## Tractor wheel compaction effects on infiltration and erosion under rain.

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### Introduction

Controlled traffic is expected to increase infiltration in non-traffic areas, presumably leading to reduced soil loss. However, actual measurements of these effects for Australian conditions are rare. Field studies of runoff and erosion effects of controlled traffic have only recently begun in Australia (D.Yule, QDPI; J. Tullberg, UQ, pers.comm). Controlled traffic or `permanent' beds are now reasonably common in irrigated cotton farming. Differences in infiltration and runoff behaviour between traffic and non-traffic furrows are observed by irrigators, and were evident during our studies of runoff and erosion in irrigated cotton fields. Thus, furrows used in our studies were selected according to prior traffic status so that differences between other experimental treatments could be determined. Data from these studies relating to effects of prior wheel traffic on runoff and erosion are presented here. Also, data for stubble retention are presented to show the relative benefits, and the interaction, of the two methods of management.

A related issue is that of effects of surface compaction, for instance due to recent wheel traffic on moist soil, on runoff and erosion. Most studies of erosion are carried out on loose, fine-tilled soil, as this is seen to be a worst case erosion status. Compaction of the soil surface could potentially reduce erosion, by increasing soil strength, or increase erosion, by reducing infiltration and increasing runoff. In swelling/self-mulching soils any positive benefits of compaction may be short lived. Compaction of furrow bottoms by machines has given variable results in controlling erosion during furrow irrigation, including reduced erosion (Voorhees et al., 1979), no effect (Dickey et al., 1984) and increased erosion (Young and Voorhees, 1982). There has been some discussion of the potential for use of tractor wheel compaction to reduce erosion in dryland cotton in central Queensland (S. Cannon, QDPI, pers. comm.). This issue is addressed using experimental data and an analysis of erosion processes.

### Methods

Two forms of tractor wheel compaction were studied:-

a) short term surface compaction,
b) long term compaction related to wheel tracks in controlled traffic farming systems.

Data are taken from a number of studies of erosion from furrows where compaction was included as a treatment (short term surface compaction - at Gatton and Kingsthorpe) or occurred due to the nature of prior farming operations (long term compaction - at Emerald and Warren). At Gatton, erosion was studied soon (3 days) after compaction. At Kingsthorpe, erosion was measured several months after compaction, during a summer crop. A rainfall simulator was used to apply rain at high intensities (95-110 mm/hr) as large intense storms cause the majority of long-term total soil loss (Wockner and Freebairn, 1991). The rainfall simulator uses a line of oscillating Veejet 80100 nozzles (Loch, 1989) and can apply rain to 2 m wide plots (2 furrows) of 2 to 12 m length. Runoff rates and sediment concentrations were measured every 1-2 minutes from each of the two furrows under the simulator. General information for each study (site, soil, plot size, intensity, duration and furrow width and range of furrow slopes) is given in Table 1; site specific details are given below.

### *Short Term Surface Compaction Studies*

Compaction was applied with 0, 1, 2 or 5 passes of a tractor wheel in the furrow bottoms, or 1 pass each on the sides and bottom of the furrow. Furrows were 0.75 m wide (top to top), bare, freshly tilled, with ~50 % sideslopes and a 100 mm wide (roughly) flat section in the bottom, before compaction. Furrows were moistened and allowed to drain for 3 days, to about field capacity, prior to compaction. No attempt was made to alleviate prior compaction. The tractors used at Gatton and Kingsthorpe had rear wheels 0.46 m and 0.38 m wide, and rear axle weights of 2930 kg and 2830 kg, respectively.

**Gatton.** The simulator plots were run two days after compaction. Compaction treatments are compared with data from furrows with no additional compaction, run as part of another study at the site. Two furrows were rained on for each compaction treatment. No plots were run for the 2 wheel pass treatment.

**Kingsthorpe.** The aim of this study was to see if effects of compaction persisted over a summer crop period. Treatments, furrows and methods were the same as used at Gatton, except that a) compaction was performed in early December after sprinkler irrigation, cotton was planted the same day and rainfall simulations were carried out in mid-March, 95 days after compaction, and b) a wheat cover crop treatment was included; wheat was grown on the hills and furrows before cotton was planted, giving 24 % cover of anchored stubble under the cotton in March. Natural rainfall was below average in the period between planting and simulation studies - 22mm (Dec), 32mm (Jan), 93mm (Feb), 16 mm (Mar). By March the surface soil (0-100mm) was dried to about wilting point by the cotton and some cracks had formed in the subsoil. Cotton plants were removed before rain was applied. The furrow hills had slumped somewhat.

