CONTROLLING RUNOFF, SOIL LOSS AND SOIL DEGRADATION WITH CONTROLLED TRAFFIC AND CROP ROTATIONS

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Abstract

A research project in central Queensland commenced in 1993 to assess the effects of downslope Controlled Traffic Farming and crop rotations on runoff, soil loss and soil structure. It aims to develop sustainable land management systems that will reduce runoff and soil loss, and optimise soil structure. Runoff is confined within a down slope bed and furrow controlled traffic system. This eliminates cross flows, and runoff is distributed across the plots and not concentrated. Mean annual runoff and soil loss have been 12-48 mm and 1.35-5.30 t/ha, respectively. These losses have been minimised by Controlled Traffic Farming (optimising soil structure), crop rotations (maintaining a high soil water deficit and producing high ground cover) and minimum tillage (maintaining high ground cover). Soil compaction is confined to an area directly below the permanent wheel track (penetration resistance 2.0-2.5 MPa at 5-10 cm depth). The crop bed has low penetration resistance (0.5-1.0 MPa at 5-10 cm depth), suitable for crop growth. These farming systems provide a sustainable future for the dryland cropping industry by improving the on-farm and off-farm natural resources while optimising crop production.

Introduction

Soil conditions optimal for traffic during field operations (firm and compacted) are in conflict to those desired for plant growth and crop production (loose and friable). There is therefore a conflict between the requirements for traffic and crop growth. A management system which overcomes these conflicts is Controlled Traffic Farming (Yule, 1995).

Controlled Traffic Farming is a system in which the crop zone and traffic zone are permanently and distinctly separated. Combined with zero tillage and crop rotations, this system has the potential to optimise soil structure, reduce runoff and soil erosion, and increase water availability.

The farm efficiencies and soil compaction control benefits of Controlled Traffic Farming were accepted by farmers, but the major constraint to adoption was the implications of down slope layouts on soil erosion. Controlled traffic layouts will strongly influence water flow when runoff occurs. Runoff water will flow along wheel tracks, crop rows, tillage furrows, etc. Yule (1995) developed two rules to control soil erosion in controlled traffic layouts:

1. The controlled traffic lines must drain to a safe disposal point - no reverse flows, no low spots. When runoff occurs, the goal is safe disposal - into a contour bank or waterway.
2. All the runoff generated within a controlled traffic line must be retained in it - no cross flows.

A study commenced in 1993 to assess the effects of down slope Controlled Traffic Farming and crop rotations on runoff, soil loss and soil compaction control. Runoff is confined within permanent bed and furrow units. This prevents cross flows, and runoff is distributed across the plot and not concentrated.

Materials and Methods

The study is being undertaken near Emerald (148° 10'E, 23° 32'S), central Queensland. The region has a semi-arid sub-tropical environment, with summer dominant rainfall. Long term mean annual rainfall and evaporation are 639 mm and 2265 mm, respectively. The soil is a shallow black cracking clay (Vertosol), with a particle size distribution in the 0-10 cm depth of 20% sand, 18% silt, and 62% clay.

Nine plots, 550 m long and 8 m wide are oriented down a 1.0% slope. Each plot consists of permanent one or 2 m wide beds. Traffic is restricted to the furrows between these beds. Dryland cotton, wheat and sorghum are grown as rotation crops to produce a range of antecedent water contents and ground cover levels at all times.

Since late 1994, runoff and soil loss have been measured from bed and furrow units of each plot (Figure 1). Runoff is measured through flumes, with the water height recorded on a data logger at one minute intervals. A discharge rating curve is used to calculate discharge rate and runoff. Soil loss is measured in two components: the coarse bedload material is collected in a trough, and the finer suspended material is collected by a flow based integrated sample. Rainfall volume is measured on a daily basis at two locations within the study area. Rainfall intensity is recorded by a pluviometer. Ground cover levels in each plot are assessed at two locations following runoff.

