Controlled Traffic and Surface Runoff Experiments At Gatton College, South-East Queensland

L.Y.Li, P.J Ziebarth J.N. Tullberg
School of land and Food, Gatton College, University of Queensland

Introduction

Interested in conservation tillage has been widespread in Australia, where large areas of land are susceptible to soil erosion. Despite a general understanding that zero tillage should be the optimal systems in terms of soil and water conservation, however, few farmers have been able to avoid all tillage. This suggests that surface and subsurface soil compaction is often a major practical problem of zero tillage. Controlled traffic is expected to control soil compaction, increase infiltration of rainfall and reduce surface runoff. Runoff is the driving force of water erosion, so the extent and magnitude of the controlled traffic effect on runoff or rainfall infiltration capacity on black cracking clay soil is of considerable importance. A research program to establish these effects started in 1994 at the University of Queensland, Gatton College with an initial focus on the assessment of tillage and traffic management options in terms of runoff, and crop yield (Tullberg *et al.*, 1996). This paper reports the effects of field traffic - its control - on runoff, infiltration capacity and crop yield within the first phase of project between 1995 and 1997.

Methods

The experimental site is located in the crop research unit at Gatton College, South-East Queensland (27 °30'S., 152° 27'E.). Soil type at the site is a self-mulching black earth (Ug5.15) (Northcote, 1979) of Lawes series with a mean slope of 5% (table 1). Average annual rainfall is 785 mm with 70 % expected between October and March; pan evaporation is about 2000 mm.

Table 1. Characteristics of Lawes black earth at Gatton

Depth (cm)	pH	Cation exchange capacity (m.e./100g)	Particle size distribution (% of total)				Moisture holding capacity (%)	
			Coarse sand	Fine sand	Silt	Clay	1/3 bar	15 bars
0-10	8.3	47	3	19	23	59	44	26
20-30	8.2	49	3	15	20	63	54	30
50-60	8.4	46	2	14	18	66	56	34
80-90	8.7	51	13	18	16	57	46	27
110-120	8.8	53	2	47	16	34		
140-150	8.7	46	3	36	29	36	43	23

Adopted from Powell, Agricultural Chemistry Branch, QDPI

Controlled traffic trials were set up in the early 1994 after the site was deep ripped to 60 cm. Four replicates (blocks) of three tillage/residue treatments (zero till, minimum till and conventional practice) were established, each plot was split into wheeled (conventional traffic) and non-wheeled (controlled traffic) with subplot dimension of 3m × 30 m. Runoff from each sub-plot was channeled through a tipping bucket unit. Tillage treatments were normally completed with a scarifier or spring tine cultivator with 3 passes and 1 pass for conventional practice and minimum till respectively. Wheeling was applied using a

9t tractor with 6t draw bar pull on the bare soil. The sequence of soil compaction, tillage treatment, crop and fallow management is given in figure 1. Residue levels were those resulting from the cropping practice appropriate to that treatment, unless otherwise noted.

