Controlled Traffic Farming (CTF) Reduces Emissions and N Loss

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Keywords

- denitrification, controlled traffic farming, fertiliser efficiency, soil emissions.

Take home messages

- Nitrous oxide (N_2O) is a powerful greenhouse gas emitted under wet soil conditions.
- N_2O emissions are an indicator of greater soil nitrogen loss (denitrification).
- Wheeled soil emits 2 – 4 times more N_2O than non-wheeled soil.
- CTF reduces wheeled area, N_2O emissions and N loss (plus other benefits).

Background

Nitrous oxide (N_2O, "laughing gas") is cropping agriculture's largest contribution to global warming. Most of it is produced in the top 10 cm of soil by microbial activity when nitrate and carbon are available, but aeration is restricted. No-till cropping usually provides carbon from crop residues, and nitrate is available from fertilisers in the weeks after seeding or top-dressing, and from natural sources. Aeration is restricted when pore space is occupied by water.

Nitrous oxide is produced when water-filled pore space (WFPS) is between 60% and 80%. Some nitrous oxide will be emitted whenever heavy rainfall occurs after nitrogen is applied in no-till, but the quantities depend on the period of time for which WFPS remains high. This period in turn depends largely on the balance between rainfall and internal drainage immediately after seeding. After top dressing, it will also be affected by crop water use.

Wheel track compaction restricts internal drainage, and has been shown to increase emissions of nitrous oxide (Ruser *et al.*, 2006), so controlling field traffic and reducing wheeled area should reduce emissions. Any nitrous oxide emitted from the soil indicates lost nitrogen – nitrogen which could have been used by the crop.

Methods

This project was designed to assess controlled traffic farming (CTF) as a practical approach to reducing soil emissions of nitrous oxide. The objective was to establish the relative emissions from non-wheeled soil, compared with emissions from soil subject to common paddock wheel traffic situations across a range of Australian grain production environments.

Monitoring sites were established near Inverleigh, Horsham and Swan Hill (Vic), Esperance (WA) and Toowoomba (Qld), in paddocks which had been managed in or close to full controlled traffic for at least 3 years. CTF paddocks already provide heavily-wheeled permanent traffic lanes and non-wheeled beds, but for this experiment a new wheeltrack was imposed on the permanent bed to mimic the effect of wheel traffic in non-CTF farming. This was carried out by driving the seeding rig (with openers lifted clear of the soil) on the bed, 0.8 m away from the permanent lane, immediately before seeding the area normally, by travelling on the permanent lanes.

This provided the 3 experimental treatments:

- Non-wheeled CTF soil – "**CTF Beds**"
- Heavily wheeled CTF permanent traffic lane – the "**CTF Lanes**"
- A single wheeling to mimic those of non-CTF farming –the "**Random**" treatment.

At each site GHG emissions from each treatment were sampled using four replicate emission chambers per treatment. Each chamber consisted of a frame or cylinder inserted 8-10 cm into the soil, enclosing the sampled area. A headspace or lid was fitted during samplings to seal off a fixed volume of air above the soil, and 4 gas samples withdrawn at fixed intervals into evacuated vials for gas chromatographic analysis. The N_2O emissions were calculated from the increase in gas concentration with time during chamber closure, adjusted for chamber area, volume, temperature and pressure. This closed chamber technique has been outlined by de Klein and Harvey (2013) and Parkin and Venterea (2010). The emission rate calculations have been described by Scheer *et al.* (2014).

Samples were taken weekly for 6 weeks following seeding and 2 weeks after top-dressing. Outside those periods, additional samplings were carried out when possible after >20 mm rain, or if soil approached waterlogging, together with at least one sampling later in the crop cycle when soil was much drier. In practice emissions were sampled between 8 and 18 (average 14), times per crop. This was sufficient to demonstrate treatment differences, despite the high level of variability of soil emissions. Greater sampling frequency would be required if the objective was a precise determination of total emissions.

Results and discussion

Emissions were initially plotted as mean treatment emissions: date, with 5% LSD bars. These emission characteristics illustrate high variability, but at all sites nitrous oxide emissions from CTF beds were significantly different (P = 5%) to those from the random treatment at several samplings. In most cases CTF bed emissions were substantially less than those

