Project ID: AOTGR2 - 0062

FINAL REPORT

NITROUS OXIDE EMISSIONS REDUCTIONS FROM CONTROLLED TRAFFIC FARMING

PROJECT DESCRIPTION

This project has demonstrated the effectiveness of controlled traffic farming (CTF) as a means of reducing soil emissions and loss of nitrogen fertiliser in extensive grain cropping. It has done this by monitoring nitrous oxide and methane emissions from trafficked and non-trafficked soil during the production of 15 grain crops. The work has been carried out on CTF farms in both high and low rainfall zones in Victoria, in Queensland and in Western Australia.

EXECUTIVE SUMMARY

USE THIS SECTION TO SUMMARISE THE FINDINGS OF THIS PROJECT.

Abstract

This project has demonstrated that farm equipment traffic increases nitrous oxide emissions and reduces soil's ability to absorb methane soil in a wide range of grain production environments. Average emissions from trafficked soil were more than twice those of soil in non-trafficked crop beds, so CTF should reduce soil emissions of grain cropping by 30 – 50% and also reduce loss of fertiliser nitrogen. Traffic impact on emissions appeared to be larger in the southern region than in Queensland.

Background & Methodology. Australian grain production depends on the use of large, high capacity equipment – tractors, seeders, sprayers, spreaders and harvesters – each weighing 10 –30 tonnes. Controlled traffic farming (CTF) adjusts unit working width and wheel settings so precise guidance can keep all the wheels (or tracks) of these units working more efficiently on compacted permanent traffic 'lanes'. More importantly, this maintains >85% of paddock area in permanent non-trafficked crop 'beds', improving crop performance. Without CTF equipment wheels or tracks will 'randomly' traffic and compact more than 50% of field area per crop, reducing soil porosity.

Nitrous oxide (N_2O) is a powerful greenhouse gas, produced by microbial action when nitrate and carbon are available, and high levels of water-filled porosity (WFP) restrict aeration. Reduced porosity following traffic compaction means that less rainfall is needed to produce high levels of WFP, and slower drainage keeps trafficked soil wetter for longer. This increases N_2O emissions and also inhibits soil's ability to absorb methane (CH_4), another important greenhouse gas.

This project used standard chamber methodology to monitor soil emissions from non-trafficked CTF 'beds', from CTF's permanent traffic 'lanes', and from single 'random' seeder traffic passes mimicking the impact of field traffic in non-CTF farming. The monitoring period averaged 148 days over 15 grain crops in 3 years, with 6 site-years in Queensland (northern region), 7 in Victoria, and 2 in WA (southern region), in both high and low rainfall zones, and in winter and summer crops. Site details are summarized in attachment C 1. Sampling intensity (once per 11 days, on average) was regarded as adequate for comparative purposes, but not for definitive statements of total emissions.

Results. Detailed variations in emission characteristics between sites can be seen in attachments A & B, but these results demonstrated a remarkable consistency in the reduction of emissions from CTF crop beds compared with the random traffic treatments. This difference was also significant (P=0.05) in all cases, whereas traffic lane emissions were more variable: Usually greater than bed emissions, but occasionally similar or greater than those of the random treatment. Results from all 15 sites are presented in Attachment C 2, which shows mean emissions over the sampling periods for nitrous oxide (as N_2O-N) and methane (as CH_4-C), expressed in g/ha per day for all sites.

These mean values (in g/ha per day) have been averaged for the southern and northern regions, and for all sites, in in Table 1a) . The N_2O and CH_4 effects are also combined in a single global warming potential value (GWP, CO_2-e) expressed in the same units. In Table 1b) Traffic Impacts on nitrous oxide and GWP are expressed as the ratio of traffic treatment emissions to those from non-trafficked CTF beds. The GWP data are the basis for statements of the mean reduction in emissions to be expected from CTF adopted by grain producers in Table 1c). The CTF effect will clearly be greater when a larger proportion of field area was previously trafficked, so values are quoted for 50% and 100% prior compaction.

