CONTROLLED TRAFFIC FARMING AND SOIL EROSION CONSIDERATIONS

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Abstract
Controlled traffic farming, where tractor and other machine wheels are confined to permanent traffic lanes with crops being grown in the intervening area, has been implemented to varying extents in the main grain growing areas of Queensland and the rest of Australia. Controlled traffic farming has many operational advantages over conventional tillage systems but debate continues on some aspects of the system, for example, the impact of traffic lane orientation and cultural practice combinations on runoff and soil erosion risk. Information to inform this debate was obtained for southern Queensland using field studies (contour bay catchments at four sites), computer simulation of erosion processes and stakeholder discussions. Soil cover and reduced tillage were identified as effective runoff and soil erosion control mechanisms. Runoff and soil erosion levels were usually slightly higher on the contour bays with up/down track orientation than for contour bays with across slope track orientation. Soil erosion levels estimated using soil erosion prediction models concurred with these findings. Stakeholder opinion on traffic lane orientation and soil erosion was divided.

Additional Keywords: soil conservation, WEPP

Introduction
Tullberg 2001 defined controlled traffic farming (CTF) as a farming system where all field traffic is restricted to permanent, distinct parallel traffic lanes. These traffic lanes are normally untilled and not planted to optimise traction and trafficability. Soil in the intervening beds is managed to provide the most favorable conditions for crop performance uncompromised by traffic and associated compaction. CTF has been promoted as a revolutionary farming system that offers many benefits including reduced erosion, increased efficiency of inputs (smaller tractors – due to lower draft requirements - less fuel, time, seed, fertiliser, herbicides – through reduced overlap), and increased crop yields (better timeliness of operation, less compaction, better water infiltration). These factors all point towards a sustainability (productivity and environmental) advantage of CTF over other farming systems.

CTF was initiated in central Queensland in the early 1990's (Chapman et al 1995) and a CTF adoption and investigation program has been ongoing throughout Queensland since. Anecdotal evidence is that many farmers are interested in implementing CTF for field efficiency and other economic reasons. They are, however, unsure of layout orientation due to the uncertainties with regard to runoff and soil erosion levels in relation to land slope, cultural practices and traffic lane direction. A survey of 64 farmers was conducted at the start of this study to gauge expectations and interest in CTF. In relation to traffic lane orientation, 37 % thought that erosion would be lower for traffic lanes running mostly up/down the land slope, 22 % thought that erosion would be higher, and the remainder (41 %) either thought that erosion would be similar or were unsure. Despite this, 52 % indicated they would run their traffic lanes in the most convenient direction (longest run) irrespective of the slope direction, 29 % would run the traffic lanes up/down slope, with the remainder (21 %) orientating their traffic lanes across slope.

The issue of traffic lane orientation and soil erosion is the cause of much debate within the CTF interest group. There is a popularist view, supported by some observations that, provided cover levels are high, traffic lane orientation and slope is of little consequence. A consideration to this view is that the majority of CTF has been implemented in Queensland during a period of low and unreliable rainfall with few large runoff events.

Results from field trials established by Rohde et al. 2002 in the central Queensland CTF adoption program to compare the influence of CTF which had traffic lanes predominately 'up/down' the slope with traditional within contour bank cultivation on soil erosion levels were variable and inconclusive. They found runoff and soil erosion levels were dependent on soil type and rainfall event size. As such these trials did not answer the basic question of layout orientation, slope and soil erosion risk.

Soil erosion by water is a product of runoff and soil condition. To reduce soil erosion risk, it is best for CTF layouts if: a) runoff can be minimized (infiltration maximized), b) traffic lanes and intercrop furrows drain to a safe disposal point with no reverse gradients or low spots; c) runoff generated within each traffic lane or furrow is retained in itself, d) soil surface conditions in the crop area increase erosion resistance of that soil and e) traffic lane/furrow gradients are such that any soil movement within them is minimized.