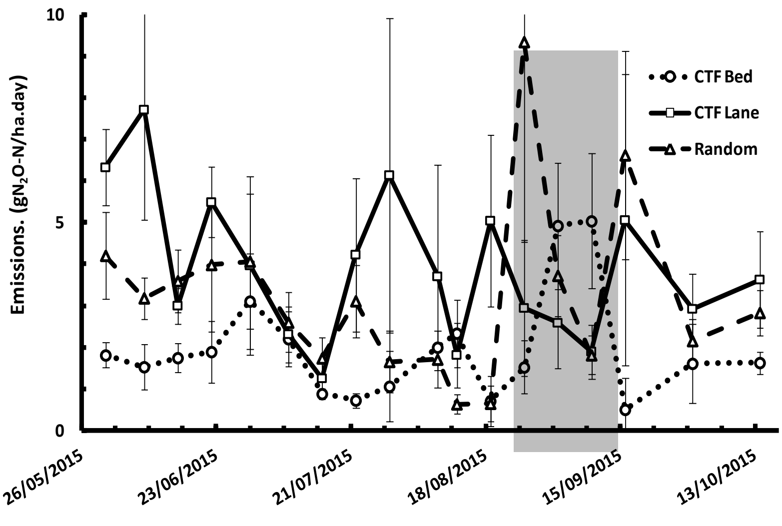

Figure 1. Mean N_2O Emissions, Inverleigh Barley, 2015.
(With 5% LSD bars. Shading is rainy period after top dressing)

from both random and CTF lane treatments, but the example in figure 1, from Inverleigh (Vic) shows one exception: CTF bed emissions were significantly greater than CTF lane or random emissions when 37mm rain fell in the weeks after top dressing.

A clearer illustration of treatment impacts can be seen when the same data is plotted as the cumulative total emissions from each treatment (figure 2). The cumulative totals can be used to show that mean daily CTF lane and random wheel track emissions (3.9 and 3.2 g/ha.d) were 110% and 72% greater respectively than those of CTF beds (3.1 g/ha.d) in this case.

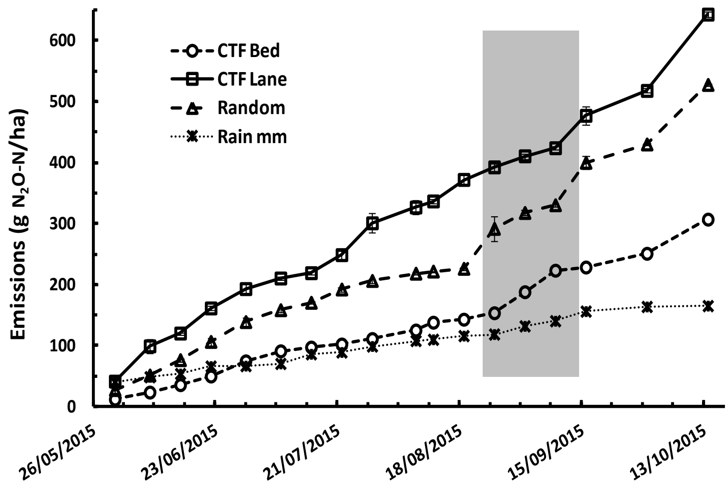

Figure 2 Cumulative Mean N2O Emissions, Inverleigh Barley 2015.
(Shading illustrates rainy period after top-dressing)

Methane (CH_4) concentration changes were also available from chromatography, so the cumulative methane emission characteristic for the Inverleigh example is shown in figure 3, illustrating a consistent effect: CTF beds always absorbed small amounts of (CH_4), which was significantly different to CTF lane or random wheeltrack treatments, which sometimes emitted and sometimes absorbed extremely small quantities. In this case, CTF beds absorbed methane at an average rate of 0.96 g/ha.day, while CTF lanes emitted 0.04 g/ha.day and random wheeltracks absorbed 0.07g/ha.day.

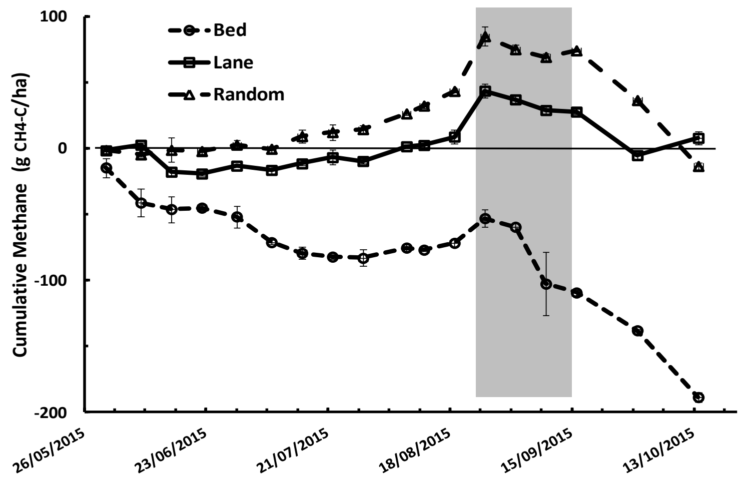

Figure 3 Cumulative Mean Methane Emissions, Inverleigh Barley 2015.
(Shading illustrates rainy period after top-dressing)

The 2015 Inverleigh example has been used here because sampling occurred at a greater frequency than other sites, and substantial rain after top dressing provided additional interest. The methane results for this site were typical, but the nitrous oxide results were unusual in showing greater emissions from permanent lanes than from the random treatment. It should be noted that, as is common practice in the Southern Victorian High Rainfall Zone, the permanent wheel tracks at the Inverleigh site were not left bare at seeding, but had seed and banded fertiliser (DAP) applied at sowing, and substantial amounts of poultry manure had earlier been applied at this site.

