

Unearthing problem soils in the Lachlan Valley

By Edward Cay and Stephen Cattle, The University of Sydney and Australian Cotton CRC

A number of scientific studies and grower observations suggest that land-levelling for furrow irrigated cotton production increases the in-field variation of crop yield. In many cases, the removal of topsoil from cut areas has been strongly correlated to reduced crop vigour and subsequent crop yields.

In the central Macquarie Valley, land-levelling or landforming has been shown to affect soil properties by exposing sodic or saline subsoils, and removing nutrients and organic matter with the topsoil layers. For example, in 1985, a research team showed that potential cotton yield (indicated by the total number of bolls) of cut sites was only 32 per cent of that on fill sites on a red-brown earth (red sodosol) near Trangie.

The reduced crop growth was attributed to the less developed structure and dispersive nature of the exposed subsoil. Evidence from growers in the adjacent Lachlan Valley also suggests that cut and fill processes influence crop production, although very little research has been undertaken to quantify the effect on soil profile attributes.

During 2002 we conducted a study on two cotton-producing properties, 'Morrowie' and 'Yilgah', north of Hillston. We examined how soil profile characteristics changed in the upper two metres between cut and fill areas within fields and relative to nearby uncultivated sites. The amount of soil removed or added in cut and fill areas varied, but was between 0.1 metre and 0.4 metres. Sample sites were also distributed evenly over the three major soil units used for cotton growing in the area.

Soil types of the area



An NDVI image showing poor crop vigour (dark red) in the cut areas of an irrigated cotton field in the Hillston area of the lower Lachlan Valley.

TABLE 1: Average topsoil (0-0.4 m depth) physico-chemical attributes for cut, fill and native profiles of the TQs, Qaf and Qa soil units

	TQs			Qaf			Qa		
	Cut	Fill	Natural	Cut	Fill	Natural	Cut	Fill	Natural
pH	9.3	8.5	7.9	8.5	8.3	7.7	8.3	7.4	7.6
EC (dS.m ⁻¹)	0.23	0.20	0.13	<0.10	<0.10	<0.10	0.171	0.24	0.11
Clay (%)	50	45	37	51	54	47	54	49	50
ECEC (cmol(+).kg ⁻¹)	24.6	22.7	15.1	28.4	31.7	24.6	32.2	24.3	28.4
ESP	8.1	5.1	2.9	4.5	4.1	3.3	2.7	1.4	1.7
ESI	0.07	0.12	0.02	0.07	0.07	0.05	0.13	0.26	0.23
ASWAT	5.3	3.7	4.5	2.8	3.3	6.0	4.0	0.7	2.3

The three major soil units used for cotton production in the Hillston area are clay-rich and can be largely identified by their surface colour:

- Grey;
- Grey-brown; and,
- Red.

The NSW Department of Mineral Resources (DMR) map that was used as a framework for sample site allocation, names these units as Qa (predominantly grey), Qaf (predominantly grey-brown) and TQs (predominantly red).

Differences between the three units are largely a result of their position relative to current and relict watercourses. For example, the uniform grey and grey-brown clays of the Qa and Qaf units are situated in the active alluvial floodplain around the Lachlan River and its effluent streams, while the TQs unit has been formed on very old river sediment in slightly higher elevations.

In their natural state, the units which make up the active alluvial floodplain consist of uniform, medium–heavy clay soils (vertisols). The most frequently flooded unit, Qa, exhibits a uniformly grey colour and the less frequently flooded Qaf unit displays slight colour differentiation between brown clay topsoils and grey/brown subsoils.

It was found that within these units there are isolated areas of both subsoil sodicity and salinity. On the other hand, the older TQs unit was found to display thin, loam or clay-loam, red topsoils overlying red-brown and yellow, medium to heavy clay subsoil horizons (Figure 2). In these chromosols and sodosols (red-brown earths), patches of natural gypsum and carbonate are common throughout the subsoil layers, as well as areas of high sodicity.

Which soils are most vulnerable to change?

The degree of soil profile change caused by landforming is relative to the nature of the original soil profile and the amount of cut or fill.



A typical soil profile of the TQs unit.

In soil profiles that display similar topsoil and subsoil characteristics, the removal or addition of topsoil can have a relatively minor impact on soil attributes compared to soils with contrasting horizons.