To assist farmers in their decision-making, the research question becomes – what combination of these runoff and soil erosion factors minimizes runoff and soil erosion risk? In order to fill some of the knowledge gaps around this question, research was undertaken in southern Queensland using field studies (contour bays at four sites), computer modeling and collating observations of stakeholders such as farmers, agronomists and soil conservationists.

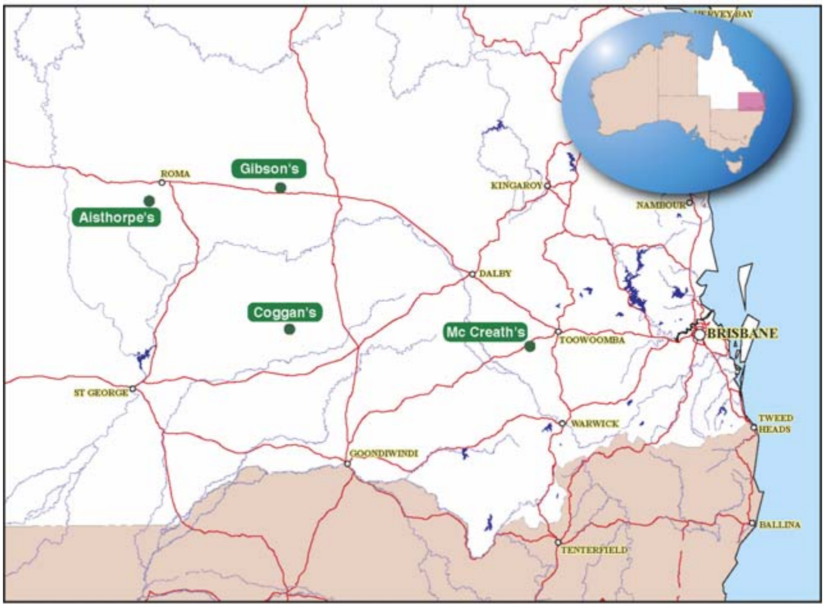
Materials and Methods

Field Sites

Pairs of contour bays at each of four sites in southern Queensland (Aisthorpe's near Roma, Coggan's near Meandarra, Gibson's near Dulacca and McCreath's near Southbrook, see Map 1) had CTF layouts implemented on them and instrumented for hydrologic and soil erosion data gathering. At each site and, as far as local topography allowed, one bay had traffic lanes oriented mainly up/down the slope (CTF U/D) and the other had traffic lanes oriented mainly across the slope (CTF A).

These sites cover a range of slopes, soils and climatic conditions. Aisthorpe's (2 % land slope) has a deep brown cracking clay developed on mudstone, Coggan's (3 % land slope) a hard setting clay loam over clay developed on sediments, Gibson's (4 % land slope) on a gray clay developed on sediments while McCreath's (5 % land slope) has a deep dark cracking clay developed on basalt. Average annual rainfall declines from about 640 mm/year at McCreath's to 550 mm/year at Aisthorpe's. Rainfall is also highly variable in intensity and amount at all sites with a high incidence of high intensity thunderstorms. Evaporation rates are high (ranging from 1800 mm/year in the East to 2000 mm/year in the West).

Measurements included rainfall intensity and depth (pluviometer and volumetric rain gauge), runoff (San Dimas flume), suspended sediment concentrations (rising stage sampler), rill and sediment fan volumes after major runoff events (length, width, depth), soil surface cover (visual, bimonthly).



Map 1 Location of field sites.

Computer Modeling

The computer models, ANSWERS, (Beasley et al 1980), and WEPP, (Flanagan and Nearing 1995) were used to estimate soil erosion levels for alternate CTF layouts.

The work with ANSWERS has been reported previously (Titmarsh et al 2003). They predicted soil loss resulting from a single storm on a 1ha catchment for three farming situations: 1) conventionally tilled, 2) CTF with traffic lanes orientated up/down and, 3) CTF with traffic lanes orientated across slope. This was for two soil conditions: 1) young sorghum on a bare, finely cultivated soil and, 2) high stubble cover level zero till.