Table 1 - General information about the rainfall simulator studies

| Site | Soil | | Rainfall Simulator | | | Furrow | |
|---|---|---|---|---|---|---|---|
| | Great soil group/Type | Texture | Plot Length (m) | Intensity (mm/hr) | Duration of Rain (min) | Width (m) | Channel Slope (%) |
| **Short term surface compaction** | | | | | | | |
| Gatton QLD (University of Queensland Farm) | Prairie soil, Alluvial (Lockyer) | clay loam /clay | 1.8 | 95 | 40 | 0.75 | 0.25 - 6 |
| Kingsthorpe QLD (QDPI Research Station) | Black earth, (Craigmore) | clay | 1.8 | 107 | 30 | 0.75 | 0.6 - 4 |
| **Long term controlled traffic** | | | | | | | |
| Emerald irrigation area ( left bank EIA) | Black earth | clay | 12 | 105 | 40 | 1.0 | 0.75 |
| Warren NSW (Auscott Field 23) | Grey clay | clay | 12 | 100 | 40 | 1.0 | 0.5 |

### *Long Term Compaction and Controlled Traffic*

**Emerald.** This study was carried out soon after planting of irrigated cotton on 'permanent' 1 m wide beds. Runoff and erosion was measured separately from two furrows for each simulator run, one being a wheel track and one a non-wheel track. Surface cover of none (bare), or two levels each of wheat stubble or cotton trash, were studied. Cover was mainly in the furrow bottom.

**Warren.** This study was carried out several weeks after cotton planting on `permanent' 1 m beds. Treatments included:- bare, cotton trash (in furrow bottom, about 40 % cover overall), and wheat cover crop. The wheat cover crop was grown on the beds over winter, sprayed out in spring and cotton planted without extra tillage or hilling-up. All plots were on non-wheel track furrows, except the cotton trash treatment where non-wheel track and wheel track furrows were studied.

## Results and Discussion

### *Short Term Surface Compaction Studies - Gatton and Kingsthope*

Runoff was 23-44 % greater for the compacted furrows than for the bare non-compacted furrows at Gatton (Table 2). Increasing the severity of compaction in the furrow (5 passes) or proportion of area compacted (sides&bottom) maximised runoff and reduced infiltration to 13-16 % of rain applied (Table 2). A cover of 2 t/ha wheat stubble caused a large reduction in runoff compared with the bare and compacted furrows. At Kingsthorpe, runoff was only slightly greater for all compacted treatments except the 5 pass treatment (Table 2), indicating that surface effects of these treatments had been ameliorated by wetting, drying and self-mulching during the summer crop. Five wheel passes gave 35 % more runoff and halved the total infiltration. The wheat cover crop significantly increased infiltration, even though it gave only 24 % cover.

Table 2 - Runoff and infiltration for furrows with various compaction treatments, at Gatton 2 days after compaction (65mm rain in 40 min) and at Kingsthorpe 95 days after compaction (54mm rain in 30 min).

| | Number of Plots | Runoff [mm] | Infiltration [mm] | Infiltration [% of rain] |
|---|---|---|---|---|
| **Gatton** | | | | |
| Bare non - compacted | 22 | 39 | 25 | 39 |
| 1 wheel pass in furrow | 2 | 48 | 16 | 24 |
| 5 wheel passes in furrow | 2 | 54 | 11 | 16 |
| 1 wheel on sides & bottom | 2 | 56 | 8 | 13 |
| Covered non - compacted | 4 | 13 | 50 | 79 |
| **Kingsthorpe** | | | | |
| Bare non - compacted | 2 | 31 | 23 | 42 |
| 1 wheel pass in furrow | 2 | 33 | 20 | 38 |
| 2 wheel passes in furrow | 4 | 34 | 20 | 37 |
| 5 wheel passes in furrow | 2 | 44 | 10 | 18 |
| 1 wheel on sides & bottom | 2 | 32 | 21 | 39 |
| Covered non - compacted | 2 | 10 | 43 | 81 |

As soil loss is highly influenced by slope, and slope of each furrow could not be controlled precisely, soil loss data from the compaction treatments are compared in terms of their deviation from the erosion-slope response derived for non-compacted furrows. At Gatton, soil losses for all compaction treatments equalled or exceeded those from furrows receiving no additional compaction (Figure 1). Compaction with one wheel pass caused little or no additional soil loss, however soil loss was almost doubled for one each of the furrows given five passes and side&bottom compaction. Evidently, surface compaction did little to reduce the soil available for erosion. At Kingsthorpe, no major differences are apparent between bare non-compacted and compacted treatments (Figure 2), with all soil losses in a band of about +/- 2 t/ha around the general trend of increasing soil loss with increasing furrow slope. Effects of compaction on soil loss appear to have been ameliorated during the summer crop. The greater runoff for the 5 wheel pass treatment did not result in greater soil losses, indicating a reduction in sediment concentration

