after the first irrigation. The plants before first irrigation are showing stress at a water deficit of 76 mm, with water extraction only to 60 cm depth. Following the irrigation, the plants begin to extract water beyond 60 cm to a deficit of 94 mm, indicating that the roots have penetrated a compaction zone.

Figure 2.5.4 Heavily compacted soil, extraction pattern



The profile in Figure 2.5.4 shows what may happen with severe compaction. The diagram shows 5 subsequent refill points as the season progresses. Following each irrigation, the crop is able to utilise more water as it penetrates the compaction zone, however the crop is never able to extract as much as a crop on a well-structured soil (the G line).

Managing the soil environment

Do I have a soil problem that needs to be addressed?

Simple soil observations can be made to determine if you have soil structural problems. The manual *SOILpak for cotton growers* is a valuable source of information on what to look for in soils if you suspect a problem. Part C of the SOILpak manual ('Diagnosing soil condition') outlines simple methods of diagnosis.

Major problems that interact with irrigation include:

Compaction

- A problem common to all soil types in the Australian cotton industry. Over recent years the use of permanent beds and minimum tillage systems has lowered the incidence of this problem, but wet harvests and movements in plant beds with time can reintroduce the problem.
- Cracking clay soils are particularly vulnerable to compaction damage if trafficked when the soil is moist. If traffic has occurred under these conditions, observations should be made to determine the extent of damage and whether remedial measures are needed.
- Compaction can be managed, and, if confined to limited areas away from the water infiltration and rooting zone, its effects can be minimised.
- Use a visual inspection using a spade or backhoe pit to determine if a problem exists.

Sodicity

- This soil problem caused by high levels of sodium adhering between clay particles is inherent in some Australian cotton soils – the problem can be increased or induced by using irrigation water that is high in sodium levels. Sodicity leads to excessive swelling of the soil and dispersion and breakdown of soil structure. On the surface this can lead to crusting, with associated problems of poor plant establishment and lowered infiltration. At depth it can lead to massive soil structures with reduced pore space that increase problems with infiltration and waterlogging.
- It is possible to address surface sodicity problems with the addition of calcium-based soil amendments such as gypsum and lime. Sodicity at depth can be more of a problem.
- Management should avoid bringing this soil to the surface with tillage operations.
- Use data from a soil test to determine if a problem exists.

Salinity

- In some regions salinity from accumulation of salts within the root zone is a problem. When salt accumulates in the root zone it lowers the amount of water available to plants. Plants become water stressed even if the soil is not dry. Cotton is fairly tolerant of salinity, but rotation crops, especially legumes, can be very susceptible.
- Rising watertables, caused by excessive drainage, can create salinity issues. Conversely, a buildup of salts within the rootzone can also occur from too little drainage, particularly when poor quality water is used for irrigation. This may be a particular issue in dry seasons, especially when using CPLM or drip irrigation (see WATERpak chapter 1.5).
- Management to counteract rising watertables includes lining leaky storages and supply channels. Crop irrigations should be scheduled according to actual crop requirements. If hotspots within the field can be identified, different management on these areas may reduce the salinity problem.
- Management to counteract rootzone salt buildup requires an understanding of the salinity of irrigation water and ensuring the leaching requirement is met. More information on salinity and leaching requirements is included in WATERpak chapter 2.10. A tool for determining the quality of blended water sources is available on the COTTassist website
- Soil test data indicate salinity. Regular soil testing will indicate rising or falling salinity levels (see WATERpak Chappter 2.10).

Low organic matter levels

Low organic matter levels can lead to a lowering of soil stability during rapid wetting, especially in soils that also have a problem with sodicity. Organic matter helps bind the soil in stable aggregates, especially when wetting happens very quickly, as is common with surface irrigation. Organic matter can also partly overcome the effects of sodicity. Soil management practices to enhance organic matter retention include retaining stubble within the field (either standing or incorporated) and the use of minimum tillage principles.

Soil test data can indicate if your organic matter levels are falling or rising over time.

Management issues for soil types common in the Australian cotton industry

Grey and brown cracking clays (vertosols)

In the Australian cotton industry most cotton is grown on this soil type. Features of these soils in terms of irrigation include:

- a high storage capacity for water
- easily damaged if trafficked or worked wet
- self-mulching (repairing)

To manage grey and brown cracking clay soils:

- Be mindful of soil moisture content when working. Use the plastic limit test.
- Controlled traffic limits compaction. Think about traffic wheel patterns in unusual situations.

Controlled traffic has advantages on this soil type - compacted zones in wheel tracks can even be advantageous for support of machinery when the soil is moist.

The key to managing grey and brown cracking clay soils is to be careful of moisture conditions when the soil is worked or driven upon.

A simple test to show if the soil is too wet for working is the **plastic limit test**. Roll some soil from a given depth in your hand. If you can form a ball and then roll a rod shape of 3 mm diameter without the soil crumbling, then the soil is wetter than the plastic limit. Working soil at this moisture content will only remould the soil, destroying pores and creating smeared layers with few pores and high soil strength that makes it difficult for plant roots to penetrate.