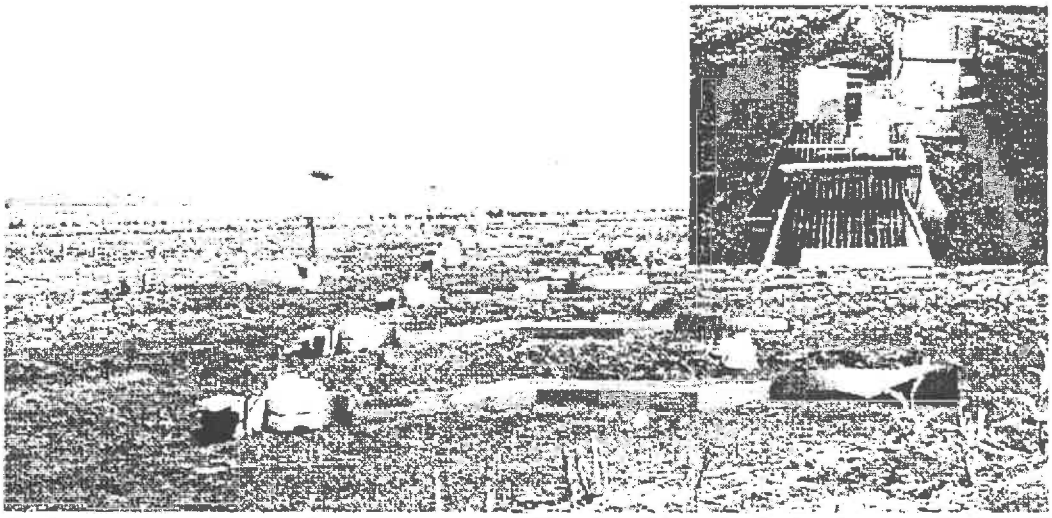

Figure 1 - Instrumentation used to measure runoff and soil loss in dryland controlled traffic layouts

Soil compaction control was assessed in a 2 m transect across a permanent wheel track ("WT") and root bed ("bed") using a recording cone penetrometer. Increments of 1.5 cm to 45 cm depth, and 10 cm intervals across the transect were used. Changes in water content at 20 cm intervals across the transect were measured over a five week period using 5 cm diameter cores, with increments of 10 cm to 100 cm depth.

Results and Discussion

Runoff and Soil Loss

Nine rainfall events since 1994, ranging in amount and intensity, have produced runoff. At the time of runoff, the plots provided a range of ground cover levels and soil water contents. Figure 2 shows the effects of available soil water on runoff, soil loss and suspended sediment concentration on 9/10/96 using data from four cropping histories. The rotation crops had produced plots of various fallow lengths and water contents. The shortest fallow (ex. wheat, 70 mm available soil water) had the driest profile. No runoff or soil loss occurred from this plot. Plots which were ex. cotton had been fallowed longer, and were subsequently wetter (100-130 mm soil water). Runoff was low (1-3 mm), and soil loss was low (0.02-0.03 t/ha). The plot with the longest fallow period after harvest (ex. sorghum, 150 mm soil water) was the wettest, and produced the most runoff and soil loss - 25 mm runoff and 0.10 t/ha soil loss. Suspended sediment concentration reduced when the soil profile was dry (less than 100 mm available soil water). Wetter soils result from long fallows, and produce the highest runoff and soil loss.

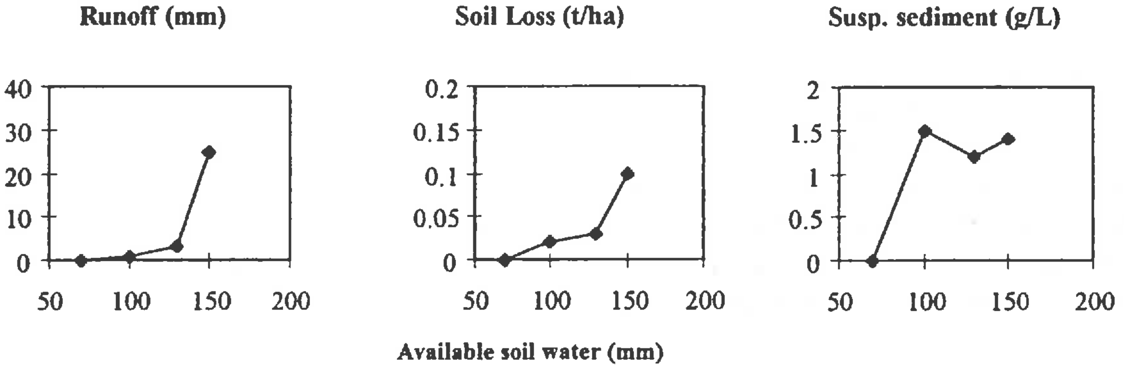

Figure 2 - Effect of available soil water on runoff, soil loss and suspended sediment concentration (9/10/96, rain = 62 mm, I_{30} = 29 mm/hr)