Table 1. Traffic Effects on Mean Emission rates, Treatment Emission Ratios and CTF Effects.

a) Treatment Emission Rates, g $ha^{-1}d^{-1}$. (means over the sampling period).									
Region	Southern			Northern			All Sites		
Treatment	N_2O-N	CH_4-C	CO_2-e	N_2O-N	CH_4-C	CO_2-e	N_2O-N	CH_4-C	CO_2-e
Random	**7.711**	0.138	2317	3.339	-0.937	980	5.962	-0.292	1782
Lane	**5.626**	-0.125	1685	3.243	-0.455	963	4.673	-0.257	1396
Bed	**3.296**	-1.892	945	1.952	-2.065	538	2.759	-1.961	783
b) Treatment Traffic Impact (v. non-trafficked CTF Beds)									
Random	2.34		2.45	1.71		1.82	2.16		2.28
Lane	1.71		1.78	1.66		1.79	1.69		1.78
c) Emissions From CTF v. Non-CTF Grain Cropping									
CTF Effect 1*	63%			77%			67%		
CTF Effect 2*	44%			60%			48%		
*Emission from CTF with 12% Lane Area as % of Emissions of Non-CTF systems (1) 50% & (2) 100% compacted area									

Discussion. These data show that farm machinery wheel traffic has increased total emissions/unit area of trafficked soil in dryland grain cropping by an overall mean "Traffic Impact" of about 2.3, (range 1.3-5.3). Most of this effect is the result of reduced nitrous oxide emissions, but the rather greater impact shown in GWP (v. N_2O-N) illustrates the effect of methane absorption. Mean emission rates and treatment impacts were substantially greater in the southern (winter rainfall) region, probably reflecting the longer duration of wet soil conditions following seeding and in-crop N application in that environment.

Accepted emission factors (EF's) for Australian grain production (0.84% for high rainfall zones, and 0.06% for low rainfall zones) have been published by Grace and Shcherbak, (2015). These have been applied to the nitrogen fertiliser inputs for each site in attachment C3, and converted to an emission rate per day over the days for which those sites were monitored. For this purpose both the Inverleigh and Esperance sites have been treated as "high rainfall". Calculated mean daily nitrous oxide emissions from this process are 3.49, 5.01 and 4.10 g/ha for the southern, northern regions, and all sites respectively. Means for all high and low rainfall sites were 5.54 and 0.182 g/ha respectively.

Published mean emission factors are based on more intensive monitoring than in the work reported here. It would also have covered a wider range of sites, most of which might be assumed to be in non-controlled traffic grain production. Emission chambers would not normally be placed on obvious wheeltracks, so published EF's might thus be expected to reflect emissions rather greater than that of CTF beds, but much less than that of random wheeltracks. This is indeed the case for southern region sites and all sites. In the case of northern sites however, mean emissions based on the high rainfall EF are 50% greater than those measured on random treatments, suggesting that the northern region emission measurements might be an underestimate. An underestimate might indeed be the product of the wide variation in emissions between seasons. The lower emissions might also reflect the fact that both northern region growers drilled their nitrogen into the soil, or the timing of samplings in relation to rainfall events.

Considering all monitoring sites collectively, a weighted mean EF of 0.63% was developed based on the published values of 0.84% and 0.06% for high and low rainfall zones, and monitoring at 11 high and 4 low rainfall sites. Applying this EF to the mean fertiliser input over all sites indicates average total emissions of 0.52 kg/ha N_20-N, or a GWP of 157kg/ha CO_2-e. If this represented emissions from CTF beds, emissions of 361kg/ha CO_2-e would be expected from random-trafficked soil, so the CTF effects in Table 1c suggests that adoption of CTF would reduce emissions by 120 or 188 kg/ha CO_2-e, when changing from farming systems with 50% or 100% of area previously trafficked. If the EF represented emissions for (e.g) 30% trafficked soil (a reasonable value when monitoring has avoided obvious wheel tracks), then the impact of CTF would be correspondingly less.

Figure 1 below provides another perspective on the effect of trafficked area in CTF adoption. In all cases, effects would be greater in the southern region, and slightly larger always when the methane effect (which might be expected to be active for a much longer period) is taken into account.