To determine if a tillage operation can be completed safely, use the plastic limit test at intervals through the soil profile to the proposed maximum depth of tillage. Don’t till into depths that are above the plastic limit.

If there is no option but to traffic the soil when it is wet, for example during a wet harvest operation, think about where wheels will be travelling with respect to existing wheel tracks: that is, try to maximise the number of non-trafficked furrows.

Cracking clay soils are prone to waterlogging because when they are wet, the soil swells and has a tendency to block pores. Soil management to overcome this problem includes:

- ensuring that there is adequate slope on the field to drain excess irrigation or rainwater. Also, ensure the field is level, with no hollows to collect water.
- building hills or beds high. If waterlogging conditions exist lower in the furrow there should still be an area above the water level that is better drained and aerated for at least a proportion of the crop roots.

Addressing compaction

Limited compaction: the current crop may act to remove some of the damage by promoting the shrink swell cycles in the soil. Watch the crop closely for signs of water stress: crops grown on a compacted soil may show signs of stress more quickly than those grown on undamaged soil.

More serious compaction: may be addressed by biological tillage, that is, growing an actively rooted crop such as wheat to dry the soil and promote swell shrink cycles. Note that the more active the root system and the more wet dry cycles the soil is exposed to, the better the result.

Severe compaction: may be addressed by mechanical tillage when the soil is drier than the plastic limit. The tillage can be targeted at specific zones. Use a spade or backhoe pit to determine the existing problem (see SOILpak Part C); for example, a compacted bed shoulder that is causing water infiltration problems could be addressed at nitrogen application time with a curving gas knife.

Sodic soils

Lack of stability of wet aggregates in sodic soil leads to the problems associated with this soil type. In sodic soils, clay dispersion and increased swelling in the subsoil block pores and reduce pore space. This stops or reduces water and oxygen entering the soils, leading to waterlogging problems. Following dispersion of nonstable aggregates (clods) into their individual constituents of sand, silt and clay, surface sealing blocks pores.

Some sodic soils, although initially stable, can become dispersive after being worked at high moisture contents. Soil management for these soils aims at restoring stability to aggregates or clods to prevent their dispersion when wet.

There are simple tests to check if your soil is dispersive. The ASWAT Test (see SOILpak Chapter C4) involves leaving air dry crumbs of soil in distilled water for a period and checking to see if a milky solution of dispersed clay is formed. The stability of the soil following wet working can be deduced by using the same test but using a piece of soil that has been moistened and then reworked before testing.

Sodic soils can also be problematic when building water storages and irrigation systems, as they are prone to tunnelling if compaction of the embankments is inadequate. Tunnelling occurs as water moves through small pathways in the embankment and dispersed particles move with it. If the wetting event is so fast that the clay doesn't have time to swell to fill the resulting pores, tunnelling can occur that can lead to bank failure. If a storage is to be made of this soil type, special attention should be paid to compaction at the correct moisture content and possibly lining the storage with non-dispersive soil (see WATERpak Chapter 1.6).

Management to avoid surface sealing problems

- Some soils have a stable surface layer overlying a sodic dispersive subsoil. Tillage operations can raise the dispersive soil to the surface, creating problems. Be careful when working this soil type.
- Be aware that tillage can create a problem with surface sealing – some marginally stable soils, if tilled at too high a moisture content, that is, above the plastic limit, can become dispersive. Always attempt to till when the conditions are right for your soil.
- Organic matter in the soil acts as glue that holds soil aggregates together. Try methods to maximise organic matter in the soils and to minimise its breakdown. Good organic matter levels can partially overcome the effects of sodicity.

Will gypsum work?

The addition of gypsum can overcome some of the effects of sodicity at the surface. Note however that gypsum will not necessarily work on all soils. If dispersion is identified as a problem, further soil tests should be carried out to see if the soil would respond positively to the addition of gypsum. A soil may be gypsum responsive if it has an exchangeable sodium percentage (ESP) of greater than 5. Calcium to magnesium ration of less than 2 can also aggravate sodicity problems when the soil is near an ESP of 5. In a responsive soil, gypsum will improve surface aggregation (for better seedling emergence), decrease dry soil strength (to give easier tillage), increase water entry (with consequent longer irrigation intervals) and lengthen the time over which soil physical conditions are suitable for unimpeded root growth.

If the soil does not have inherent chemical stability, the presence of organic matter can compensate. Soil management should aim at maximising organic matter in the soil.

Red soils (loam topsoil)

Red soils lack the regenerative capacity of cracking clay soils. Soil structural problems that will self-repair with cracking clays with a wet/dry cycle will not self-repair on a red soil. Damage to red soils should be addressed before sowing.

A soil management bonus of red soils is that they drain quickly and can be trafficked more quickly than clay soils after irrigation or rainfall events.

