7/89 to 12/92.

FINAL REPORT
Project CSO1C: Soil damage in relation to tillage and traffic at various moisture contents and relations between deformations structure and permeability of cotton soils.

Project staff:

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This project had objectives of:

1 studying the risk of damaging soil, and by how much, by tillage and traffic at various moisture contents;

2 testing further the "critical moisture" concept developed under a previous project;

3 studying the conditions under which deformations lead to good or bad structure/permeability in cotton soils.

To address these objectives, we studied soil behaviour both in the field and in the laboratory. Much of the work has been published; a comprehensive reference list is given at the end of papers arising directly from the work and papers relevant to but not arising directly from this project. Here a summary of the findings is given.

Objective 1.

We measured soil stresses beneath a range of vehicles at Togo Station, Auscott Narrabri and Condamine Plains. To measure the stresses in the soil we used stress transducers that give a voltage output proportional to the stress, which was recorded on a data logging system. The vehicles included pickers, Caterpillar Challenger 65 (rubber tracked crawler), Caterpillar D8, graders, tractors (various sizes up to a Case 9170) some with scrapers, and a Toyota Landcruiser. Vehicles were operated in various configurations, with and without tanks and cultivators.

The results provided some insight into stress distributions beneath some vehicles of the vehicles used in the cotton industry. They showed that :

- pickers did exert high stresses, though they are higher under the front tyres;
- that the maximum stress under tracked vehicles was about twice the average (though this is still lower than many tractors and pickers), indicating that they may do much more damage than is assumed on a simple calculation of ground contact pressure as vehicle weight divided by track area; and
- that scrapers did not exert much greater vertical stress than the tractors pulling them, and the pressure beneath the blade was usually less than that beneath the tyres;
- the maximum stresses were recorded at 10 cm, but we were still able to record significant stresses at 50 cm. We also found in one experiment higher stresses on the sides of a furrow, presumably because the tyre and tracks rested mainly on the sides of the furrow rather than in the centre.

In all these trials we also collected soil samples for strength and other measurements in the laboratory.

In addition we sampled the shallow leading tine trial conducted at Trangie by Palmer, and also a trial without Palmer with some tillage runs using sweeps and chisels to various depths up to 450 mm at Auscott Narrabri on soil at a moisture content of 0.35 $g\ g^{-1}$. These results are being reported mainly by Palmer, but it should be noted that the trial we performed without Palmer showed that successful tillage occurred above the critical depth while unsuccessful tillage occurred below the critical depth. The effect on permeability is commented on further below.

Objective 2.

To address this objective we compared the measured strength of the samples taken from the various trials reported above to the vehicle pressures that we had measured. We also drew on data from a previous project that had measured the mechanical properties of a wide range of cotton soils in NSW and Queensland. This allowed us to extrapolate our actual experimental results to a wider range of soils, sites and conditions than we could perform experiments at. We refined the "critical moisture content" concept to account for variations in vehicles and tyres.

We concluded that:

- it is more important to get the soil dry than to choose another vehicle or wider tyres;
- low ground pressure tyres or tracks do not prevent compaction. Compared to normal tyres or tracks, they do allow slightly wetter soil to be trafficked with minimal compaction.
- if low ground pressure tyres or tracks are used, it is more important to avoid soil that is too wet because any compaction damage caused will be spread over a wider area and hence will also go deeper into the soil.
- The plastic limit provides a reasonable rule of thumb to estimate when vehicles will cause compaction (as found in a previous project).

Objective 3.

To assess the conditions which lead to good or bad structure, we measured permeability, oxygen difussivities on samples from field compaction experiments. We also measured the influence of soil deformation on soil structure, permeability and oxygen difussivities in the laboratory.

In the laboratory we found a systematic relationship between deformations structure and air permeability. This relationship is summarised in Table 1.

We also found that the oxygen diffusivity was much less affected be deformation than was permeability. This means that it is less sensitive as an indicator of soil structure (cf the work by Hodgson). However, it may be the better indicator of conditions limiting to root growth.

In field trials we found that changes to air permeability and oxygen diffusivity were generally consistent with the laboratory findings noted above, but that there was considerable variability in the results and it was sometimes hard to find a find a significant trend in the data.

The practical implication of the results are that:

- when compaction occurs it will generally result in poor structure and permeability, but that when the soil is strong enough to withstand the vehicle pressure the impact on structure and permeability is slight;
- tillage may be performed in such a way as to produce either increased permeability or decreased permeability. Tillage to increase permeability and aeration may be performed in a sandy soil (which has no macropores with preferred orientations)

when there is any expansion of the bed. In a heavy clay (which may have many such macropores), tillage may be performed only when the expansion is very great, which will occur only when the soil is very dry. Therefore lighter textured soils can be tilled over a wider range of moisture content. Hettiaratchi (1987) also arrived at this conclusion from considerations of critical state concepts and soil deformation although he did not consider the influence of deformations on permeability.

We also found that the change in oxygen diffusivity during tillage depended on the critical depth. At shallower depths we found increases in oxygen diffusivity, whereas at greater depths we found slight decreases or little change.

Future Directions

Firstly, while we have analysed much of our data and published our findings, we have amassed a considerable amount of data and have not yet had time to analyse it as fully as we might. In particular, we have not yet performed as much advanced soil mechanics analysis as we feel is justified by the data. We do not anticipate that such analyses would change the practical findings to date that we have reported to cotton growers, but we do expect to continue to analyse and publish from the data. Any further practical findings would naturally be reported to the cotton growing community.

It should also be noted that some of the work reported here forms the basis of a Masters thesis being researched by Bruce Blunden, externally from USQ (supervised by Dr Mark Porter). This is to be submitted soon.

Secondly, we have noted some interesting effects along the way which we intend to pursue in the new project on beds (see this year's submission). In particular, we observed high stresses on bed shoulders in one of our trials.

Thirdly, the work on this project has resulted in ideas that have benefited other areas of work and these other areas have in turn provided feedback that has benefited this project. We have published information relevant to, but not arising directly from the cotton work (see reference list below), and in the further directions of this work we will continue to seek exchange that will benefit the research into cotton soils. We also believe that the demonstration that our approach is widely applicable to problems in many industries and soil types reinforces the confidence with which we can tackle problems for the cotton community.

References

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Table 1. Interaction of deformations, strcture and permeability - summary.

Type of deformation		
Compression	Shear with compression	Shear with expansion
Effect on structure		
limited at stresses less than P_C *	limited at stresses less than yield stress	limited at stresses less than yield stress
alignment of clays normal to compressive stress	alignment of clays in direction of shear	alignment of clays in direction of shear
general rearrangement rearrangement of structure	general rearrangement of structure	local of structure
Effect on permeability		
decreasing permeability (depends on structure)	decreasing permeability	increasing or decreasing permeability initial
Typical occurence in agricultural operations		
compaction	compaction	tillage for seedbed production
	ploughpans	tillage above critical depth
	tillage below critical depth	
	mole drain formation	

* Note P_c denotes the pre-consolidation stress, which is a stress below which little compaction occurs and above which compaction does occur.