Erosion control in southern Queensland - experiences and the future developments.

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Introduction

Conservation tillage systems have provided an effective set of practices to greatly reduce soil erosion. These systems have generally been applied within soil conservation earthworks such as contour banks and waterways in upland situations or as part of a strip cropping layout in flood plains. Improvements in fallow water storage also provide improved yields and with declining costs of key herbicides, the relative cost of mechanical cultivation have risen compared to chemical weed control. In general, conservation cropping systems make better use of rainfall and maintain soil in place and in better condition. The main questions we have relating to controlled traffic are; what are the extra benefits to a) machinery efficiency and b) soil management and yield and c) soil erosion control.

Broad acre developments in control traffic have been initiated in central Queensland (the traffic triplets -Yule, Chapman and Cannon), with the longer term research based mainly at Gatton campus (Tullberg et al). Controlled traffic promises to improve farm machinery efficiency, efficacy of herbicides, and through zonal tillage, improved soil conditions. Fine tuning of farming systems involving confining machinery to specific tracks offers improved efficiency in operations, reduced soil compaction and better root growth. Potential savings in energy use appear large, and farmers are adopting elements of this technology rapidly. Experimental results are highly variable both in magnitude and direction of responses to tillage treatments. This variation is probably due to different seasonal conditions, operators, crop and soil type. Early results show that yields may be improved, although the weight of evidence is not yet strong. It appears to us that controlled traffic has sufficient benefits to be justified without a yield bonus.

The concept of up and down cultivation has raised some questions about the relative erosion control benefits compared to "contour' based conservation tillage systems. It appears to us that we often compare the worst system with the very best, thus not attributing incremental benefits where they belong. It is proposed to trail alternative tillage systems at the farm scale with farmers and agencies being co-researchers. In the end, hard evidence will be needed to justify any sustained revolution in agricultural practice.

The contour bank story

Adoption of contour or graded banks as a means to reduce slope length and control runoff water has been well accepted by farmers for more than 60 years. These hydraulic structures have been constructed at considerable expense by farmers even though their presence often entails reduced cultivation efficiency with cultivation time increases due to smaller blocks and extra overlap in corners and cut outs.

What happens when the big storms occur?

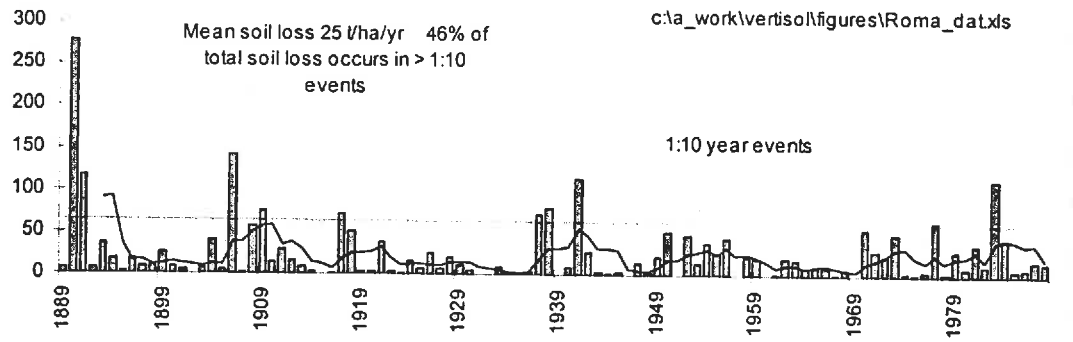
Like all hydraulic structures, contour banks are designed to contain the flow resulting from a specified design storm or runoff event. The normal design criteria for contour banks is that they be able to contain the 1:10 year event (the storm which has a 10% chance of being exceeded in any one year) (Figure 1).

By definition, these structures will fail on average once every 10 years, and in the case of contour banks, when failure of one bank occurs, a cascade of failures further down slope will also occur. Such a failure will result in much of the soil conserving effectiveness of the banks being lost, with concentrated flow often causing severe damage in the form of wide rills and gully initiation. Such failures invariably need ameliorative action soon after the event to avoid further concentrated flow.

Structures are generally constructed to 'over design' standards, but through the life of a structure ie between 'top ups', specifications may be below design standard. The most common reasons for structure failure are; an over design storm occurs, loss of capacity due to cultivation or previous erosion deposition, or self destruction during 'the big storm' due to deposition from a rill, or overtopping of a structure above such as a diversion bank or dam failure.

We would expect that the frequency of over topping would decrease in a controlled traffic system due to a) better stubble cover associated with reduced tillage (not exclusively a CT advantage) and b) better distributed overland flow with less occurrence of self destructive silt fans blocking channel flow.