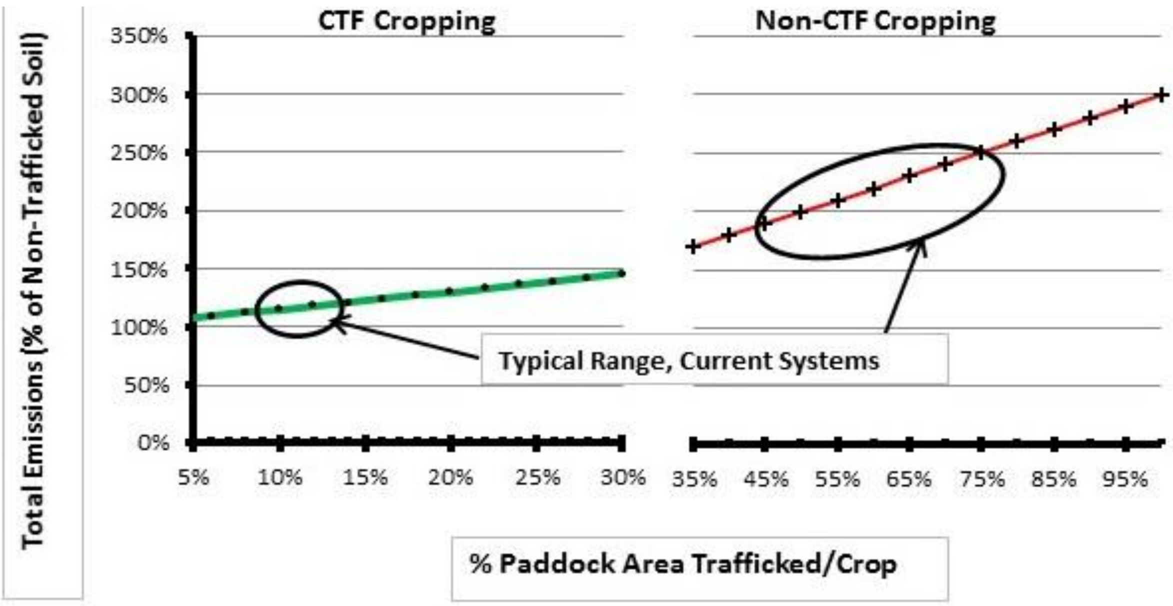

Figure 1. The impact of trafficked area on emissions from CTF and non-CTF grain production systems

Nitrous oxide emissions are generally regarded as an unreliable indicator of total denitrification N losses, which can be greater than N_2O losses by a factor of up to 70. These losses represent a significant cost (if made up by additional fertiliser) or yield loss if not replaced. Applying the weighted mean emission factor to the N input for these sites suggests an average loss of 0.52 kg/ha as nitrous oxide, but this might well indicate a total denitrification loss of around 16 kg N/ha – which is about 20% of the nitrogenous fertiliser input to sites involved in this project. The economic impact of these losses is not insignificant with fertiliser N costing about $1/kg on-farm. It is worth noting that CTF has also been shown to reduce another pathway of N loss in the run-off events that occur sporadically throughout the grain growing areas, sometimes contributing to nitrate pollution of watercourses.

As noted earlier, the emphasis of this work was on relative, rather than absolute emission effects of field traffic, and these data confirm that field traffic has a substantial effect on soil emissions. It is encouraging to note the similarity between emissions calculated directly from these raw results, and those calculated from established emission factors, but further work is required to establish absolute values.

It was also interesting to note instances where emissions from permanent traffic lanes were substantially less than those of random traffic. This might have occurred because less nitrate from fertiliser was present in those areas, suggesting that emissions and N loss from field traffic could be further reduced by better fertiliser placement. This might be one of the factors responsible for the increased emissions from southern systems, where in-crop “top dressing” of nitrogen is normally carried out by broadcast units. Interestingly, at least one grower was considering the use of an air-delivery fertiliser distributor capable of delivering to individual rows and avoiding nitrogen input to traffic lanes. These more precise systems are relatively common in Europe but found only occasionally in Australian grain production.

Emissions and N loss effects of field traffic will be much greater in the intensive cropping industries such as horticulture, cotton and cane, where greater N inputs and wetter soils are combined with more intense trafficking. The CTF effect is also likely to be much correspondingly greater.

