WET PICKING AND SOIL COMPACTION

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Clay soils in Australia largely underpin the cotton industry due to their excellent water-holding capabilities. However, this beneficial trait can pose challenges when rainfall coincides with cotton harvest season, particularly between defoliation and picking. When clay soils become wet, they lose their structural stability, become plastic and are vulnerable to compaction.

Once the crop has been defoliated, it loses the ability to extract water from the soil, meaning if it rains after defoliation the crop won't remove the moisture from the soil. This fact, coupled with cool autumn conditions, means a choice of waiting a long time for heavy clays to naturally dry out before harvest or facing the risk of soil compaction. With the extensive weight of round module pickers and tight timelines around harvest period, compaction is likely to occur. Recent studies have shown that the impact of this compaction can be extensive and cause lint yield reductions of up to 27%.

While prevention is better than repair, this is not always possible or practical under large-scale commercial cotton production. When compaction occurs, it is important to assess the severity and plan a remediation strategy to contain future impacts.

Picture 1. shows the change in wheel rut depth after cotton picker traffic on a wet soil at Narrabri.

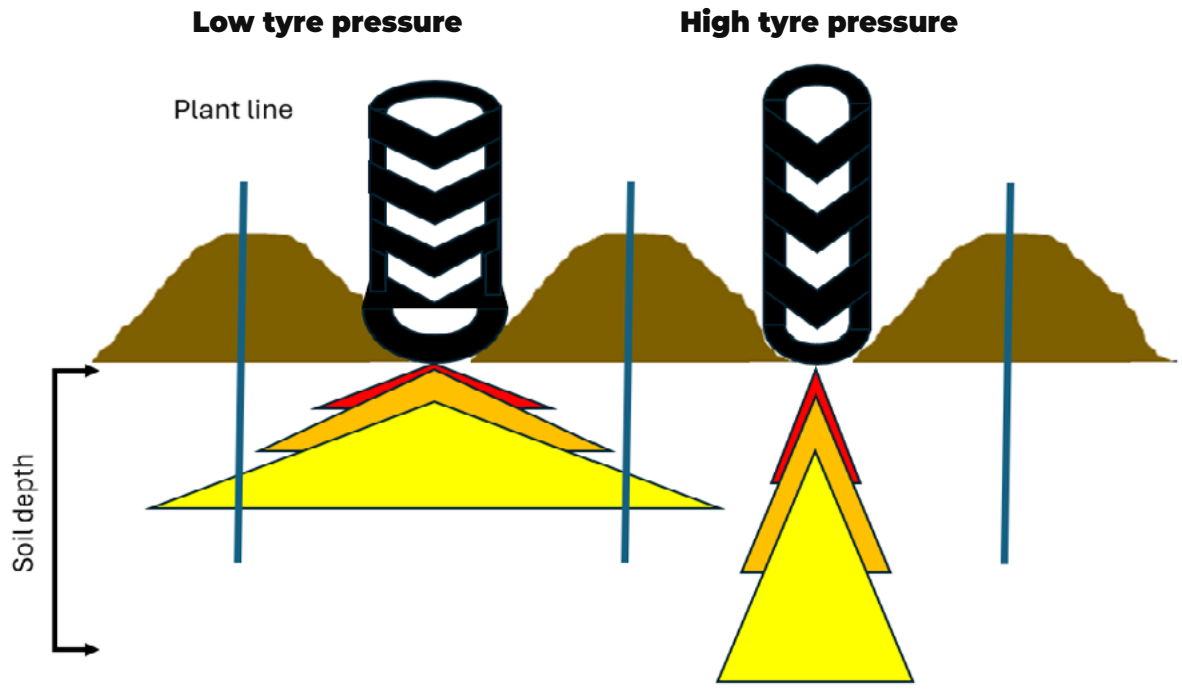
ASSESSING THE IMPACT

The first step in identifying soil compaction following a wet pick is to observe the depth of wheel ruts and the footprint of the picker wheels on the shoulders of the hill. There will almost always be some amount of compression in the wheel tracks after traffic. The relationship between the depth of wheel ruts and the severity of soil compaction will vary depending on your soil type, moisture and structure. Use wheel rutting as an initial flag for further investigation, thinking about past observations of what the tracks behind the picker looked like in dry years. For example, picture 1 shows the depth of wheel rutting on a heavy clay

at Narrabri increased by around 7cm following traffic on wet soil – much deeper than normal. On this soil, this was enough to cause compaction down to 50cm deep.