On 15/12/96 (Figure 3), the effects of ground cover levels on runoff, soil loss and suspended sediment concentration are shown. All plots had similar soil water contents due to previous rainfall. Increasing ground cover levels decreased runoff and soil loss. The lowest cover (9%) was produced from plots of 1995/6 cotton. 47% cover was provided by a wheat plot, and 52% by a growing cotton crop. The highest ground cover level (68%) was provided by a growing sorghum crop. No runoff or soil loss occurred from this plot. Carroll *et al.* (1997) found that 30% ground cover was required to control erosion, but these results suggest that 50% cover is needed. Suspended sediment concentration decreased with increasing ground cover. Concentrations were decreased from 12.0 g/L with 9% cover to 8.3 g/L with 52% cover. Suspended sediment concentrations in this event are much higher than the event presented in Figure 2. This is due to the higher maximum rainfall intensity (55 mm/hr compared to 29 mm/hr) and subsequent increase in runoff rates (0-14 mm/hr compared to 9-52 mm/hr).

Suspended sediment concentration is more sensitive to soil water deficit and ground cover than runoff or soil loss. Less than a half full profile and more than 50% cover are required to reduce suspended sediment. The implications are very significant, as suspended sediment moves long distances in rivers and carries enhanced levels of nutrients and pesticides, and generally has high off-farm environmental impacts.

Other runoff events were described by Rohde and Yule (1995) and Yule and Rohde (1996). Stubble from dryland cotton crops generally produced less than 10% ground cover by the end of the fallow. Wheat and sorghum stubble, and growing crops produced greater than 40% ground cover. These results show that rotation crops and minimum tillage practices, which produce and maintain high cover levels and soil water deficits, are essential in minimising runoff and soil loss.

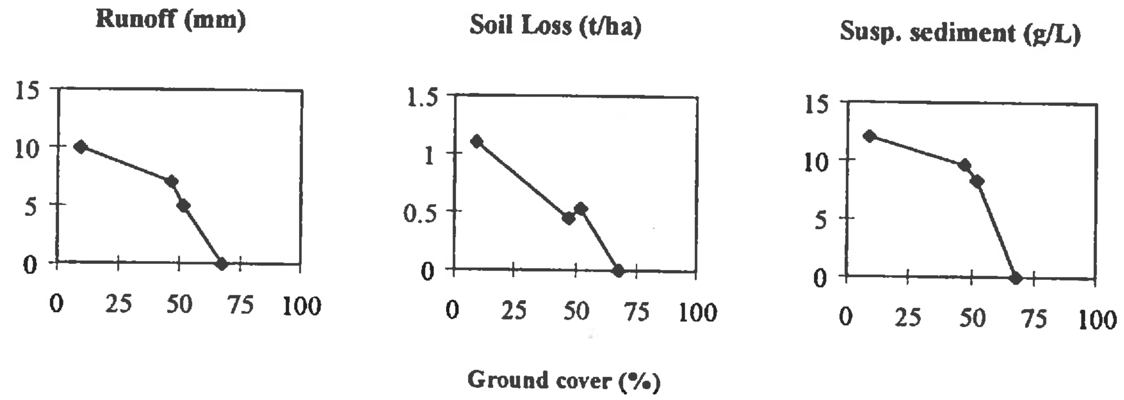

Figure 3 - Effect of ground cover on runoff, soil loss and suspended sediment concentration (15/12/96, rain = 31 mm, I_{30} = 55 mm/hr)

Table 1 shows the annual rainfall and range of runoff and soil loss produced by the plots. Mean annual runoff was 12-48 mm depending on plot history (ground cover, soil water deficit, etc.), and soil loss was 1.35-5.30 t/ha. Work by Carroll *et al.* (1997) showed that annual mean runoff and soil loss was 19-33 mm and 1.42-4.01 t/ha, respectively, depending on tillage history. The median cover level for this study (16%) was lower than the study undertaken by Carroll *et al.* (1997). Results of Freebairn and Wockner (1982) showed that annual soil loss was in the order of 50 t/ha. Results from this study highlight the benefits of down slope controlled traffic layouts in controlling soil erosion.