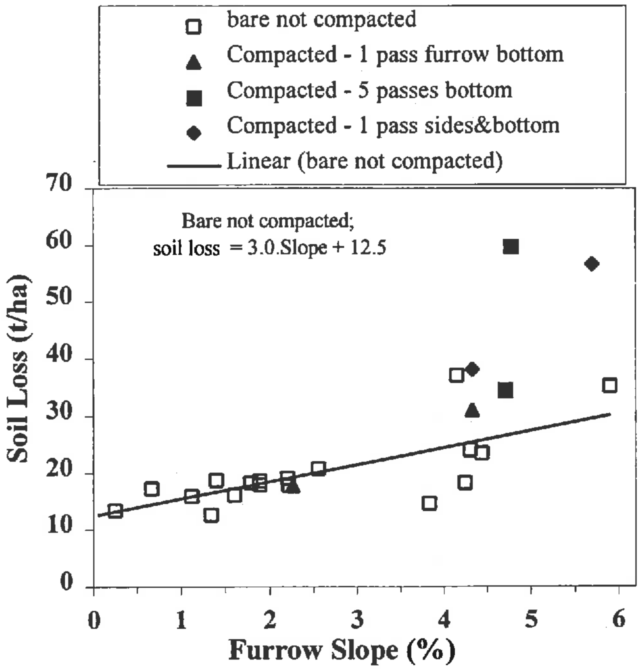


Figure 1 - Soil loss from for bare furrows, with and without short term surface compaction, at Gatton on a clay loam (40 min of rain).

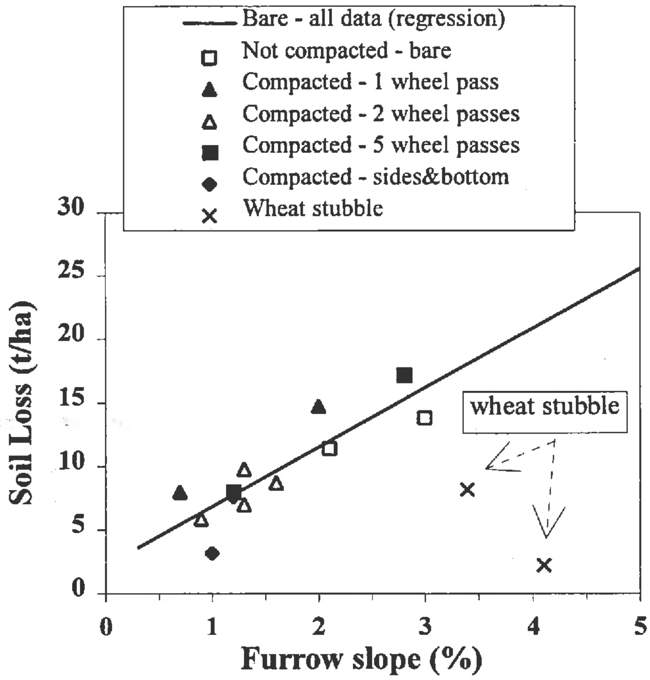


Figure 2 - Soil loss from furrows, bare with and without compaction, and with standing stubble; black earth at Kingsthorpe (30 min of rain).

possibly related to some residual effects of the compaction treatment. The 24 % wheat cover reduced soil loss by 55-90 % compared to soil losses expected for bare furrows of the same slopes (Figure 2).

### *Long Term Compaction and Controlled Traffic*

**Emerald.** Total runoff decreased with increasing cover (Figure 3), with wheel track furrows giving more runoff than non-wheel track furrows at all covers. This difference was small for bare furrows and increased with greater cover. Surface sealing restricts infiltration on bare furrows, overriding the improved infiltration potential of subsoil in non-wheel track furrows. On partially covered furrows the proportion of the plot that is sealed (and therefore the runoff) is reduced but on wheel track furrows the compacted subsoil restricts infiltration, reducing the effects of cover. Soil losses are reduced by an order of magnitude when cover is > 40% (Figure 4), compared with 17 % lower soil loss from no wheel traffic on bare furrows. The combination of retaining cover and controlled traffic gave the least runoff and soil loss. However, of the two practices retaining cover had the greater effect. Controlled traffic alone is of limited benefit for increasing infiltration and reducing runoff and soil loss from storms on this soil.

