Controlled traffic/ permanent bed farming reduces GHG emissions

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Introduction

Tillage might be unnecessary for crop production, but no practical mechanised system can avoid field traffic, usually by wheels, often when subsurface soil is moist. Soil damage is rarely obvious in CA, because soil compaction is universal when we “random wheel” about 50% of crop area in each crop cycle in mechanised systems, and natural amelioration takes several years.

Research comparisons between wheeled and long-term non-wheeled soil have consistently demonstrated major wheel impacts on run-off and infiltration, plant available water capacity, soil biota, planting energy requirements and crop performance. Some evidence from Australia and China is summarised in table 1, and is consistent with wheel compaction results from elsewhere, including some with small-scale equipment, when the control was long-term non-wheeled soil.

In practical terms, wheel damage can be minimised only by the use of controlled traffic or permanent bed farming (CTF), where all load-bearing wheels are restricted to permanent traffic lanes oriented for drainage. Precise crop management in soft soil from hard compacted traffic lanes also provides a range of ‘system’ benefits, improved timeliness and cropping opportunities being the most obvious (McPhee et.al 1995). Productivity and sustainability benefits of CTF have been confirmed by surveys of CTF farmers in Australia which have demonstrated increasing yields and cropping frequency, with less time, fuel, fertiliser and agricultural chemicals (e.g.Bowman 2009).

CTF will reduce environmental impact by reducing energy requirements, runoff and soil loss, and the emission impact of partial CTF in organic vegetables in the Netherlands has been demonstrated by Vermeulen and Mosquera (2009). The likely magnitude of this effect in Australian broadacre production was explored by Tullberg (2010), and this paper reports a pilot trial of CTF emissions.

Materials and Methods

The work was carried out on the eastern Darling Downs in an area that had been in permanent CTF no-till for 3 years, in a heavy black vertosol with ~2% slope (located at 151°44'49"E 27°44'55"S). Emission monitoring chambers were installed shortly after wheat was seeded at 35 cm row-spacing on 16th June 2010. A narrow-tine-and-disc opener combination no-till seeder (Excel Ag. "Stubble Warrior") simultaneously injected 80 kg/ha N (anhydrous ammonia) in the interrow.

Tyres (0.45 m section width) of the tractor used for seeding (Deere 8400, 3 m track width, mass approx. 10 Mg) were normally restricted to permanent traffic lanes by precise 2cm GPS “autosteer" (Leica). For this experiment the tractor was driven twice on the permanent beds, prior to seeding, offset first by 0.75 and secondly by 1.0 m from the permanent lanes, to create a 0.8 m zone of once-wheeled soil, representing random traffic (non-CTF) cropping. Two rows were planted in this zone.

Static chambers (0.254m ID, 0.35 m height) were installed in the interrow of this "random traffic” wheeled zone; in the non-wheeled "permanent bed" interrow; and in the non-seeded-or-fertilised permanent "traffic lane". These were driven to a depth of about 10 cm, in lines roughly on the contour, at right angles to the row direction. Four sets of chambers were spaced ~ 10 m apart.

Chambers were sealed only during emission monitoring, when 20 ml samples were collected from headspaces after 20, 40 and 60 minutes, for methane and nitrous oxide analysis with a Shimadzu GC-2014 Gas Chromatograph. Flux rates were calculated from the linear increase in gas concentration (Butterbach-Bahl et al., 2011). Soil temperature and moisture content at 10 cm depth were sampled with a TDR, and soil samples taken for of nitrogen analysis at the start and conclusion of this trial.

Emissions were monitored four times in the first 24 days to establish background emission levels. Rainfall was small (21mm total) during this time so 50 mm water was added to each chamber on day 26, after which several minor rain events were recorded. Final monitoring occurred on day 42.

Results and Discussion

Nitrous oxide and methane emission rates are illustrated in Figure 1, together with rainfall events. N_2O emission from all treatments were similar for 20 days after planting, with only non-significant increases from wheeled treatments effects after 20mm rain on day 17. No further rain was forecast so 50mm irrigation was applied to each chamber on day 28. This immediately stimulated an order of magnitude increase in N_2O emissions from random and traffic lane treatments, but little change from the permanent bed. This effect was maintained by further rainfall on days 36(6 mm) and 43(18 mm). Surface water persisted for > 24h after rainfall events in the wheeled treatments..

Mean N_2O emissions from random wheeling were non-significantly greater than those from permanent traffic lanes, but both were significantly greater ($P<0.05$) than emissions from the permanent bed treatments on 3 occasions. Differences in methane flux were significant on only one occasion when it was being absorbed by the permanent bed but emitted by wheeled treatments. These outcomes are broadly consistent with those of Vermeulen(2009) and Ruser et al(1998) with larger emission differences coincided with greater soil moisture levels in the wheeled treatments.