Figure 1. Time series of estimated annual soil loss in southern Queensland, showing 5 year running mean. Events greater than 1:10 year return period are above the horizontal line. For events larger than 1:10, contour banks are designed to fail.



The stubble story

Retention of crop residues and reduced or no till systems have been adopted to varying degrees across the northern cereal belt. The main drive for this change has been the realisation that better water conservation in fallows can be achieved, and this improvement in water supply for crops results in improved yields, especially in drier growing seasons (Marley and Littler, 1989, 1990; Thomas et al., 1990; Radford et al., 1995, Freebairn et al., 1991). Also, with a decline in the relative cost of glyphosate, a major herbicide for fallow weed control, the economy of chemical weed control has become more favourable. Use of chemicals for weed control still has several challenges - cost, effectiveness of weed control and efficiency of application.

Figure 2 and 3 show the impact of stubble retention on runoff, runoff rates, erosion and sediment load in runoff water. It is clear that stubble has a large effect on the hydrology and sediment movement from agricultural systems. Stubble reduces soil losses by an order of magnitude, and can reduce peak runoff rates by 50%. At this stage it is unclear what down hill cultivation will do to peak flow rates and channel flows.

Figure 2 Influence of soil surface conditions on hydrology and soil erosion from a 6% slope Vertisol on the eastern Darling Downs, Queensland. Tillage treatments referred to are Bare - stubble removed at harvest by burning, Incorporated - stubble partly buried by disc tillage, Mulch - stubble retained on the surface using 1 m sweeps, and Zero till - weed control by chemicals, no tillage. Average soil cover is shown in brackets.

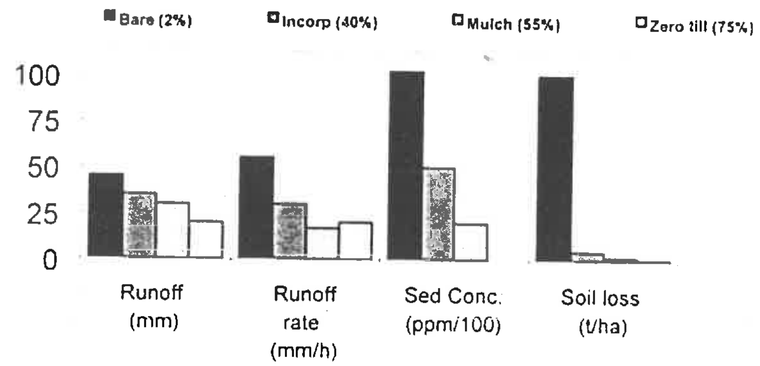
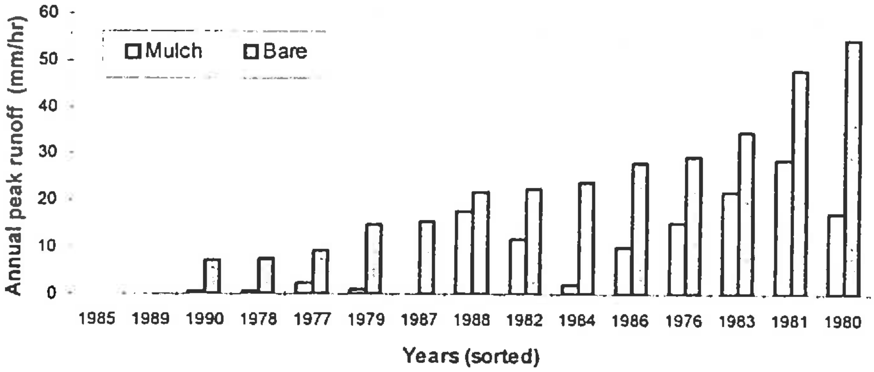


Figure 3 Series of annual peak runoff values from 1.2 ha catchments with two tillage treatment; winter wheat and stubble burnt after harvest in November - *bare fallow*; and winter wheat with stubble retained on the surface with sweep tillage - *stubble mulch*, for the period 1976 - 1990. The maximum peak runoff from the conservation tillage catchment is 50% of that from the bare fallow - when combined with a 10 fold reduction in soil movement, enables soil conservation structures to withstand greater than 1:10 year deign storms.



Modifying slope and slope length

Slope can be managed in some cropping systems where there is control of the direction of runoff. Row crops are one such case where each row carries all the water from its own 'catchment'. Within the limits of practicality, slope can be modified by a scheme similar to that shown in Figure 4. By running furrows oblique to the slope, slope is reduced while slope length may be increased. The main consideration is that each furrow is capable of carrying its own water without overtopping, hence the two systems will perform in a similar manner. One advantage of the oblique furrows is that when erosion does occur, sediment is deposited evenly along the interception channel (contour bank) thus reducing the chance of self-destructing silt fans which reduce channel capacity and cause the structure to fail. A simple empirical model such as the Universal Soil Loss Equation (USLE) can be used to determine whether the risks of erosion are reduced sufficiently to justify the change in tillage layout.