**Warren.** The combination of cotton mulch in non-traffic furrows gave much less runoff (7mm) than cotton mulch in wheel track furrows (25mm) (Figure 5). Runoff from furrows with cotton mulch and traffic was similar to runoff from bare non-traffic furrows (27mm). Reduced infiltration in the traffic furrows eliminated most of the benefits of cover. However, soil loss was still reduced in the cotton mulch traffic furrows (1.7 t/ha) compared with the bare non-traffic furrows (3.3 t/ha), due to trapping of sediment in the mulch. Soil loss from the cotton mulch non-traffic furrow was 0.5 t/ha. Wheat stubble cover gave the least runoff (5.4 mm) and soil loss (0.1 t/ha). This treatment had cover on both the hills and furrows, and had non-traffic furrows, reducing runoff from both areas.

### *Erosion Processes in Hill-Furrow Systems*

The geometry of hill-furrow systems has a large effect on erosion processes and whether or not compaction affects erosion. In a hill-furrow system, the hill (or bed) is subject to net erosion and is a lateral source of sediment to the furrow. The furrow can be a net sink (deposition site) or source of

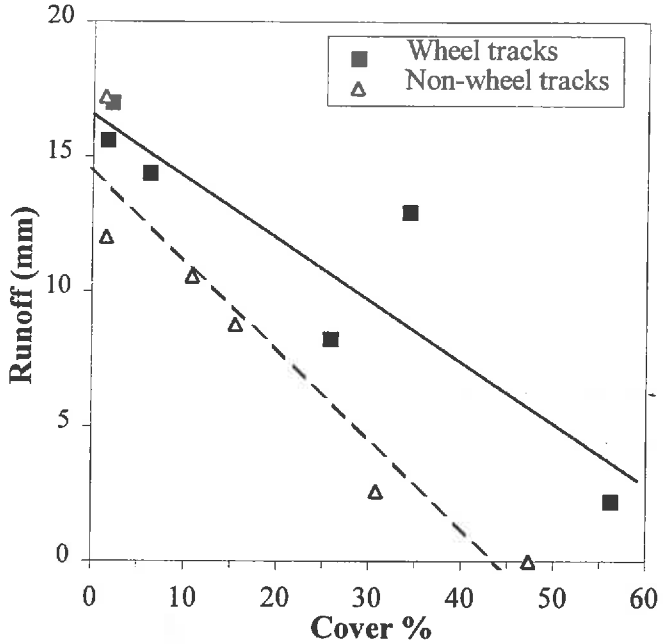


Figure 3 - Runoff from a 40 min storm as affected by cover and wheel traffic (Black Earth-Emerald).

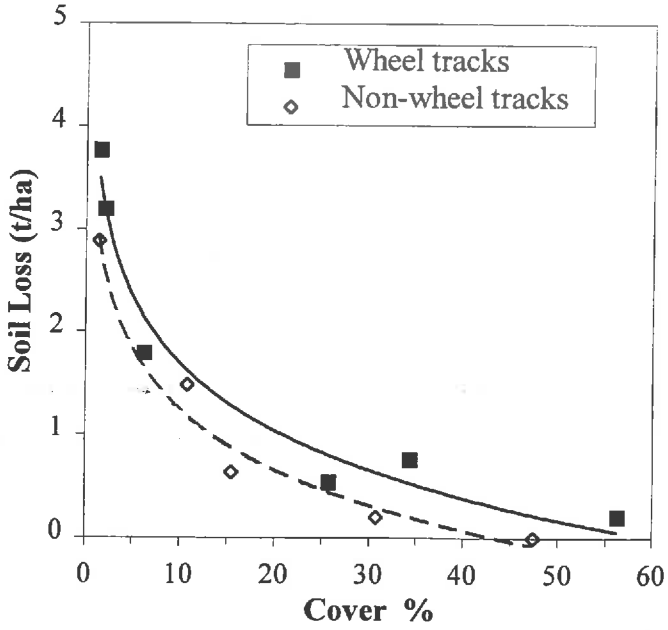


Figure 4 - Soil loss from a 40 min storm as affected by cover and wheel traffic (Black Earth -Emerald).