Also take note of the overall footprint left behind by the picker tyres, especially looking for any tracks on the shoulders of the hills. A moderate amount of compaction in the wheel track furrows is normal and is something we manage for with GPS guidance and by controlling traffic, but compaction in the plant line will directly impact crop performance and yield. If you see any impact from the tyres on the shoulders or on the tops of the hills, this is a red flag that compaction has occurred (see pictures 2 and 3). It's important to note that even without signs of traffic impacting the hills, significant compaction in the furrows can spread to under the beds and into the plant line, so

Picture 3. (Right) Shows a deep rut forming following a wet pick on a heavy clay soil at Narrabri. You can also see the impacts from the picker tyres compressing the shoulders of the hills. This is an example of severe compaction.



Picture 2. highlights the impact of tyre pressure on the shoulders of the hills and the extension of soil compaction to under the plant line.

if wheel rutting is observed, then it's time to pull out the shovel for deeper investigation.

Using your shovel, take a 20cm deep cube of soil from within an un-trafficked furrow, a trafficked furrow and from under the hill. You can compare how easily diggable the soil feels as a first indication of compaction and whether it has spread beyond the wheeltrack furrow. When you've removed your shovelful, examine the clods of soil by looking at the porosity and structure of the soil. A reduced amount of soil pores and the presence of a 'platy' structure are signs of compaction (examples in pictures 4, 5 and 6). You can also pull apart the soil clods, feeling how much force it takes them to break. The more force required, the more likely the soil is compacted. Soil compaction which spreads to under the hills is of significant concern as this is most likely to restrict root growth – this can be exacerbated by dual tyres, creating 'V' shaped compaction under the hills.

Whilst symptoms at the surface provide an indication of severity, it is important to note that the impact of compaction can be more severe in the subsoil (at 30-50cm depth). Compaction at this depth may go somewhat unobserved without digging a soil pit, taking a soil core or using a penetrometer to test for resistance. However, keep in mind that the latter two methods are significantly influenced by the soil moisture which can mask compaction at the time of sampling.

REPAIRING THE DAMAGE

Soil compaction management can be broken down into short, medium and long-term strategies and will depend on the degree of compaction and your goals for the following cotton season. Tillage is often used as the go-to compaction fix, but any deep tillage performed while the soil is still wet will do

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Non-compacted soil with good porosity

Severely compacted soil with poor porosity

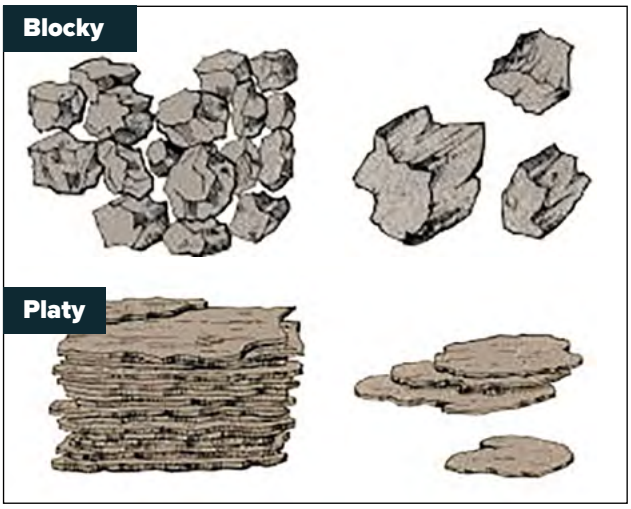
Picture 4. Shows a soil clod from an un-trafficked area of a field in Narrabri compared to a soil clod which was compacted during a wet pick. The un-trafficked clod shows good porosity, where the clod from the wet picked area shows few signs of porosity.