WEPP is a process-based model that can be used to estimate spatial and temporal distributions of soil loss over hillslopes or catchments. A long-term (100 years) daily climate file suitable for use as input into WEPP was developed for Aisthorpe's using CLIGEN, a stochastic weather generator, by way of a methodology developed by Yu 2003. Soil erodibility parameter values suitable for the particular soil there were developed previously (Titmarsh et al 1996) and other soil parameter values necessary for WEPP input were obtained from McNish 1987. WEPP was then used to predict soil loss for various layout and surface treatment scenarios. The crop rotation described by Gaffney and Wilson 2003 (wheat-wheat-wheat-long fallow-sorghum long fallow wheat) as typical of the area was used in those simulations.

Water balance and crop yield values from some of the WEPP simulations were compared with output from the 1-dimensional daily water balance model, Howleaky (Freebairn et al 2003), and field knowledge to test WEPP predictions for reasonableness.

Stakeholder views
Comment on the pros and cons of CTF was sought from stakeholders via surveys using fixed questions during field days at the field sites, via email chat and one on one conversations.

Results and Discussion

Runoff generation
Overall at all field sites where runoff was measured, runoff was greater for the CTF U/D than for the CTF A bays (Table1). This extra runoff provided increased opportunity for soil erosion.

Table 1. Runoff and soil loss measured.

Site	Treatment	Total rain mm	Total runoff mm	Total soil loss t/ha
Aisthorpe's	CTF U/D	140	81	1.6#
	CTF A		60	0.7#
Coggan's	CTF U/D	2244	142	10.4
	CTF A		30	4.1
Gibson's	CTF U/D	1391	Na	13*
	CTF A		Na	11*
McCreath's$	CTF U/D	2596	71	6.9
	CTF A		24	2.5

#Single event.
* Rills only, three events.
$ Different rain on the two treatments for several early events then treatment site shifted to adjacent to each other.
Na Not available.

The influences of cover and tillage on runoff and consequent soil erosion are well demonstrated by an event during February 2004 at Coggan's where, prior to the event to remove a persistent weed problem, the CTF U/D bay had been cultivated leaving a relatively smooth surface. This resulted in much higher runoff and soil loss levels (51 mm and 7 t/ha for the CTF U/D bay and 5 mm and 1 t/ha for the CTF A bay).

Other examples of the impacts of cover and tillage level and type on runoff and soil erosion have been demonstrated in this region. For example Freebairn 2004 found stubble mulched areas had a lower daily runoff volume than bare areas. This is confirmed by data from Wallumbilla (east of Roma) where when stubble is present runoff is reduced (Figure 1). That study also showed that once stubble is lost, soil surface condition resulting from the tillage implement used can have an important influence on runoff amounts. Li et al 2001 found that the steady infiltration rate for non-trafficked soils was 4- to 5 times greater than for trafficked soil regardless of cover levels but the presence of cover led to increased infiltration rates for both states. Tullberg et al 2001 found that tillage and reduced cover levels decreased infiltration rates and that the tillage and traffic effects were additive.

An important issue is the reliability of having high cover levels present. If cover cannot be retained due to drought, tillage or other reasons, then the soil erosion risk is increased.

