Cropping Systems for Climate Change

Jeff Tullberg

Dr Jeff Tullberg lectured in farm machinery management at the University of Queensland, Gatton for many years. He started research on the fuel energy effects of uncontrolled field traffic in the early 1980's, and subsequently led a series of projects to evaluate the practicability of controlling traffic. This included assessments of tillage/traffic impacts on soil physical and biological parameters, erosion and crop yield in Australia and China. He originally trained in agricultural engineering in UK and USA. Now with CTF Solutions, his interest in cropping energy requirements was the starting point for an evaluation of tillage/traffic effects on input-energy-related and soil emissions of greenhouse gasses. This presentation is based on his keynote paper to the 2009 ISTRO conference in Izmir, Turkey. Email: jeff@ctfsolutions.com.au

Greater concentrations of atmospheric greenhouse gasses (GHGs) are expected to reduce average annual rainfall and increase the frequency of climate extremes in most Australian cropping zones. Climate and certainty are words that don't go together, but model predictions are consistent with recent data, so we can reasonably anticipate the need for:

- Resilience under decreased rainfall, with extremes producing greater erosion hazards:
  Rainfall use efficiency and soil surface protection must be improved.
- Incentives or compulsion will be used to make all industries more 'climate-friendly':
  GHG balance of cropping must be improved.

Farm machine and system management decisions have a profound effect on each of these factors, These effects are illustrated here by comparing three generic systems:

<u>Mulch tillage</u> (or stubble mulching). 1-3 tillage, and 1-3 herbicide operations between crops. 100% soil disturbance (tillage); >60% area wheeled per crop; some residue retained.

<u>Zero tillage.</u> No soil disturbance except at planting, full herbicide weed control. Occasional tillage to deal with compaction, or ruts after wet harvests; ~50% soil wheeled/crop; most residue retained.

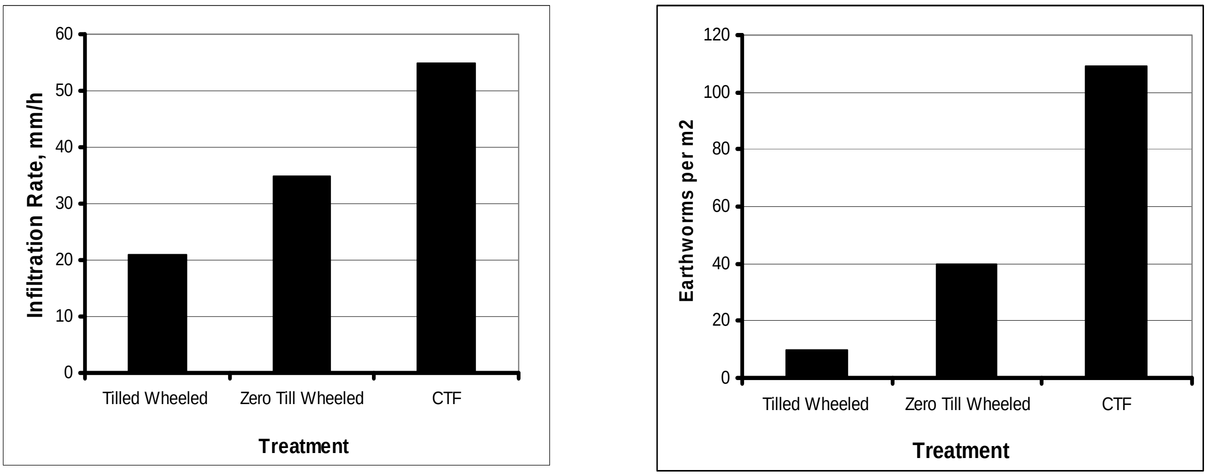
<u>Controlled traffic farming,</u> (CTF) Zero tillage with all heavy wheels restricted to precise permanent traffic lanes oriented to provide drainage and safe disposal of surface water. <15% soil disturbed at planting; <15% soil in permanent lanes; 100% residue retained.

The advantages of minimising tillage are now widely understood by farmers and their advisors, but wheel traffic effects are still often ignored, despite the evidence. One pass by a wheel carrying <1t has a major effect on porosity of the top 10cm of moist soil; common tractor and harvester wheels carrying 2-10t damage porosity to a much greater depth, where amelioration is much slower. Unless traffic is actively controlled >50% of crop area is wheeled in every cropping cycle even in zero tillage systems, and the effects last several seasons. The known, published and demonstrable consequences of uncontrolled field traffic vary with soil type and environment, but commonly:

- Fuel requirements of crop production are increased by 60 --100% .
- Infiltration rate, plant available water capacity and soil biota are reduced by 40-50%.
- Fertiliser is placed in compacted soil, reducing N efficiency by 10-40%

Rainfall Use Efficiency and Soil Surface protection

Tillage and wheel traffic reduce infiltration rates by removing protection from surface soil, and damage to subsurface soil structure, respectively. Maximum infiltration occurs where both sources of degradation are controlled in CTF or permanent bed cropping. The same is true of soil biological activity. Both reflect tillage and traffic effects on porosity and continuity and explain the >40% increase in plant available water capacity in non-wheeled, non-tilled soil. This helps to support greater cropping frequency and biomass production in CTF.



a) Infiltration under >80 mm/hour rainfall. **b.) Mean earthworm numbers in surface 15cm.**

Figure 1. Tillage and wheeling effects on infiltration and earthworms in a vertosol. (CTF = no-wheels or tillage).