Picture 5. Shows a soil clod from an un-trafficked area of a field in Narrabri compared to a soil clod which was compacted during a wet pick, both growing Phalaris. The un-trafficked clod looks softer in appearance with abundant roots growing downward and obvious porosity, where the clod from the wet picked area shows some evidence of platy soil structure, has roots forced to grow at right angles and looks harder and more solid in appearance with few soil pores.

more damage than good and often the compaction is deeper than your tillage depth. Strategically using rotation crops can repair the damaged soil in a way that actively builds soil structure and protects from future compaction or, if necessary, can dry the soil profile to where tillage will be effective.

Short-term

Short-term strategies should focus on completing essential post-harvest management practices such as mulching and pupae busting as soon as you can to meet your pest management obligations and allow as much time as possible for bed preparation before planting the next crop. In moderately to severely compacted soil then most of the damage already happened from picking and if the field is trafficable, further machinery passes are unlikely to cause more damage, unless tilling when the soil is



Picture 6. is an image from the FAO showing an example of blocky and platy soil structure. Both these structures are common in heavy clays, however platy structure is often an indication of severe soil compaction.

Rotation crop	Advantages	Disadvantages
Winter cereals	- Fibrous root system - Dry stubble, relatively easy to deal with	- Ploughed-in stubble can tie up nitrogen - Crop should be well established before winter for best results – this may require some early irrigation - Poor returns in some years
Winter grain legumes	- May improve soil nitrogen fertility if inoculated - Grow well in alkaline soil that is medium to heavy in texture	- Susceptible to Helicoverpa at pod fill - Susceptible to disease - Residues decompose quickly, so protection of the soil surface from erosion is limited
Canola	- High value	- A good drying crop, but yields tend to be badly affected by compaction - Does not host mycorrhizae
Grain sorghum	- Fibrous root system	- Uses large amounts of nitrogen - Some herbicides may affect the following cotton crop - Stubble may be difficult to incorporate

Table 1. Adapted from SOILpak for cotton growers, showing the advantages and disadvantages of using common rotation crops to ameliorate soil compaction.

too wet. Because the soil won't dry down to depth without growing a crop, short-term tillage should be restricted to pupae busting in the top 10-15cm and rebuilding damaged hills if they were impacted by tyre traffic.

Medium-term

Medium-term strategies will depend on your goals for the following cotton season, but your focus will be on fixing compaction either mechanically through tillage, biologically through growing a crop and getting roots down into the soil profile, or both.

Option A – Grow a full season rotation crop

If cotton won't be in this field next season, then growing a full season rotation crop will help repair the soil while also building better soil structure through creating root channels, putting organic matter through the soil profile and increasing biological activity, all building resilience to compaction in the future. If your field is mostly cracking clay soils then growing any crop is better than leaving the field fallow as the crop using up soil moisture will drive the shrink and swell of the clay particles, pulling apart the compacted layers and bringing them back together. In non-cracking soil types, then growing a crop with a strong taproot could help penetrate deep compacted layers and dry the soil to depth, and a fibrous rooted crop like wheat will improve topsoil structure.

Rotation crop decisions should make sense for your farm, balancing the decision between fixing the soil, their overall profitability and soil water usage – as this may be critical to your water budget in the coming cotton season (though keep in mind, the soil won't be repaired, either mechanically or biologically, without drying). Table 1 outlines some advantages and disadvantages of common rotation crops, which may guide your decision.

If after growing your rotation crop signs of soil compaction persist, then you could consider tillage as an option, however it is critical that you do not till below the depth of soil drying as tillage in wet soil is spending money to create further damage.