Findings.

The results of this work indicate that Controlled traffic farming (CTF) should reduce soil emissions from dryland grain production by 30 – 50% on average. Further work with more intensive sampling over longer periods is required to confirm these effects, but applying these ratios to accepted emission factors suggest that CTF adoption could reduce emissions by 100 – 200 kg/ha CO_2-e.

- CTF should also provide a useful reduction in N fertiliser losses in denitrification.
- Southern region soil emissions and N losses were substantially greater than those in the North.
- Further work is required to develop and validate APSIM-based soil emission models to predict CTF effects in grain cropping, and inform life-cycle analysis of CTF adoption.
- Field work is required to investigate the emissions and N loss impact of improved fertiliser placement.

Policy implications.

- CTF has already been adopted on approximately 22% of the Australian grain production area. This occurs because it provides benefits in terms of fuel use, power requirements, and operational timeliness, in addition to increasing infiltration rates, available water capacity and soil health. These usually result in improved crop yields, and some might be expected to have positive impacts on system emissions. Encouragement of greater CTF adoption will have a positive impact on grain cropping emissions, in addition to other environmental and productivity benefits.
- CTF adoption presents a greater technical challenge for growers in irrigated agriculture (specifically cotton, cane and horticulture), but these are systems which normally apply greater rates of nitrogenous fertiliser to wetter soil. CTF impact on soil emissions and denitrification is thus likely to

be much larger, although benefits may be smaller in the case of sugarcane, due to the higher proportion of the field trafficked multiple times every year. Field investigation should be combined with modelling to quantify CTF effects over a greater range of environments, and is likely to demonstrate benefits large enough to attract Emissions Reduction Fund support.

Unanswered questions

- The absolute values of emissions from all treatments over full seasons.
- This work considered only the emissions impact of major load-bearing wheels of tractors and harvesters, but there is a need to investigate the impact of lighter wheels – e.g. implement frame support wheels.
- The potential to reduce emissions by more precise placement of nitrogenous fertilisers (this is already occurring on a large-scale in Europe, driven by the need to improved efficiency and reduce nitrate leaching to aquifers). This needs to be balanced against tradeoffs in operational efficiency achieved by broadcast fertilizers across large land areas – an issue under active consideration in the northern grains region.
- The extent of CTF impacts on emissions from more intensive irrigated cropping.

METHODOLOGY

Monitoring sites were established on 6 extensive grain growing farms: in the northern region there were 2 in Queensland where warmer temperatures and summer-dominant rainfall patterns allowed some double-cropping. In the southern region there were 3 sites in Victoria, covering both high and low rainfall zones, and there was 1 in Western Australia, with the southern and western regions characterized by cooler temperatures and winter rainfall patterns and an increasing predominance of annual cereal cropping. Compared with the original schedule, this project monitored an additional crop in W.A., and established an additional site at Swan Hill as a cooperative exercise with GRDC's "CTF in the low rainfall zone" project. The central Queensland site proved impractical, so a 2nd site was established in southern Queensland. More site information can be found in Table 1.

Controlled traffic had been maintained for more than 2 years and up to 15 years on some experimental sites. Systems had been in place for only 2 years at Inverleigh (2014) and Swan Hill (2016) but in all cases the traffic lane/bed distinctions were clear. CTF paddocks always have heavily-trafficked permanent traffic lanes and non-trafficked beds, but for the purposes of this experiment an additional seeding tractor and seeder pass was imposed on the permanent crop beds to mimic the impact of traffic in non-controlled "random" traffic farming. This was installed during the seeding operation, when growers were asked to make a single equipment pass to impose traffic on a 50 m length of crop bed, 0.8-1.0 m away from the permanent lanes, with all soil-engaging components lifted clear of the soil. This was carried out immediately before seeding the site normally, travelling on the permanent lanes.

This layout was used on all sites with minor variations depending on grower equipment. It provided the 3 treatments with space for 4 replicates with minimum additional traffic damage to the long-term non-trafficked cropping beds of controlled traffic farms. In all cases, the site was positioned on permanent traffic lanes that would not be required for in-crop spraying or fertiliser spreading.