sediment (scour site), depending on the furrow slope, hydraulic conditions and runoff rate. Looking at each component in turn, the hill is typically a short but steep (eg. 50 %) slope or a nominally flat bed with steep slope into the furrow. Laboratory studies (Silburn and Mitchell, unpub. data) of bare short steep slopes (0.55-0.35 m long, 50 % slope) gave erosion rates of 20-50 t/ha (depending on soil type) for a 40 min 100 mm/hr storm (similar to the storms applied in the field). Erosion rates were similar when half of the slope was made nearly level and the rest 50 % slope. At the furrow scale, soil losses for bare soil (eg. at Gatton) were 12-35 t/ha (Figure 1) while lateral supply from hills on this soil was 38 t/ha, ie. flow in the furrow was not capable of removing all soil supplied by erosion on the hills. Only at furrow slopes >6% would the flow in the furrow be able to remove all sediment supplied and begin to erode the furrow bottom on these plots. Until this happens, soil strength in the furrow bottom can have no effect in reducing erosion.

Furrow discharge, and related variables such as velocity and depth, increases with length of furrow under rainfall. Thus, the critical conditions for initiation of net erosion in furrows (rather than net deposition) would be defined by a combination of slope and length. Soil strength in the furrow bottom (eg. from compaction) can have no effect in reducing erosion from furrows at low slopes and shorter lengths (ie. where deposition rather than erosion occurs), and may increase erosion if it is also related to decreased porosity and infiltration rates. For furrows on steep slopes and longer lengths, or where lateral sediment supply from the hill is reduced (eg. by cover), greater soil strength in the furrow bottom will reduce erosion (see also Titmarsh et al., this proceedings).

## Conclusion

Surface compaction from tractor wheel traffic on moist soil (clay loam) resulted in reduced infiltration, and increased runoff and soil loss compared with non-compacted furrows, when intense rain was applied two days after compaction. These effects were largest where the severity (number of wheel passes) or proportion of area compacted were greater. When intense rain was applied 95 days after compaction on a swelling clay where cotton was grown, infiltration, runoff and soil loss were similar for non-compacted furrows and furrows compacted by one and two wheel passes. Reduced infiltration was still evident on furrows that received five wheel passes. Otherwise effects of wheel traffic were largely ameliorated by wetting, drying and self-mulching during the summer crop. On both the clay loam and clay, surface compaction was not effective in controlling soil loss. Cover from cereal crop residues gave large reductions in runoff and soil loss on both soils.

On controlled traffic furrows in irrigated cotton, wheel track furrows gave more runoff and soil loss than non-wheel track furrows across a range of cover levels. The difference was small for bare furrows and increased with increasing cover. The combination of retaining cover and controlled traffic gave the least runoff and soil loss. However, of the two practices, retaining cover had the greater effect. Controlled traffic without retained cover gave little or no increase in infiltration and reduction in runoff and soil loss from storms, as surface sealing restricts infiltration on bare furrows.

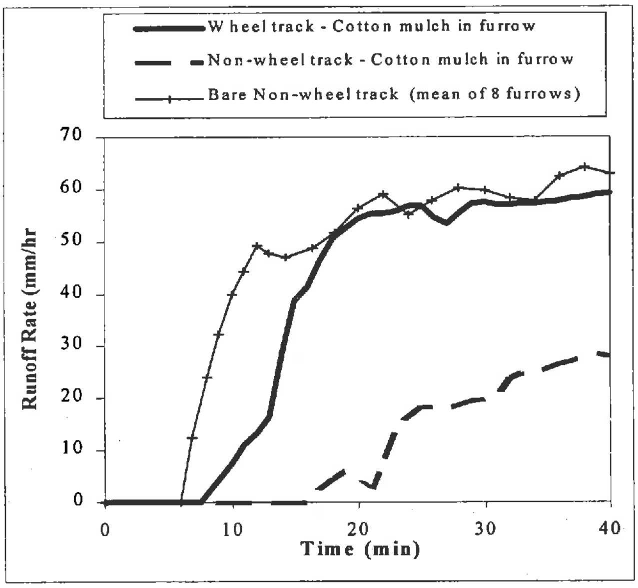


Figure 5- Runoff from furrows with cotton mulch, with and without wheel traffic, during a 40 minute storm on grey clay, Warren.

In hill-furrow systems where the furrow bottom is subject to sediment deposition rather than scour (ie. furrows with lower slopes or shorter lengths), compacting the furrow bottom will not be effective in controlling erosion and may increase it. In steep furrows, where the furrow is subject to erosion rather than deposition, compaction may decrease erosion, but only by the amount of scour occurring in the furrow itself and large soil losses will occur if no other management practices are used.

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