Option B – leave fallow and grow cotton in the upcoming season

If growing cotton in this field in the next season, you

Benefits	Risks
- Can improve the structure of compacted soils without sacrificing growing a cotton crop in the next season - Can dry down the soil profile to allow for any deeper tillage to be performed before planting cotton - Adds underground biomass through root growth which will help building lasting soil structure - Supports biological activity through what would otherwise be bare fallow - May increase soil water storage	- To be effective, the crop must be well managed, like a cash crop with associated costs but without direct financial returns from harvest - Significant biomass production can be hard to manage post-cover crop when preparing beds for cotton, can interfere with irrigation and may need more nitrogen applied to avoid N-tie up as the biomass breaks down - If planted late due to further picking delays the cover crop may not have time to significantly improve the soil structure - If cover crop isn't terminated before maturity due to delays, then volunteers may become a problem - Depending on the cover crop grown there may be risks for creating a disease bridge which will impact the following cotton crop - Research is not yet clear on the best cover crops or their management for this purpose in Australian cotton systems

Table 2. Some of the potential benefits and risks of managing a short season cover crop to repair soil compaction.

may leave the field fallow over winter to plant your crop in spring. For this option, it will be a priority to ensure beds are prepared as early as possible following pupae busting as this will allow the soil to settle over winter before planting. Effective crop establishment will be critical for this strategy's success. Cotton itself is a good drying crop and irrigation will drive multiple shrink-swell cycles in cracking clays and work towards fixing compacted layers in lightly to moderately compacted soils. However, a recent study at Narrabri found a 27% yield loss from compaction as the crop struggled to extract water from the 30-50cm depth – meaning that in choosing this option you should accept yield loss and reduced returns per megalitre of water used until the soil is repaired.

If the soil is significantly damaged or a wet summer prevents major shrink-swell cycles, then one season of cotton may not do much to fix the damage. To assess this, you can perform the observations outlined in part A. If using moisture probes you can monitor this data to see where the crop is extracting water from later in the season and get a feel for rooting depth which, if restricted, may indicate that compaction is still an issue. You can also excavate a few plants and look at the root structure. Fat, swollen stems and roots travelling at right angles (Picture 7) are clear signs that the compaction has not been fixed. Where compaction persists as a problem this may be an opportunity to follow this cotton season with a rotation crop or consider deep tillage.

If you want to grow cotton in this field next season, but want to either dry the profile down to allow for deeper tillage, or use a rotation crop to biologically remediate the compaction before you plant

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Picture 7. Shows a cotton root which has veered off at a sharp angle, showing clear signs of growing in compacted soil.

cotton in spring, then growing a winter cover crop which you terminate before maturity may be an option. Although seemingly the best of both worlds, this strategy has not been thoroughly researched in Australian cotton systems and the benefit to risk ratio needs to be better understood (Table 2). That said, there has been some evidence of good structural improvements from even a late planted wheat cover crop in a field compacted from a wet pick when compared to being left as bare fallow over winter (Picture 8).

Long-term

While the short and medium-term strategies may help reduce the impacts of soil compaction, they do not entirely fix the problem. For this, we need to focus on long-term management strategies that build resilient soils through improving soil structure. Soil structure will be improved by reducing tillage, controlling traffic and rotating crops.

Reduced tillage: Tillage should mostly be restricted to the topsoil (around 10-15cm to pupae bust and maintain hills) and, when deep tillage is necessary, only undertaken when the profile is dry to avoid causing further structural damage. You can use an occasional strategic deep tillage as an opportunity