GHG fluxes were measured using the widely accepted closed chamber technique, which uses a gas-tight chamber to enclose a fixed area of soil for a given time interval. The chamber consists of a frame driven 60-100 mm into the soil and a headspace or lid that is fixed to the frame throughout the sampling period. Chamber enclosure is achieved by a sealed gasket at the lower edge of the lid. (Figure 2)

Chambers of 2 types were used during this work:

Figure 2. Fitting chambers to frames

- Cylindrical chambers: 400 mm lengths of 220 mm diameter plastic pipe, chamfered on the outside to facilitate insertion to a depth of 80-100 mm. Tight-fitting lids with sample extraction taps were fitted when monitoring emissions.
- Rectangular chambers: 100 mm deep, 450×650 mm bases of 2 mm stainless steel were inserted to 80-100 mm. 50L rectangular plastic crates fitted with a foam sealing strip and septum for sample extraction were used as headspaces, held in place by strong elastic cords. Chamber bases were positioned as soon as possible after seeding, with 4 replicate chambers sampling each treatment, representing permanent non-trafficked CTF 'beds', permanent CTF traffic 'lanes', and 'random'-trafficked soil of non-CTF farming. As far as possible, chamber positioning was consistent with respect to crop rows, across all treatments.

Emissions were monitored by collecting air samples from the chamber head spaces. After the soil was covered, 4 samples were taken at fixed intervals from the chambers and transferred into evacuated vials. Samples were subsequently analyzed for N_2O and CH_4 concentrations, using the USQ gas chromatograph. Emission rates were calculated from the slope of the linear change in concentrations within the closed chambers over the closure time (60 or 90 minutes for cylindrical and rectangular chambers, respectively).

Emission rates, corrected for air temperature and pressure during measurement and adjusted for chamber volume were initially expressed on an elemental weight basis for N_2O ($\mu g\ N_2O\text{-}N\ m^{-2}\ h^{-1}$) and CH_4 ($\mu g\ CH_4\text{-}C\ m^{-2}\ h^{-1}$), and the cumulative sum of these values was and plotted against date to illustrate treatment effects. An example from the southern region is shown in figure 3, and results from all sites are included in attachments 1 and 2. (N.B. time between samplings was not uniform, so cumulative emissions are not necessarily representative of the whole crop growing season – just the sampling events that were conducted at each site).

The emission sampling protocol indicated sampling should be carried out where possible on a weekly basis for 6 weeks following seeding/ fertilizing, with two more weekly samplings carried out after fertiliser top-dressing. Additional samplings were taken where possible after >20 mm rain, with at least one taken later in the crop cycle when soil was significantly drier. Sampling was carried out by consultants, and the actual schedule was influenced by factors such as weather, site access and competing tasks. In practice, sampling frequency varied from 8 to 22times/crop (average 14).

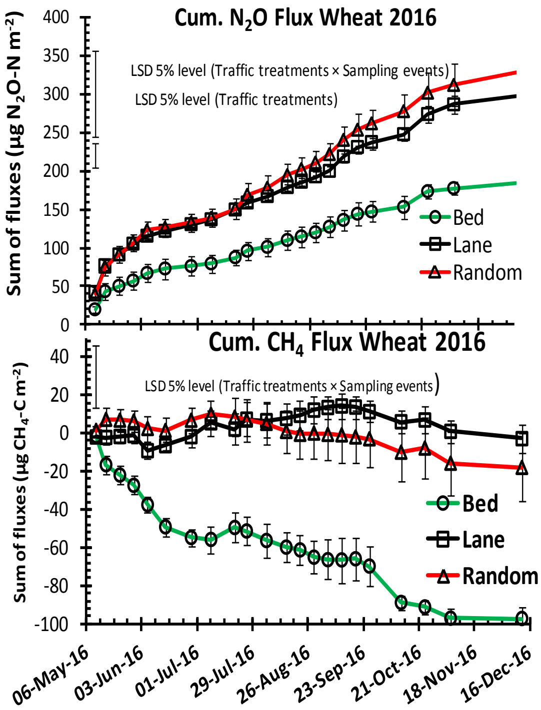

Figure 3. Traffic effects on N_2O and CH_4 Emissions (Example from Inverleigh, Victoria)

Fieldwork followed the plan set out in the original proposal with minor departures caused by the failure of the first winter crop at Felton 1 (inadequate rainfall) and the requirement to move sites at Inverleigh when pending equipment changes threatened a temporary disruption in field traffic patterns.