Visually, the TQs unit shows the greatest within-profile contrast. Anecdotal evidence suggests that this unit is the most vulnerable to crop yield variation as a result of cut and fill operations. Cut areas in the TQs unit had greater surface cation exchange capacities due to the removal of lighter textured topsoils, but this benefit was offset by the exposure of problematic subsoils.

Table 1 compares average soil characteristics for cut, fill and native sites in the upper 0.4 metres (where the majority of cotton roots are found) of the three soil units. The most important effects of landforming on the upper 0.4 metre of the TQs unit include exposing or apparent raising of strongly alkaline, sodic and dispersive subsoil horizons in cut areas.

The average pH value for cut areas (9.3) indicates that strongly alkaline subsoils at approximately 0.4–0.8 metre depth in the native profiles are being exposed. Strongly alkaline pHs reduce the availability of some nutrients, particularly micro-nutrients such as zinc, copper, iron and manganese, and macro-nutrients like nitrogen.

Cutting processes are also responsible for exposing subsoil layers with greater levels of exchangeable sodium, which have a moderate tendency to disperse. Cut areas of the TQs unit also exhibit 'aggregate stability in water' (ASWAT) and 'electrochemical stability index' (ESI) levels that are higher than in fill or native areas, and include some areas that SOILpak guidelines identify as worth ameliorating.

There is a strong propensity for soil to slake in the TQs unit and anecdotal evidence suggests hardsetting is likely to be a result of low Ca:Mg ratios and the relatively low organic matter levels, which are also a common feature of the unit.

Obviously, the removal of topsoils in cut areas reduces the amount of surface organic matter and raises magnesium-dominant subsoils. Across all three soil units, the organic carbon contents in the surface soil of cut and fill areas were only 52 per cent and 69 per cent of the native profiles, respectively.

Landforming had a large effect on soil profile characteristics in the Qa and Qaf units where there was subsoil sodicity, salinity or alkalinity, although for most of the sample sites, the more uniform nature of these units resulted in a relatively smaller degree of change in cut and fill areas. The most significant effect of landforming occurred where dispersive, sodic subsoil layers of the Qaf unit were exposed or raised into the root-zone.

What are the management options?

This study did not include any amelioration trials for soil problems caused by landforming. But there are a number of management strategies that have been identified by other studies for ameliorating sodicity, dispersion and hardsetting on landformed soil.

Gypsum and lime

Gypsum and lime have been used effectively to reduce dispersivity and increase the infiltration of soil by increasing the relative percentage of calcium on the cation exchange sites of soil particles. SOILpak guidelines suggest that at an ESI less than 0.05, an economical response may be gained by adding gypsum or lime.

But in cases where subsoils are high in salinity, the addition of gypsum or lime will contribute still more soluble salts to the soil and may have a negative effect on crop production. This situation is apparent in areas of the TQs unit, where deep cuts have created sodic topsoils and effectively raised the yellow subsoils that contain electrical conductivities of around 0.7 dS per metre.

Also, the addition of gypsum and lime is less effective in soils with pH above 8.5 (1:5 CaCl₂) because the calcium in these compounds

remains in solid form. Most cut areas in the TQs unit with greater than 0.2 metres of soil removed have a pH that is not conducive to effective gypsum and lime application.

Organic matter

Organic matter plays an important role in binding soil material. It is particularly important for preventing slaking, but has also been shown to partly suppress dispersion in sodic topsoils.

The accumulation of topsoil organic matter through the use of mulch crops, manure spreading or stubble retention is a long-term management technique, but is possibly a very effective means of ameliorating hardsetting and possibly dispersive soil characteristics.

Synthetic polyacrylamides (PAMs) have also been studied as a possible short-term substitute for organic matter due to their potential soil binding capabilities.

Leaching

This potential alternative should be approached with great caution. The leaching of salts through the soil by irrigation implies that water may be used to flush salts below the root zone. In some cases this strategy will have an undesirable effect on watertable levels and the potential salinity threat because groundwater recharge is increased.

But leaching of salts, particularly sodium, may be a short-term means of reducing dispersion where gypsum and/or lime are not appropriate. The effectiveness of this method will be relative to the level of soluble salts in the irrigation water, the hydraulic conductivity of the soil, and depth to groundwater.

In summary, the results of this study on landformed soil units of the Hillston area indicate that future research should be aimed at discovering exactly which of these methods, if any, are suitable and/or ideal for the different soil units used for cotton production.