Total emissions over the full 42 days post-seeding were calculated by summing [mean emissions (start and end each period) x duration]. The accumulated values were converted to CO_2-e, using GWP of N_2O =310, CH_3 =23, indicating emissions of 57.8, 325.0 and 370.0 kg/ha CO_2-e from permanent bed, permanent traffic lane and “random” wheeled soil respectively. This would indicate 42-day post-seeding CO_2-e emissions from this CTF grain production system of 90kg/ha (39kg from 12% traffic lane, 51 kg from 88% permanent bed). This is about 40% of the emissions of 214 kg (185 from 50% random traffic and 28kg non-wheeled) likely from non-CTF management. Better spatial/temporal fertiliser placement should further reduce traffic lane nitrate and emissions.

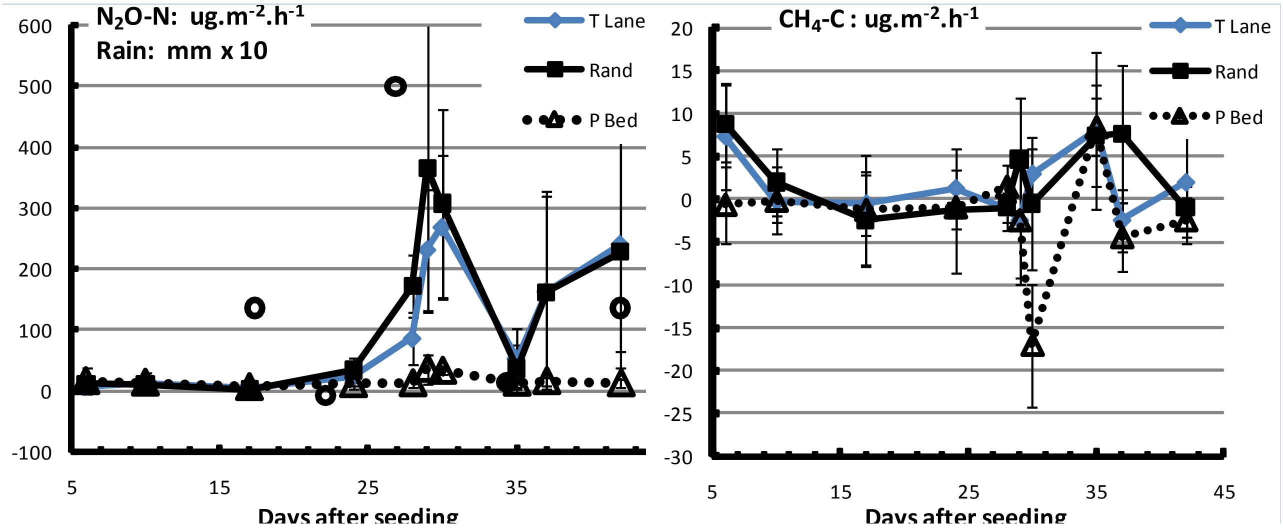

Figure 1. Wheel effects on post-seeding emissions of N_2O and CH_3. Rain (mm x 10) indicated by ○

Table 1. Some broad comparisons between wheeled and non-wheeled soil

Parameter		Units	Australian Vertosol		China, Loess	
			Wheeled	Non-wheeled	Wheeled	Non-wheeled
Wheel Load		t/axle	4-5		1-2	
Rainfall (5year mean)		mm/yr	907 (incl. irrigation)		558	
Runoff (5year mean)		mm/yr	193	112[L]	32	18[W]
Grain yield(5year mean)		t/	3.70	4.05[T]	3.05	3.25[W]
Infiltration (80mm/h ~ 1h)		mm/h	27	97[L]	12	41[W]
Available water	Top 300mm	mm	29	47[M]	27	30[W]
Bulk density			1.36	1.28[M]	1.51	1.59[W]
Fuel use, seeding		l/ha	5.6	3.0[T]	/	/

[L] Li et (2007); [W] Wang et al(2009): [T] Tullberg et al(2007); [M] McHugh et al(2009)

Conclusions

These pilot trial results indicate that post-seeding emissions from CTF are about 40% of those from non-CTF no-till crop production. Nitrous oxide is a major component of emissions from cropping, so this will be a useful mitigation opportunity if confirmed in further work. CTF also provides substantial reductions in fuel and other inputs. Improved rainfall infiltration, storage and cropping opportunities under CTF will also enhance resilience to climate change.

Multiple environmental and economic problems are caused by our failure to recognise the system impact of wheels in mechanised farming. CTF systems are conceptually simple, but practical and economic implementation is complex, and defeats many intending adopters. CTF is used by ~ 15% of Australia's leading farmers, but this would be much greater if machinery, technology and farming system standards were developed. This will happen much faster once CTF permanent bed technologies are recognised as an essential "4th pillar" of CA, along with no-till, cover and rotation, and seen as standard practice by the agricultural research and extension community.

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