The demonstration aspects of this project departed from the original proposal of on-site field days. Discussion with local growers suggested that these would be unlikely to attract worthwhile attendance, particularly given the inevitable delays between fieldwork and useful results. Instead, results have been published via conference papers, field day and GRDC Update presentations. Substantial further publicity can be expected after completion of this project, particularly if the results can be used to improve and validate Simulation models looking at traffic compaction effects on emissions in CTF/non-CTF crop production, particularly those where high-quality rainfall, soil moisture and soil analysis data is available (4 sites).

DISCUSSION

Nitrous Oxide

These results demonstrate the consistent, substantial and statistically significant impact of random traffic on soil emissions in all 15 crops monitored as part of this project. Compared with soil in non-trafficked CTF crop beds, nitrous oxide (N_2O) emissions from random trafficked soil were greater by a mean "traffic impact" factor of 2.3 (range 5.3 -1.34). N_2O emissions from permanent lanes were often similar to those of random trafficked soil, and greater than beds by a mean factor of 1.72 (range 4.14 -1.04). The few cases where lane emissions were similar to those of the beds suggests the possibility that lane emissions might be further reduced by better fertiliser placement.

Impact factors for N_2O emissions were generally greater in the more temperate (southern) Australian environments of Victoria and Western Australia (mean 2.48), compared with those of Queensland (mean 1.81). This was not unexpected because the southern grain production system is dominated by annual winter cereals, with April/May seeding and fertilising operations coinciding with the start of comparatively reliable autumn rains. Some N fertiliser was applied at seeding at 8 of the 9 southern region sites. The soil surface can remain wet for long periods in this environment, and N availability is increased with the in-crop broadcast fertiliser application that occurred at most sites.

In the northern regions (Queensland) rainfall is summer-dominant, often storm-related, and generally less reliable, so crop production is more reliant on the comparatively larger soil moisture store. "Opportunity cropping" is common, with winter and summer crops planted when the combination of soil moisture and seasonal outlook are favorable, but with little in-crop N fertiliser application. Recently published results have demonstrated that emission levels from this system can be very high or very low, depending on the coincidence of rainfall events and available nitrogenous fertiliser.

These results show a smaller traffic effect than those found in overseas work, which has shown for example that emissions from the compacted furrows of potato paddocks were greater than those of tilled potato beds by factors ranging from 4 to 10. This is unsurprising in view of the relationship between N_2O emissions, nitrate availability and high levels of soil moisture, because most overseas work was carried out in systems with greater nitrogen inputs and more frequent rainfall and/or irrigation.

Methane

Data from all sites was consistent in demonstrating greater absorption of methane (CH_4) from non-trafficked permanent crop beds, while CH_4 was both absorbed and emitted from trafficked treatments. The net effect was that trafficked treatments always made a smaller contribution to methane absorption than non-trafficked crop beds, with small difference between random traffic and lanes.

The overall mean differences between CH_4-C absorption of untrafficked crop beds and trafficked treatments was 0.23 kg/ha, over the monitored period, but this effect might be expected to occur over the full year, producing a greater effect than indicated here. Southern region differences were again larger than those from the northern region. While N_2O emissions were greater after rain, CH_4 characteristics often appeared to show reduced absorption after large rainfall events. This is consistent with the understanding that CH_4 uptake is primarily controlled by soil compaction and soil moisture due to retarded gas diffusion.