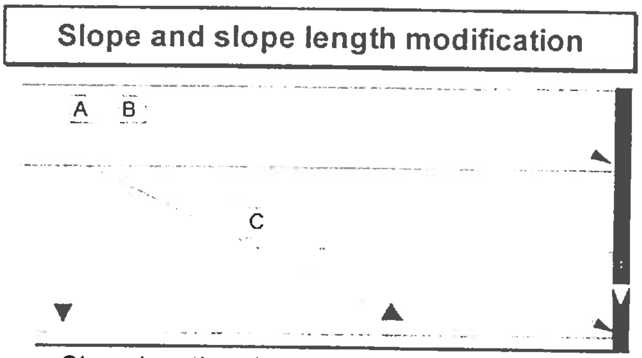
It remains to be determined whether cultivation down slope in a stubble system results in acceptable soil losses in all environments.

Controlled traffic so far?

Tullberg (1995) started exploring the possibilities of energy and time improvements associated with confining wheel traffic to alleys in the early 1980's. His team also are investigating whether there are improvements in soil conditions as a result of removal of tractor wheel loads and compaction. Yule (1995) and Chapman et al., (1995) began developing with farmers, practical approaches to implementing controlled traffic on broad acre farms in central Queensland. His team put forward the proposition that tillage could be oriented with the slope as long as the field was managed with maximum crop or crop residue cover. This approach has the following attributes; by confining runoff flow to single cultivation furrows, catchment size between contour banks rarely exceeds the slope length by one row width (100 m^2). This is considerably smaller than 'rill" catchments which may collect 30-50 m width of water with a slope length of 100-150 m at 1-2% slope (3000 -7500 m^2), sufficient to generate enough erosive power to cut significant rills (> 20 cm depth) regardless of surface cover (Yule, Cannon and Chapman, personal communication). The spreading of water prevents rilling and associated sediment deposits from creating "failure" points in graded or contour channels. Visual evidence after large storm events (> 1 in 10 year return period) suggest that this system is much more resilient than the traditional "contour" cultivation, although anecdotal evidence in southern Queensland suggests that rilling may be exacerbated by down hill cultivation. Ziebath and Tullberg (1995) showed that a trafficked micro catchment yielded considerably more runoff (30-60 mm) than an un-trafficked area over a one month period of above average rainfall.

Additional benefits of controlled traffic can be more efficient tillage and spray operations (10-20% saving in overlap), ability to apply chemicals sooner after rain and at night (lower temperatures → lower chemical rates and more efficacious), lower tractor draft requirement (Tullberg, 1995),

Figure 4. Slope and slope length can be modified by soil conservation structures and tillage/planting direction in a row crop situation. Case A is before any water control structures have been constructed, Case B is when the paddock is divided into three units by banks, and Case C is where slope has been reduced by oblique cultivation furrows. Note that slope length increased in C, but slope was reduced, reducing the erosivity of the layout, according to the USLE LS relationships (Wischmeier and Smith, 1978).



Slope length configuration	*Length (m)*	*Slope (%)*	*Slope length factor*
A	150	5	1.19
B	50	5	0.69
C	150	2	0.33

compaction confined to wheel tracts where it is needed, and eliminated or reduced from where crops are grown, and more timely operations (spraying, planting) because of a firmer traffic zone. Benefits above are not always expressed in yield improvements (Yule and Tullberg, 1995), although Ziebath and Tullberg (1995) have found consistent yield advantages on a clay loam near Gatton.

Regardless of the scientific details, farmers in some areas are adopting controlled traffic as a means of applying no till principles in a practical and efficient system of farming. While there are some issues as to the generality of applying down slope cultivation, it is fair to say that scientific and farmer interest is high in this relatively new development.

Erosion and controlled traffic -how we are going about filling the knowledge gaps

Focus groups with farmers on the central Downs (Meandarra, Condamine) (Peterson and Neale) found that farmers were interested in the concepts of controlled traffic, but were wary of some perceived evangelical messages. A common statement made was " we want well researched facts to base changes in practices upon". While the concepts of controlled traffic were accepted by some, even the keenest farmers indicated that they would not cultivate down the slope wherever they had contour banks. This suggests that they would only try controlled traffic layouts on their low slope areas. These farmers had observed rills cutting back from the steep cut slope immediately above the contour channel.