The overall mean results from all southern sites are set out in table 1 on a per ha, per crop basis – i.e. the emissions expected from a complete hectare of CTF bed, CTF lane or random-wheeled soil. Practical outcomes obviously depend on the relative areas of each treatment in a farming system.

Table 1. Nitrous oxide (N_20) and methane (CH_4) emissions/crop, with carbon dioxide ($CO_{2)}$ equivalents. (Overall mean values from southern region (Vic. and W.A.) sites.)

Treatment	Nitrous Oxide N_20-N		Methane CH_4 -C		Total Emissions CO_2 Equivalent
	g/ha.d	kg/ha	g/ha.d	kg/ha	kg/ha.
CTF beds	2.11	0.42	-1.81	-0.661	183
CTF lanes	4.85	0.97	-0.07	-0.026	453
Random wheeled	6.27	1.25	+0.05	+0.018	585

Discussion

These small quantities of nitrous oxide and methane might appear trivial, but they can be important from both an economic and an environmental perspective, because:

- Nitrous oxide is only an indicator of denitrification. It normally represents a very small proportion of total N loss, which might be greater by a factor of up 40 i.e. 0.65kg/ha N2O-N might indicate a nitrogen loss of 26kg/ha.
- Nitrous oxide and methane are both very powerful greenhouse gases, having a "Global Warming Potential" of approximately 300 and 20 times that of carbon dioxide (CO_2) respectively. This is why 1.25 kg N_20 and 0.018 kg CH_4 together are the equivalent of almost 600 kg CO_2 (Table 1).

To consider the implications of these results from a nitrogen and cost perspective, assumptions are required about the ratio of nitrous oxide emission to total N loss. If for present purposes this ratio is assumed to be 20, then N losses from CTF beds, CTF lanes and random wheelings would be 8.2, 19.4 and 25 kg/ha respectively.

Practical impact obviously depends on the proportion of paddock area represented by each treatment. In a good CTF system (12% lanes, 88% bed), N loss would be 9.5 kg/ha. This could be compared with a non-controlled traffic system with 50% random wheeled area in which losses would be 16.6 kg/ha if the other 50% is the equivalent of CTF beds. In those cases where inconsistent wheeling means the whole paddock is effectively compacted, losses would be between 19.4 and 25kg/ha.

On the basis of these figures the nitrogen loss saved by CTF (v. non-CTF) operation might be between 6.1 and 15.5 kg/ha, with an emissions reduction of between 142 and 363 kg CO_2-e/ha. It is important to stress that uncertainty in the nitrous oxide/nitrogen loss ratio alone would be able to halve or double these values, but this is still the best information available at present. What is certain is that growers who have adopted CTF usually report slow improvements in soil condition, reduced fuel and power requirements, greater productivity and – once the system is established – an easier way to farm.

The results of our work across all sites in three states show that two further benefits of CTF adoption are reduced GHG emissions from cropping paddocks, and lower losses of valuable nitrogen. If urea costs $300/t, that 6.1 – 15.5 kg/ha of nitrogen saved by adopting full CTF is worth $4 - $10 per ha ($5.30 – $13.50 with urea at $400/t). If the N loss is in fact 30 kg/ha, the saved nitrogen (at $400/t urea) could be worth over $25,000 per 1000 hectares cropped.

If you want to check the proportion of paddock that gets wheeled by your farming system, this can be done using the "Trackman" app (see Resources, below). All you need to know is the operating width, tyre widths and track gauge widths of each item of your farming equipment.

Conclusions

Our work (with two full years data at time of writing) has shown that soil compacted by machinery wheels consistently emits significantly more nitrous oxide than does the uncompacted soils between the tracks in paddocks farmed using controlled traffic farming (CTF).

It is clear, therefore, that increasing the adoption of full CTF to minimise the proportion of cropping paddocks compacted by machinery wheels would lead to a very large reduction in the amount of greenhouse gasses emitted by Australia's grains industry. This is also likely to be true for sugar, cotton, forage and horticulture.

All nitrous oxide emissions inevitably mean that valuable nitrogen is being lost from the soil, although there is not a fixed ratio of N_2O emission to actual N lost.

Even using the lowest ratio of N_2O emission to N fertiliser loss, our results show that the cost savings to farm businesses from reducing N losses through CTF adoption are significant. At the higher ratios of N_2O emission to N fertiliser loss the nitrogen saved by adopting CTF could be worth as much as $25,000 per 1000 hectares of crop.

Useful resources

- **Australian Controlled Traffic Farming Association (ACTFA): http://actfa.net/**
- **Controlled Traffic Farming Technical Manual http://www.nacc.com.au/publications/**
- **Trackman (I'm still trying to discover the hyperlink – it's not on GRDC's website yet!)**

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