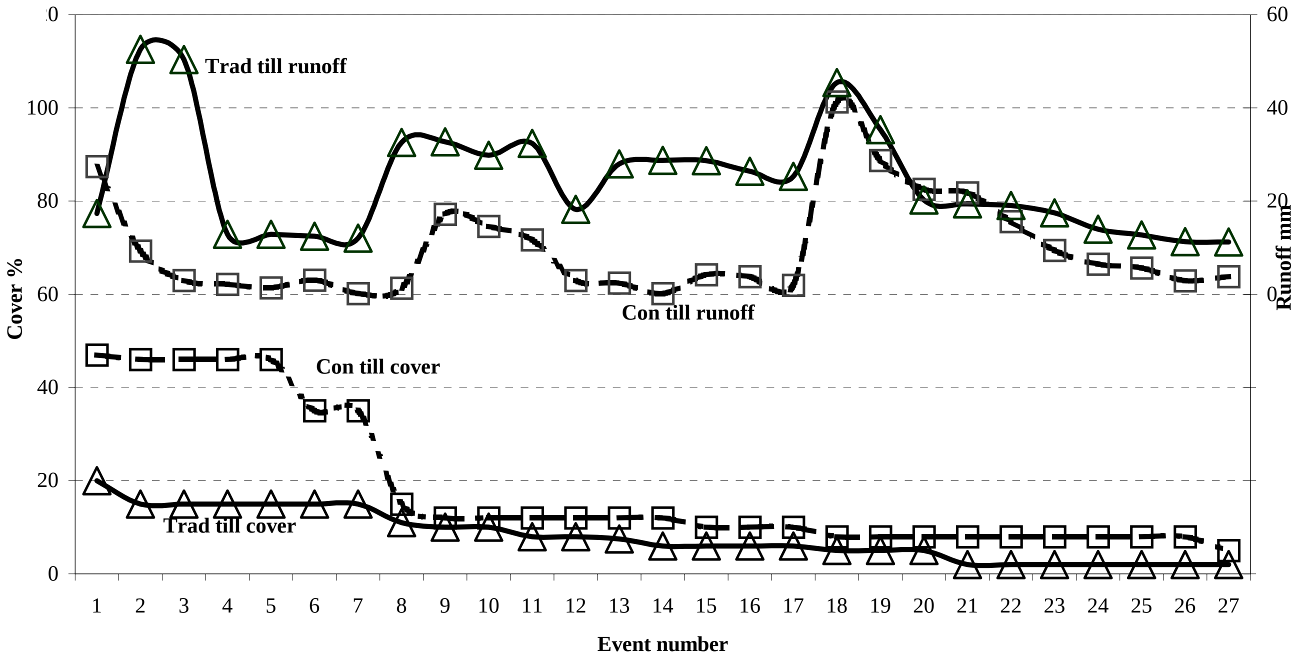


Figure 1. Runoff and cover levels for Wallumbilla, largest 27 runoff events during the course of the study sorted by cover level. Con till: blade plough Trad till: Chisel plough/scarifier Source: D Freebairn and G Wockner

Soil movement

Soil movement as rills or sheet erosion occurred at all field sites (Table 1) with the majority of soil movement being restricted to a few runoff events. It must be noted that differences between treatments are small and could well be within sampling error. Generally more soil was lost from the CTF U/P bays than the CTF A bays but, overall for both treatments, soil loss levels were low, (Table 1) being below levels that are generally classed as acceptable. This is not a reason to be complacent however because, as Littleboy et al 1992 showed, rates of productivity decline due to erosion are greatest on shallow soils such as those at the western sites.

Some rilling occurred at all sites but in different patterns. In the CTF A bays, the rills that developed were always in depressions that were in existence prior to the implementation of CTF on the trial site such as old plough out corner lines and linear gilgais. This was particularly the case at Gibson’s where a large rill developed down an old corner line. Whilst these rills were very noticeable and gave the impression of high soil erosion levels, they were only local in extent. They are difficult to repair by cultivation alone and many soil conservation manuals recommend filling these depressions as part of maintenance. This would also assist in removal of any reverse grades in furrows as recommended by Yule 1995.

Rilling was also observed at McCreath’s (a cracking clay soil very susceptible to rilling / gullying) along crop rows in the CTF U/D bays. Due to the land slope, crop harvesting has to be carried out across slope, and these rills have developed to such an extent that crop harvesting is slowed and causing extra wear and tear on farm machines.

Sheet erosion was more common at Aisthorpe’s, Coggan’s and Gibson’s (the soils there being more susceptible to sheet erosion than rilling). This type of erosion is not easily identifiable, often unnoticed by farmers but may be significant.