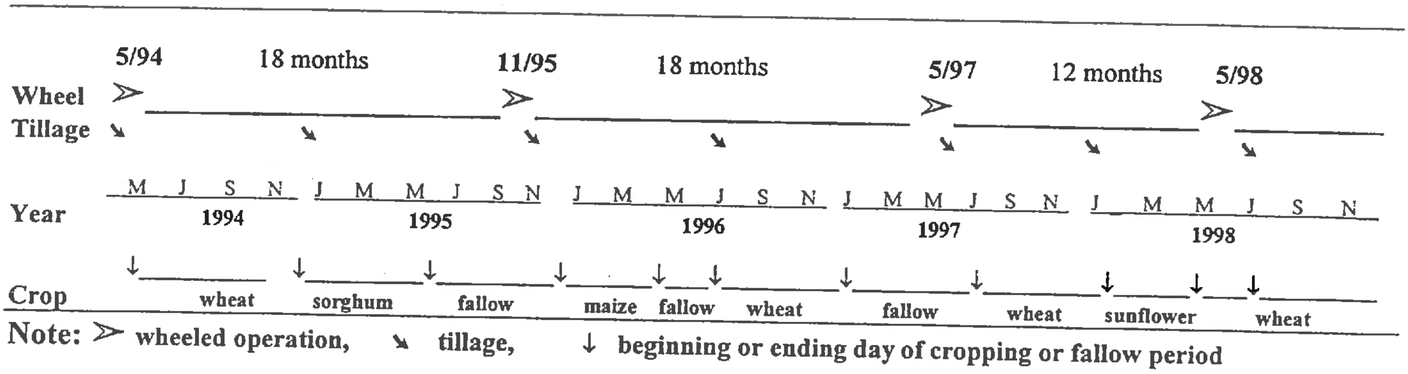

Figure 1. Tillage, traffic and cropping management at experimental site, Gatton

There are 6 treatments :
Controlled Traffic/Zero tillage (CTZ)----No wheeling on the seedbed, no tillage;
Controlled Traffic/Minimum Tillage (CTM)----No wheeling on seedbed, 1 pass of spring tine or scarifier;
Controlled Traffic/Conventional practice (CTC)----No wheeling on the seedbed, 3 passes of spring tine or scarifier;
Wheeled/Zero tillage (WZ)----Wheeled on the seedbed, no tillage;
Wheeled/Minimum Tillage (WM)----Wheeled on seedbed, 1 pass of spring tine or scarifier;
Wheeled/Conventional practice (WC)----Wheeled on the seedbed, 3 passes of spring tine or scarifier;

Rainfall and runoff has been recorded since Jan.1995 using 2 pluviometers for rainfall, 24 tipping bucket units for runoff, monitored at one minute interval by data loggers. Tip rates were converted into data such as total amount of rainfall and runoff daily-based and/or event-based (Ciesiolka *et al.*, 1995) and crop yields measured.

Results and Discussion

Runoff in 3 years

On average, controlled traffic produced 33% less total runoff than conventional traffic treatments during 1995, 1996 and 1997 (figure 2). About 16% and 24% of total rainfall ran off from controlled traffic and wheeled plots respectively, although there was great variable from storm to storm. In the largest runoff event on 5 May 1996, for example, 78% of rainfall ran off from both wheeled conventional practice and wheeled minimum tillage, while 47% ran off from controlled traffic/zero tillage. Over 90 % of total runoff occurred in 1995, and 1996. It was very dry in 1997 with total annual rainfall of 628mm and runoff less than 20mm.

A total of 64 runoff events occurred during experimental period. Runoff varied greatly among treatments in every event, but there was an excellent correlation between wheeled and non-wheeled treatments in terms of total runoff (figure 3).