Nitrogen Impact

Across all sites, mean N_2O emissions from random treatments were greater than those of CTF beds by a mean factor of 2.3, indicating that denitrification losses from beds will be similarly smaller. CTF with 12% of field area trafficked might thus be expected to reduce denitrification losses by 30- 50% respectively compared with non-CTF systems with 50% and 100% of field area trafficked. Nitrous oxide emission quantities are small, but might indicate much larger total denitrification losses comprised of both N_2 and N_2O emissions. Calculations based on published emission factors suggest that random traffic might increase overall denitrification losses by 16 kg N /ha, and CTF adoption could be expected to reduce this loss by 50%. Nitrogen input reductions greater than this have appeared in anecdotal claims by CTF graingrowers in Victoria and WA.

Environmental Impact

Regional and overall mean N_2O and CH_4 fluxes were converted to global warming potentials (GWP) and combined in Table 2, to provide a first estimate of CTF impact. This shows the GWP effect of areas of random traffic and CTF lane is greater than that of CTF beds by overall mean factors of 2.3 and 1.8, respectively (2.5 and 1.8 in the southern region, and 1.8 and 1.7 in the northern region). Compared with a random traffic system with 50% trafficked area, emissions from a typical CTF system would be reduced by an overall mean value of 33% (37% in the southern region and 23% in the northern region). Where larger or smaller proportions of field area are compacted, these effects would be correspondingly greater or less.

This work was designed to demonstrate the emissions impact of CTF relative to non-controlled traffic farming, so the emphasis has been on a greater number of sites and environments, rather than the greater sampling intensity associated with more precise emissions estimates. Data presented here can nevertheless be seen as first estimate of field traffic effects. It suggests that the adoption of the well-established CTF system with trafficked area falling from 50% to 12% of field area, would reduce mean emissions by 25-35%. This reduction would be substantially greater in circumstances where larger areas had previously been compacted, and if fertiliser N input to permanent lanes could be avoided; for example, through improved placement.

Controlled traffic farming provides a number of GWP benefits in addition to those noted here. Its effect on reducing power and fuel requirement of cropping operations – with corresponding reductions in emissions from this source – has been demonstrated in both research and grower reports. Similarly, in addition to the reduced N_2O emission and absorption of CH_4, research has already demonstrated the improved soil structure and increased infiltration rates under CTF, and its impact in reducing fertiliser N loss in run-off. These effects might be expected to have a significant cumulative impact on the life-cycle GWP of Australian grain production.

Conclusions

Mean results from low-intensity emission monitoring at 15 sites in the extensive dryland grain growing areas of Queensland, Victoria and Western Australia have demonstrated that:

1. Nitrous oxide emissions from random-trafficked soil are greater than those of neighboring non-trafficked soil by an average factor of >2.3. Overall mean data from these sites indicate that non-trafficked soil in these systems emitted approximately 3 g ha^{-1} d^{-1} less nitrous oxide and absorbed approximately 1.5 g ha^{-1} d^{-1} more methane than trafficked soil.

2. Controlled traffic farming reduces the proportion of field area affected by traffic, and might be expected to reduce soil emissions by 30-50%. This reduction was greater in the southern region then in Queensland, and might be greater if fertiliser N input to permanent traffic lanes can avoided or reduced by improved placement.
3. A first estimate of the quantitative impact of controlled traffic farming can be made by applying these ratios to the emission factors for Australian dryland farming.
4. Emission effects of CTF are likely to be much greater in irrigated production (e.g., cane, cotton, and horticulture) where N fertiliser inputs and soil moisture levels are greater and more frequent traffic accompanies the more intensive management.
5. Further work is required to:
   a) Confirm these findings using more intensive monitoring over full seasons.
   b) Adjust and validate soil/plant models (e.g., APSIM, Keating *et al*., 2003) to generalize and expand our understanding of traffic impact on N_2O emissions and denitrification losses in parallel with b) and c) below.
   c) Assess the soil emission impact of less heavily loaded field traffic (e.g., implement frame wheels running on permanent crop beds).
   d) Demonstrate and assess field traffic impacts on soil emissions from intensive agriculture, and the steps necessary to control traffic in these industries.

IMPLICATIONS FOR AUSTRALIAN AGRICULTURE

Explain the significance of these findings for policy makers and the Australian agricultural industry.

Policy implications.