To address some of the areas where we appear to have differing opinions, we are setting up simple experiments on a number of farms. The aim is to compare at least two contrasting practices and observe relative soil losses, machinery efficiency and any other issues that may evolve. An ideal setup is to have contour bay catchments either side of a waterway, where one side is cultivated as normal, and the other cultivated/planted down the slope. The level of instrumentation will be determined by what farmers and scientists want to get out of the exercise. It is our belief that by testing the issues on farm, at real farm scale with farmers applying the treatments, that we can learn most effectively. We are confident that the basis of science - objective observation, will provide useful insights. We do not expect to be able to detect yield difference in such large area comparisons.

To accompany this broad scale research, a number of scenarios can be examined by simulating runoff conditions using rainfall simulators and water flow, run on experiments. Computer models can also be used to explore the hydraulic consequences of changing flow regimes. We currently have the ability to simulate changes in soil structure (compaction, soil surface sealing) on water balance and grain production (Connolly, 1998). By employing these tools and experiments, our confidence in and knowledge of the implications of controlled traffic will grow. While this may seem a cautious appoach to those who are already adopting controlled traffic, it must be remembered that not all approaches work everywhere. It is the responsibility of science to provide support for improved practice, and hopefully with this better understanding, we can implement improvements more effectively.

How much soil is lost from a paddock when erosion occurs ?

The following section is included to provide some perspective on the relative impacts of different erosion control measured. Long term records of hydrology and erosion are difficult to find -at best we can muster up to 14 years of detailed erosion data at one site but most sites have less than 10 years; insufficient is we are considering design criteria in 10 to 50 year recurrence interval range. To examine how much soil erosion might occur during the so called over design events (>1:10) we used the PERFECT cropping system model to stretch our data base from a relatively short experimental period of 10^{+} years to 100 years (the period of available climate record). (Figure 1). Nearly half the soil loss occurs in the 'big' events where banks are likely to fail, especially if sediment loads are high.

Table 1 shows estimates of relative erosion for a range of configurations. Some of these numbers are estimates based on USLE relationships, model analysis and measured soil loss. Catchment studies have shown that the amount of soil lost from a paddock via contour banks and a grassed waterway can range from 10% to 50% of soil movement to the contour channel, depending on soil type and the relative slope between land slope and channel slope. The question mark for controlled traffic reflects our lack of experience

Table 1. Estimated relative soil movement from a range of conditions, based on measured soil loss from the eastern Darling Downs and predictions using a cropping system model. (+ indicates that the estimate is conservative and may be larger).

	Loss from a cultivated plane with no contour banks	Loss from a paddock with contour banks
No contour banks, no stubble	100+	
Contour banks alone, no stubble		55+
Stubble alone, no contour banks	10+	2+
Contour banks and stubble		2
Contour banks, stubble, controlled traffic down slope		?

Assumption 10 - 50 % of eroded soil is lost from paddock, with contour banks - 20%

Assets and liabilities statement

As a summary of the key features of conservation tillage and controlled traffic systems, Table 2. compares a number of attributes of two contrasting systems. While figures used as semi-quantitative, they are presented to give an idea of key elements of these scenarios. Magnitude of values need to be customised for each location, soil type and cropping system.

Successful farming is about getting all the important elements together in a system. Since there is often considerable interaction between factors in a natural system, it is generally very challenging to sort out exactly what element is producing what improvement. Traditional scientific methos tries to isolate each factor, but this approach risks missing out on the synergies between factors. The challenge is for us to exploit those factors that give us the greatest return.

Table 2. Assets and liabilities for two contrasting tillage systems

	Frequent tillage	*Reduce/no tillage/controlled traffic*
Runoff	10% rainfall	
Fallow water storage	20% fallow rain	25% fallow rain (extra 25-50 mm)
Erosion (eg 60m slope at 6%slope)	40 t/ha.yr poor management	< 5 t/ha/yr
Contour bank failure	1 in 10 years	less than 1 in 30-50 years
Soil nitrate at planting		10-20 kg/ha less NO_3-N
Yield - water supply	higher in wet years due to better N supply	100-400 kg/ha extra in dry year
- water use efficiency		10% extra yield potential in controlled traffic -less compaction
Protein		lower protein in high yield season
Fuel	67 L distillate/ha (conventional tillage)	46 L distillate/ha (minimum till) 20-40% fuel saving with controlled traffic
Fertiliser	long term- crop export replacement	an extra 10-20 kg/ha N
Herbicide input	in crop only	incrop + 2- 5 x 1L/ha glyphosate + other
Area cultivated	overlap high (10-20%)	Controlled traffic 10-20% less area
Timeliness	wait for soil to dry after rain longer	timely spraying and planting
Machinery	no machinery changes	modifications may be needed
Earthworks -construction of broad based contour banks	required if not existing, but at lower cost	*broad based* banks essential if not existing
Repair of contour banks	at least every 5 years on average	much less frequently, possible once every 10-20 years
Diseases -soil and foliar	least	more likely

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