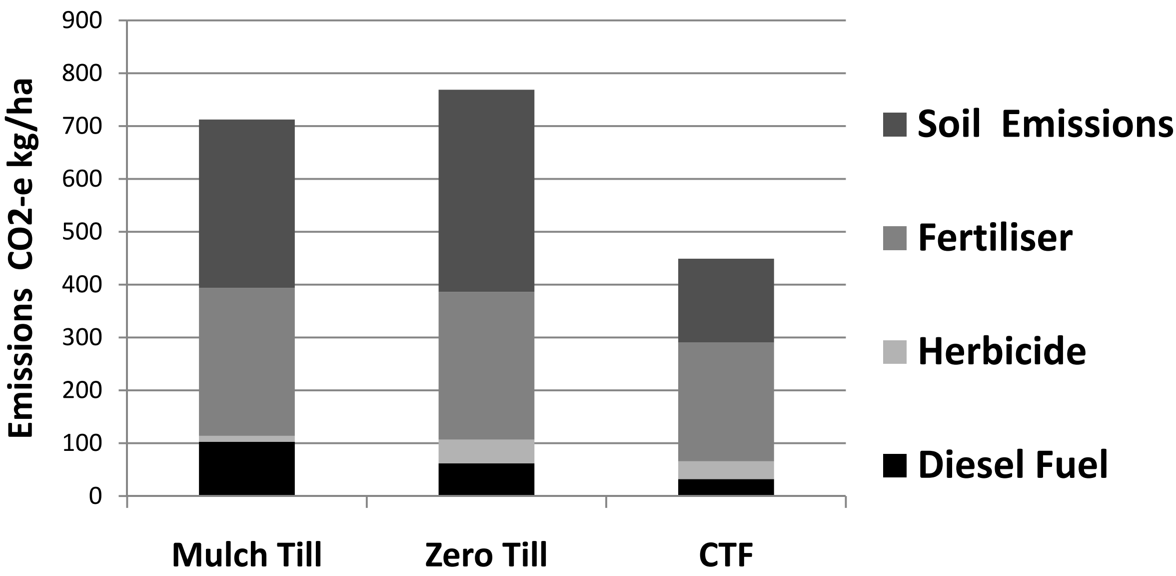
Adapted from Tullberg, Yule and McGarry (2007) Soil & Tillage Research 97 272–281)

Better rainfall use efficiency in CTF is also facilitated by the compacted permanent traffic lanes which provide more timely field access after rain and eliminate the problem of harvester wheel ruts. This means that CTF systems can be replanted directly after when harvest soil moisture is available. This might be only a cover crop, but it will still improve surface protection and the contribution to SOM.

Standing crop residue lasts longer in CTF because less is crushed by harvester and sprayer wheels, particularly when precise inter-row sowing is used to establish the following crop. Greater quantities of anchored, standing residue also improve soil surface protection. When combined with greater infiltration rates and cropping frequency (i.e. less runoff) this ensures that both water and wind erosion hazard is reduced.

Greenhouse Gas Balances

A simple spreadsheet approach has been used to compare emissions from mulch-till, zero till (both random traffic) and CTF (controlled traffic, zero till) systems. The results are illustrated in Figure 2.



Considering each emission component in turn:

Fuel requirements are less in zero tillage, and even smaller in CTF where equipment wheels always operate on firm soil, and only soft, non-wheeled soil is disturbed in seeding/fertilising operations.

Herbicide related emissions (the embedded energy of herbicide production) are greater from zero till, but improved precision, timeliness and cropping intensity in CTF reduces this by >25%.

Fertiliser nitrogen usually represents the largest single energy input to cropping, but the N efficiency of cereal production is usually <50%. Loss of unused nitrates (via runoff, leachate, and denitrification) is often associated with compaction, low SOM, and waterlogging. Zero tillage effects are mixed, but CTF reduces a number of loss vectors. 20% less N application is assumed here for CTF.

Soil Emissions are usually a substantial contributor to cropping GHG balances. If most N is applied at seeding, large nitrous oxide emissions occur when following rain increases water-filled porosity to the 60% - 80% range, a frequent occurrence in random traffic zero tillage, particularly on heavy soils. Limited testing of a partial CTF system (v. random traffic) has demonstrated 35-50% reductions in nitrous oxide emission and methane absorption instead of emission. The spreadsheet assumption is a 15% increase in emissions from zero till, and a 40% reduction for CTF (v. mulch till, in both cases).

No comprehensive assessment of CTF effects on emissions, accounting for both bed and traffic lane effects, has yet been completed. The present assessment indicates that GHG emissions from CTF must be >30% less than those from alternative systems, using assumptions that are conservative in terms of available system data and farmer experience, and supported by broad research evidence.

Conclusion

Precise CTF cropping systems minimise soil disturbance, reduce GHG emissions and improve rainfall use efficiency. Compact traffic lanes of CTF facilitate greater cropping frequency and biomass production, improving the prospect of soil carbon sequestration. Most GHG emissions are a consequence if inefficient application of expensive cropping inputs. CTF avoids the inefficiencies inherent in current systems, and is essential for more productive, climate change resilient cropping.