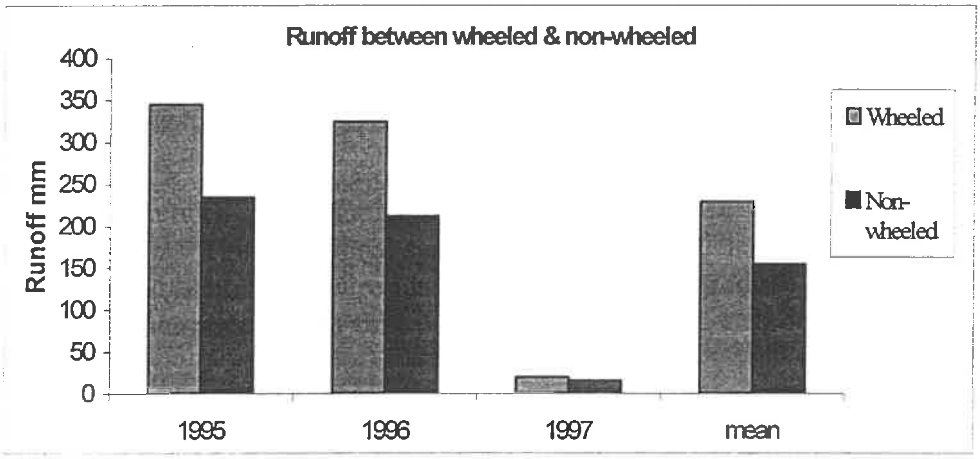

Figure 2 total runoff for wheeled and non-wheeled in 3 years

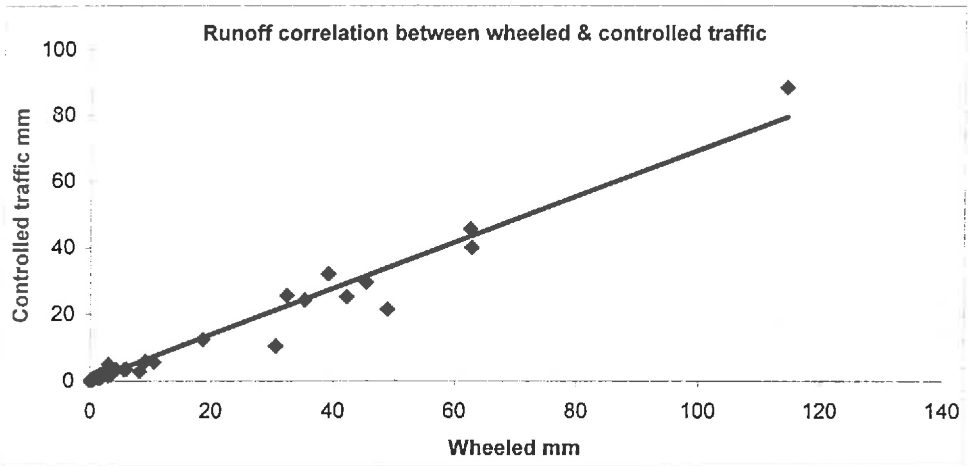

Figure 3 Correlation between wheeled and non-wheeled treatments

The correlation between controlled traffic and wheeled is:

$$Y = 0.696\,X - 0.0443 \qquad R^2 = 0.97$$

Where Y ---- runoff for controlled traffic in mm

X ---- runoff for wheeled practice in mm

The relation line also demonstrates that about 30 % less total runoff occurred from controlled traffic treatments in each runoff event compared with conventional traffic practices.

Infiltration capacity in fallow periods

In general, controlled traffic reduced runoff and increased infiltration capacity during two periods of fallow. 12% more rainfall infiltrated into controlled traffic/zero tillage plot compared with wheeled/conventional practice plot in the fallow from June to November 1995, when the soil surface was bare for all the treatments after sorghum stubble was removed in August. 27% more rainfall entered the controlled traffic/zero tillage plot in the short fallow between April and June 1996, when all the plots were covered by maize stubble.

Table 2. Infiltration capacity during fallow periods for 6 treatments

	Water supply			Treatments					
	Rain	Irrigation	Total	WC	WM	WZ	CTC	CTM	CTZ
Jun. - Nov.1995	344	171	515	147	147	140	121	114	90
RIR				71%	71%	73%	77%	78%	83%
Apr.-Jun. 96	561		561	300	300	246	216	207	151
RIR				46%	47%	56%	61%	63%	73%

Note: RIR means Ratio of Infiltration to Rainfall, RIR = (rainfall + irrigation - runoff) / (rainfall + irrigation).

Study of single event

Runoff analysis has been carried out for each treatment and runoff event, using the curve number method of the Soil Conservation Service, US Department of Agriculture (USDA-SCS method). The curve number method is based on the following equation, which represents a nonlinear relationship between rainfall and runoff (Littleboy *et al.*, 1989).

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad P \le 0.2S$$

$$Q = 0 \qquad P > 0.2S$$

Where Q----runoff volume (mm)
P----rainfall (mm)
S----retention parameter

The major input parameter into the USDA curve number method is the runoff curve number (CN). The value of CN is related to S, which reflects the capacity of surface storage.

$$S = 25.4\left(1000/_{CN} - 10\right)$$

In USDA-SCS procedure, curve number was selected based on wet, average or dry antecedent conditions, which depend on total rainfall in the previous 5 days or 10 days preceding the runoff event (Freebairn and Boughton, 1981).

The individual curve numbers for wet soil moisture conditions (5 days rainfall from 37.5 to 255m preceding the runoff event) are shown in table 3, grouped according to surface cover.

Table 3. UDSA-SCS curve numbers for single runoff event under wet moisture conditions and residue management

Treatment	Wet soil moisture condition			
	With residue cover	mean	without cover	mean
WC	70, 84, 89, 90, 92	85	88, 89, 93,	90
WM	73, 85, 88, 90, 92	86	89, 90, 93,	91
WZ	60, 78, 84, 87, 89	80	89, 90, 93	91
CTC	57, 73, 77, 78, 84	74	86, 86, 91	88
CTM	55, 72, 73, 75, 85	72	85, 86, 86	86
CTZ	56, 62, 72, 75, 78	69	82, 81, 90	84

Generally speaking, controlled traffic/zero tillage gave the smallest in curve number, whereas wheeled/conventional practice gave the greatest curve number under wet soil moisture conditions. The curve number for controlled traffic/zero tillage with residue cover in average was about 16 units less than for wheeled/conventional practice. Controlled traffic without residue cover did not give very much reduction in curve number because surface sealing restricted infiltration on bare soil and overrode the improved subsoil infiltration of controlled traffic with zero tillage. Similar results were found by Silburn *et al*., (1995). Compacted treatments had little benefits from stubble mulching because subsoil structure had been destroyed by wheel traffic.