Results obtained from the computer models indicate that up/down traffic lane orientation leads to higher soil movement levels than across slope traffic lane orientation. The hydrology and crop yields output from WEPP were similar to those expected in the field and predicted using Howleaky. Thus it was taken that WEPP would give soil loss predictions of the correct magnitude for situations it was designed to be used for.

Table 2 gives an example of soil loss predictions using WEPP. Those predictions show that increasing, inter-row furrow gradients, increases soil erosion levels regardless of soil surface condition. As a guide to comparing the field site results with simulations, the CTF A bays would have traffic lane and inter-row furrow orientations in the

0.3 – 1 % gradient range while the CTF U/D bays would have traffic lane and inter-row furrow orientations in the 1.5 – 5 % gradient range.

The WEPP results are likely to be somewhat conservative compared with steeper gradients. Whilst WEPP can predict inter-row furrows overtopping (this occurred more times during the 100 years simulation for the lower gradients than the steeper gradients) it cannot predict the consequence of that. In the paddock, this overtopping generally leads to a domino effect and increased downhill rilling.

Table 2. WEPP average annual soil loss predictions, t/ha.*

Inter-row furrow gradient, %	Treatment	
	Zero till	Stubble mulch
0.3	0.3	1.4
0.5	0.6	2.2
1	3.8	6.9
1.5	8.6	13.5
2	13.9	21.6
5	49	75

* Simulation period 100 years. 5 % hillslope, 500 m wide and 100 m long. Soil surface treatments, zero till (weed control using herbicide) and stubble mulch (weed control using tined implements. Crop rotation: wheat-wheat-wheat-long fallow-sorghum long fallow – repeat. Crop rows set at 1 m apart with an inter-row furrow depth of 100mm. WEPP soil parameters values: Ki 250 000 kg s/m^4, Kr 0.0064 s/m, Tc 3.5 Pa

Discussions/observations

Conservation Farmers Inc 2003 present testimonials gathered from farmers during this work. Those testimonials point towards improved farming efficiency as being the main motivation for farmers to move into CTF with reduced soil erosion being a useful benefit.

Farmers have given instances of unacceptable soil erosion where CTF is being practiced however. Severe rilling has occurred down rip lines where rippers were used to initially mark out traffic lines. Where runoff is concentrated, for example in depressions, rilling has occurred regardless of layout orientation. Rilling has also been observed along crop furrows, particularly for a short time after planting in the area disturbed by the planter.

Erosion of traffic lanes appears to be a problem with field observations indicating that soil erosion was more severe in the traffic lines than the intercrop furrows. This observation is in accord with work of Silburn et al 1995, who found the effect of compaction on erosion to be short lived for cracking clay soils.

There is a consensus that contour banks are still required (on sloping country) regardless of traffic lane orientation. Where the layout requires farming over contour banks, the banks require flatter batters and higher maintenance. As well, it has been observed that soil cracks align with crop and traffic lane direction even to the point of going right through contour banks where the traffic lanes cross the banks. Rilling was also a problem on the steeper area above contour bank channels where soil was borrowed from to construct the banks. Lower batters have helped to alleviate this problem.

Whilst the extra runoff from the up/down orientation seems small, one co-operator remarked that the extra soil water allowed more planting opportunities and improved crop yields.

Conclusions

The research question was: what are the CTF farming practices that give the best combination of runoff and soil erosion minimization?

This work described in this paper has shown that CTF field layouts that combine maintenance of soil cover with reduced tillage are very effective in this endeavor.

Further, it has shown that traffic lane orientation influences runoff and soil erosion with lower gradient orientations resulting in less runoff and soil erosion. Admittedly the field studies have been undertaken during low rainfall years and several large events dominate the 100 years of simulation but the findings from the two methods used are consistent.