Table 1 - Annual rainfall, runoff and soil loss for the study area

	Rainfall (mm)	Runoff (mm)	Total soil loss (t/ha)
1995	408	10-59	0.78-7.59
1996	620	25-84	3.26-8.31
1997	374	0	0
Average	467	12-48	1.35-5.30

Compaction

The WT was trafficked three months prior to the soil structure sampling. The bed had not been trafficked since 1993. Penetration resistance below the WT was higher than the bed (Figure 4). Values over 2 MPa occurred within 5-10 cm of the soil surface directly below the WT, and again at 20-40 cm below the soil surface. This narrow band of high resistance is only 20 cm wide. Penetration resistance over 2 MPa is considered to restrict the taproot penetration of cotton (Taylor and Gardner, 1963). Values over 3 MPa have stopped the development of cotton roots (McGarry, 1994). Penetration resistance was lower in the bed. At 10-20 cm below the soil surface, the average penetration resistance was 1.69 MPa below the WT, and 1.48 MPa in the bed.

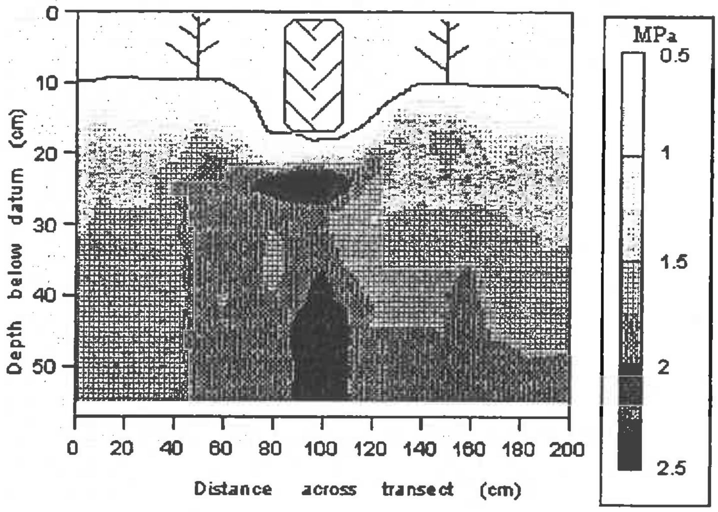

Figure 4 - Penetration resistance (MPa) across a 2 m transect of a permanent wheel track and bed. The soil surface profile, wheel track and plant rows are also shown.

These results show no evidence of soil compaction in the bed, or lateral spread from the WT. Any soil structural damage is restricted to a zone 40-60 cm wide directly below the WT. Soil structural damage in the WT did not affect the change in soil water content measured over a five week period. The change in water content in the WT is similar to that in the bed (0.045 Mg Mg^{-1}).

Conclusions

High soil water deficits and high ground cover levels have reduced soil loss by minimising runoff. Ground cover levels greater than 50% dramatically decreased suspended sediment concentration, further reducing the rate of soil loss. Suspended sediment moves long distances in rivers and carries enhanced levels of nutrients and pesticides, and generally has high off-farm environmental impacts. The average annual soil loss of 1.35-5.30 t/ha is less than that measured at other sites. These data show the benefits of down slope controlled traffic layouts in controlling soil erosion. Dryland crops which do not provide high ground cover levels (e.g. cotton) can not be grown sustainably, as runoff and soil losses are high. Rotation crops, such as wheat and sorghum, will reduce these losses.

Penetration resistance is greater in the wheel track than the root bed. Restricting all traffic to permanent wheel tracks has maintained the bed in an uncompacted condition so that plant root development and crop production are optimised.

These dryland farming systems provide a sustainable future for the dryland cropping industry by improving the on-farm and off-farm natural resources.

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