Crop yield

In general, winter crop increased crop yield by 23%, 21% and 27%, in controlled traffic plots compared with wheeled plots in 1994, 1996 and 1997 respectively, while 5% and 15% for summer sorghum and summer maize in 1995 and 1996 respectively (figure 4). Zero tillage increased crop yield by 5.5 % on average compared with conventional practice except for the first (1994) winter wheat crop (8% reduction).

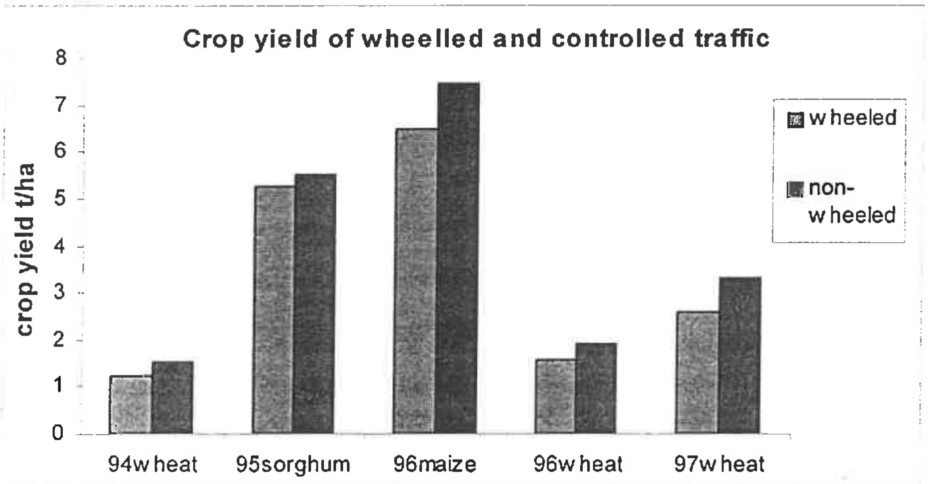

Figure 4 . Crop yield of winter and summer crop during experimental period

Conclusion

In summary, controlled traffic farming reduced runoff, improved infiltration capacity, and increased crop yield compared with random traffic farming. The optimum practice was controlled traffic with zero tillage.

Reference

Ciesiolka, C. A., Coughlan, K. J., Rose, C. W., Escalante, M. C., Hashim, G. M., Paningbatan Jr, E. P., and Sombatpanit, S. (1995). Methodology for a multi-country study of soil erosion management. *Soil Technology* **8**, 179-192

Freebairn, D. M., and Boughton, W. C. (1981). Surface runoff experiments on the Eastern Darling Downs. *Aust. J. Soil Res.* **19**, 133-46.

Littleboy, M., Silburn, D. M., Freebairn, D. M., Woodruff, D. R., and Hammer, G. L. (1989). "PERFECT A computer simulation model of Production Erosion, Runoff Functions to Evaluate Conservation Techniques," Department of Primary Industries, Queensland, Queensland, Australia.

Northcote, K. H. (1979). "A Factual Key For the Recognition of Australain Soils," Fourth/Ed. Rellim Technical Publications Pty.Ltd.,, Coffs Harbour N.S.W, Australia.

Silburn, D. M., Titmarsh, G. W., Wockner, G. H., and Glanville, S. F. (1995). Tractor wheel compaction effects on infiltration and erosion under rain. *In* "National Controlled Traffic Conference" (D. F. Yule and J. N. Tullberg, eds.), pp. 138-144, Queensland, Australia.

Tullberg, J. N., Ziebarth, P. J., McGarry, D., and Pillai-McGarry, U. (1996). Wheel effects on soil structure in a vertosol. *In* "ASSSI and NZSSS Natonal soils conference", Vol. 3 Poster paper, pp. 259-260. New Zealand Society of Soil Science, the University of Melbourne, Australia.