This study leads to several follow on questions.
1) There is no dispute that cover is very effective in reducing erosion but what is the reliability of having that cover present? The problem then becomes one of minimizing the risk of soil erosion when cover levels are low, and
2) The maintenance of a productive soil base is vital to long-term crop production with that productive life being dependent on soil surface treatment and depth. Due to farm efficiency considerations, farmers are implementing CTF layouts on the 'longest run' principle. The question is then: are the farm efficiencies gained by using these 'longest run' layouts sufficient to overcome any possible disbenefits of higher runoff and soil erosion levels?

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References
Beasley, D., Huggins, L and Monke, E. (1980). Answers: A model for watershed planning. *Transactions of the American Society of Agricultural Engineers*, 23(4), 938-944.
Chapman, W., Spackman, G., Yule, D. and Cannon, S. (1995). Controlled traffic development on broadacre farms in Central Queensland. *Proc Nat Controlled Traffic Conf., Rockhampton*, p115-122.
Conservation Farmers Inc. (2003). Controlled traffic farming guide. Conservation Farmers Inc., Toowoomba.
Flanagan, D. and Nearing, M. (1995). USDA Water Erosion Prediction Project (WEPP). Technical documentation. NSERL Report 10, USDA_ARS- MWA West Lafayette, IN.
Freebairn, D. (2004). Erosion control: Some observations on the role of soil conservation structure and conservation. *Natural Resource Management* 7,1, 8-13
Freebairn, D., McClymont, D., Rattray, D., Owens, J., Robinson, B. and Silburn, M. (2003). Howleaky? An instructive model for exploring the impact of different land uses on water balance and water quality. *Proc 9th PUR$L Nat Conf, Yepoon, October 2003*.
Gaffney, J. and Wilson, A. (2003). The economics of zero tillage and controlled traffic farming for Western Downs farms, *Proc. ISTRO Conf, Brisbane*. 458-464. Int. Soil Tillage Research Org.
Li, Y., Tullberg, J. and Freebairn, D. (2001). Traffic and residue effects on infiltration, *Australian Journal of Soil Research*, 39, 2, 239-247.
Littleboy, M., Freebairn, D., Hammer, G. and Silburn, D. (1992). Impact of soil erosion on production in cropping systems. II. Simulation of production and erosion risks for a wheat cropping system. *Australian Journal Soil Research* 30, 775-788.
McNish, S. (1987) Land management field manual, Roma District. QDPI Training series QE87001. Queensland Department of Primary Industries.
Rohde, K., Carroll, C., Lotz, G., Chapman, W., Stevens, S., Yule, D. and Loadsman, R. (2002). Adoption of controlled traffic farming across central Queensland. NHT Project 972255, Final Report.
Silburn, M., Titmarsh, G., Wockner, G. and Glanville, S. (1995). Tractor wheel compaction effects on infiltration and erosion under rain, *Proc Nal Controlled Traffic Conf, Rockhampton*, p138- 144.
Titmarsh, G., Sallaway, M., Mason, F., Glanville, T. and Gilley, J. (1996). Interrow furrow management for erosion control. *Conf on Engineering in Agriculture and Food Processing.* Paper No SEAg 96/102. The Institution of Engineers, Australia.
Titmarsh, G., Waters, D., Wilson, A., Wockner, G., Burgis, M. and Connolly, R. (2003). Experiences in runoff and erosion of controlled traffic farming systems, southern Queensland, *Proc. ISTRO Conf, Brisbane.* p1235-1240. International Soil Tillage Research Organisation.
Tullberg, J. (2001). Controlled traffic for sustainable cropping, *Proc 10th Australian Agronomy Conference, Hobart* 2001.
Tullberg, J., Ziebarth, P . and Li. Y. (2001). Tillage and traffic effects on runoff. *Australian Journal Soil Research*, 39, 2, 249 –257.
Yu, B. (2003) An assessment of uncalibrated CLIGEN in Australia. *Agric and Forest and Meteorology*, accepted May 2003.
Yule, D. (1995). Controlled traffic for broadacre dryland farming: better than sliced bread, *Proc Nat Controlled Traffic Conf., Rockhampton*, p12-17.