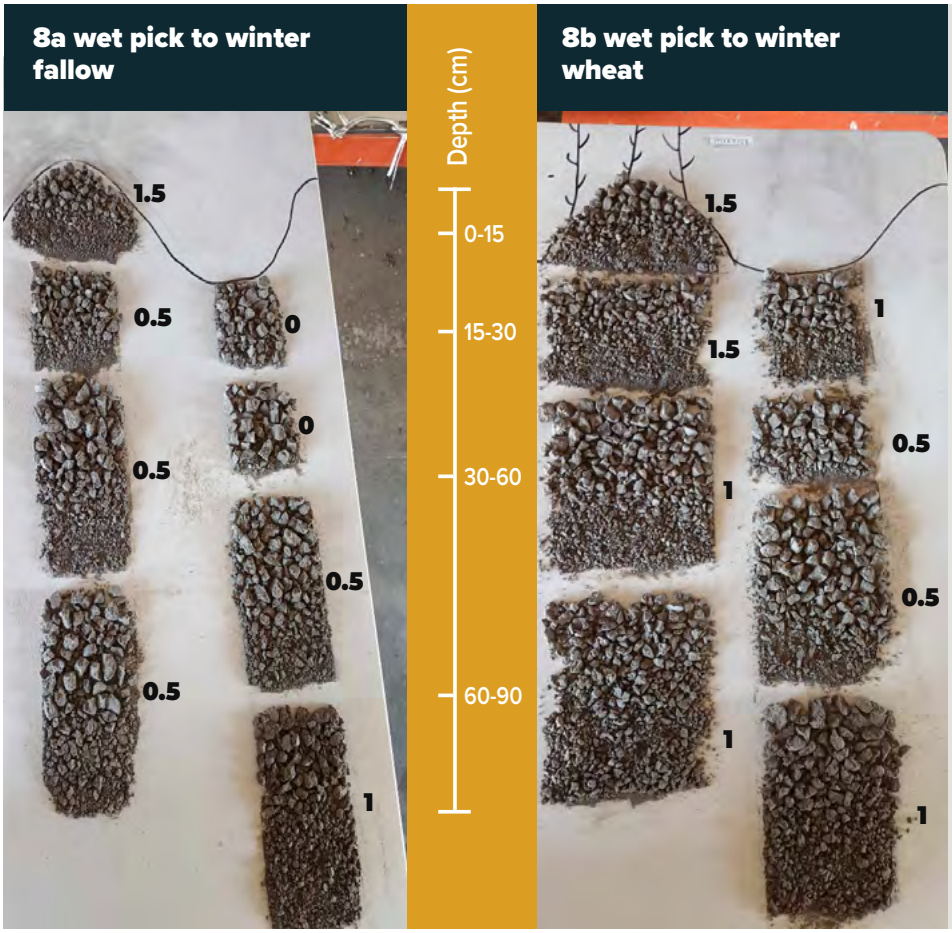
to mix immobile nutrients like phosphorus or incorporate soil ameliorants like gypsum if necessary.

Controlling traffic: Understanding that true controlled traffic farming is challenging in irrigated cotton systems, you can still restrict traffic to some extent by driving only within the wheel track furrows, avoiding driving over or on the sides of hills and avoiding entering wet fields where possible.

Crop rotation: While they can be used as a once-off tool to repair compacted soil, consistent crop rotation is the key to improving soil structure for lasting resilience. Through the creation of new rooting channels, bringing more above and below ground organic matter into the system and supporting biology, crop rotation is necessary to give your soil the bounce-back factor for long-term resilience.

SUMMARY

Despite all the best efforts, sometimes wet picks will happen, and you will compact your soil. Your goal after a wet pick is to bring your field back to the best possible condition before your next cotton crop. You will be able to do this by pulling out the shovel and assessing the damage and then deciding on how to make your repairs, either through crop rotation, tillage or a mix of both. Thinking in terms of short, medium and long-term steps will both minimise future yield losses from damaged soil structure and maximise your soils' overall resilience so the next time there's a wet pick, you will be able to bounce back quicker.



Picture 8 shows soil cores taken from bare fallow over winter (8a) compared to a wheat cover crop (8b) after cover crop destruction in spring. Samples were taken from the hill and furrow in each treatment and scored using an adapted visual assessment (FAO VSA) rating soil structure as poor (0), moderate (1) or excellent (2).

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FURTHER READING:

SOILpak for cotton growers
www.cottoninfo.com.au/publications/soilpak

Soil compaction in a new light: Know the cost of doing nothing – A cotton case study
www.sciencedirect.com/science/article/pii/S0167198721002312

CottonInfo Soil Health
www.cottoninfo.com.au/soil-health

Managing heavy clay soils of the Bland
www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/79420/managing-heavy-clay-soils-bland.pdf

Protect your soil from compaction
www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/79420/managing-heavy-clay-soils-bland.pdf

Consider controlled traffic farming to minimise soil compaction
www.youtube.com/watch?v=mPfh9Qv5I-M

Soil compaction and controlled traffic considerations in Australian cotton-farming systems
www.researchgate.net/journal/Crop-and-Pasture-Science-1836-5795

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