Soil problems associated with red soils include:

1. Infiltration problems due to hard setting. This hard setting is brought about by a combination of factors that are associated with this soil type including the particle size make-up. The different sized particles found in loam soils can easily pack together, limiting pores for water and oxygen entry.
2. Red soils often do not have enough stable swelling clay (non-sodic) at the surface to encourage self mulching and deep cracking.
3. Low organic matter levels mean that the soil can collapse or slake on wetting (see point 1 above).
4. Rapid surface drying requires irrigation management aimed at watering up rather than planting to moisture.
5. Where red soils are on very permeable subsoils – for example if they are located over recent alluvium – rapid movement through the profile and beyond the root zone results in loss of water from the crop. Aim to manage irrigation to minimise this loss in order to reduce water use and lower the potential for irrigation salinity.
6. Red soils have a very narrow tillage window. The soils can be compacted if too wet and due to low inherent strength they can be reduced to dust if tilled when they are too dry. Avoid the use of disk ploughs and rotary hoes under dry conditions.
7. Where sodicity is also a problem there can be naturally restrictive subsoil layers that prevent irrigation water entry.

Management of red soils

Address problems on red soils before growing a crop as there is limited self-regeneration potential in these soils. Any restrictive layers should be disrupted, keeping in mind that there is a limited moisture window when this can be done without causing damage.

If the soil is in good structural condition, maintain it this way by using minimum tillage, surface mulches, including planting into standing cereal stubble, slow wetting irrigation systems and addition of soil conditioners such as gypsum to maintain the soil structure.

Overcoming red soil problems

Use mulches to minimise the collapse of soil aggregates into micro-aggregates from raindrop impact (this is called **slaking**). Slaking increases as initial water content of the soil decreases and rate of wetting increases, and so slow irrigation delivery methods such as drip and overhead sprinklers (with reduced droplet size and fall distance) can be an advantage.

Slaking under furrow irrigation has been minimised by starting the irrigation with normal discharge siphons, then switching to smaller diameter discharge siphons, although the impact on irrigation performance of this approach should be understood.

Sow into standing cereal stubble to improve infiltration via stable biopores (old root channels). Anchored stubble in the rows also slows down the rate of water movement, increasing the time the water is in the furrow and moving down biopores. When retaining stubble cut it into small lengths to prevent clogging of machinery. Roots should be left anchored.

Trials have been conducted on hard setting soils that showed improved water infiltration over a season. With conventional tillage the soils would not fill the profile following the initial watering. Using a retained stubble system a full profile was achieved with each irrigation. This lowered the irrigations required and increased water use efficiency.

Where fields contain a mixture of soil types including hard setting soils, retained cereal stubble in the systems ensured at least that the hard setting part of the field will receive a full profile.

Further information on the advantages and problems of planting into stubble can be found in the document 'Planting cotton into standing wheat stubble'.

In red soils the short-term benefit of green manure crops can be as much from the production of stable biopores as from the increase in organic matter. Attempt to minimise soil disturbance, especially in the furrow and bed shoulders where biopore retention is important for water infiltration. Try to incorporate stubble with the least disturbance possible, as tillage itself helps speed soil OM breakdown.

Profile inversion using deep mouldboard ploughs can also be used in some cases where a hard setting surface overlies reactive clay. This is in the specific circumstance where the topsoil thickness is not more than 30 cm deep and the subsoil to be brought to the surface is not saline or sodic. The cation exchange capacity of the subsoil should be at least double that of the topsoil. A full soil survey should be done to ensure that this expensive operation would have results.

Deep ripping and chiselling when the soil is just below the plastic limit has been effective in some situations as an alternative to more expensive mouldboard ploughing.

Chisel ploughing furrows in the cotton season when the soil is dry may improve infiltration in the very short term, but there is a big risk of serious damage due to organic matter loss and dust formation from repeated working.

Increasing the time water remains at any given point on a red soil, whilst minimising the amount of tailwater return, is a key to maximising water intake on red soils. As well as the use of standing stubble, 'dammer-dyking' may be of benefit on red soils, especially if planting to fields where no cereal stubble exists. Basically this system involves a machine that places small stops at regular short spacings within the furrow to retain water longer in small puddles. This method is particularly useful under rainfall or overhead irrigation systems. When used in a furrow irrigation system the dams tend to fill quickly with silt unless the depressions are filled with a mulch. The impact of this technique on furrow irrigation performance is unknown, but is most likely negative.

Gypsum application can be of benefit if the clay content of the surface soil is at least 30% with a surface electrochemical stability index (ESI) of less than 0.05. The ESI is equal to electrical conductivity of a 1:5 soil water extract ($EC_{1:5}$) divided by exchangeable sodium percentage (ESP).

Anionic polyacrylamide applied at low rates (7 kg/ha) has been shown to improve seedling emergence and water infiltration in this soil type (see WATERpak Chapter 1.9).