- CTF has already been adopted on approximately 22% of the Australian grain production area, because it provides other benefits in terms of power requirements, soil health and productivity. Encouragement of CTF adoption will have positive impacts on grain cropping emissions.
- CTF adoption presents a greater technical challenge for growers in irrigated agriculture (specifically cotton, cane and horticulture), but its impact on soil emissions and denitrification will be much larger in these systems which apply greater rates of nitrogenous fertiliser to wetter soil. Field investigation combined with modelling to quantify CTF effects is likely to demonstrate benefits large enough to attract Emissions Reduction Fund support.

ENDORSEMENT

See attached letters from

- Dr Clemens Scheer, Queensland University of Technology
- Dr Tim Chamen, CTF Europe.
- Prof. Mike Bell, University of Queensland.

PLAIN ENGLISH SUMMARY

Nitrous oxide emissions reductions from controlled traffic farming

Background & Methodology. Australian grain production depends on the use of large, high capacity equipment – tractors, seeders, sprayers and harvesters – each weighing 10 –30 tonnes. The wheels or tracks of these units normally "traffic" and compact about 50% of field area, reducing soil porosity. Controlled traffic farming (CTF) uses precise guidance to keep >85% of paddock area in permanent non-trafficked crop beds, improving crop performance and allowing wheels to work more efficiently on compacted permanent traffic lanes.

Nitrous oxide (N_2O) is a powerful greenhouse gas, and agriculture is responsible for >75% of N_2O emissions. It is produced when high moisture levels restrict aeration and nitrate and crop residues are available in the top 10 cm of soil, so high emissions are common when significant rain occurs after fertiliser is applied to no-till systems. Less rainfall is needed to saturate the soil when traffic compaction has reduced porosity, and the slower drainage rates ensures that trafficked soil remains wetter for longer.

This is why soil compaction increases N_2O emissions, and it also inhibits soil's ability to absorb methane (CH_4), another important greenhouse gas. This project was designed to demonstrate that by reducing trafficked area, CTF would also reduce soil emissions from grain production. This was achieved by monitoring soil emissions from non-trafficked CTF "beds", from CTF permanent traffic "lanes", and from single "random" seeder traffic passes on the permanent beds of CTF. This random treatment mimics field traffic in non-CTF "random" traffic farming.

Emission monitoring used standard methodology, where closed chambers were placed over frames inserted in the soil, (Fig 1) and gas samples withdrawn periodically so changes in gas concentration (determined by chromatography) can be used to calculate emission rates. In this project, 4 replicate chambers were used in each of the 3 traffic treatments. Emissions were monitored 14 times (on average) over a mean period of 148 days between the seeding and harvesting of each grain crop. The process was completed in 15 grain crops over 3 years (6 in Queensland, 7 in Victoria 7, 2 in WA), taking in both high and low rainfall zones, and winter and summer crops.

Results. Emission characteristics were plotted for each of these crops as the cumulative sum of emission measurements against time, illustrating the consistent impact of traffic in increasing emissions from fertilised soil. When effects are averaged across all 15 sites, daily N_2O emissions from bed, lane and random treatments were 2.76, 4.63, and 5.96 g/ha, and daily methane absorption was 1.96, 0.26 and 0.29 g/ha respectively. The combined effect of these in terms of global warming potential is that emissions from trafficked soil are greater than those of non-trafficked soil by a mean factor of 2.3, a difference that amounted to approximately 1 kg CO_2-equivalent /ha/ day in these tests. Emissions from permanent traffic lanes were greater by a mean factor of 1.8.

The change in emissions that would occur with CTF adoption in dryland grain production clearly depends on the reduction in trafficked area. Permanent traffic lane areas in CTF systems are usually about 12%, with the other 88% as crop bed, in contrast to non-controlled traffic systems, where approximately 50% is normally trafficked. These results indicate that CTF would reduce emissions by an overall mean of 33% where 50% of area had previously been trafficked, and more than 50% where area was trafficked.

The assumption that >50% of paddock area has been random-trafficked over the previous cropping cycle, can be supported from survey data, but paddock similarities with the random and bed treatments used in this project are arguable. We do know that even in the "self mulching" soils of the Darling Downs, amelioration of the 10 cm (emissions-producing) surface soil happens in about one year, depending on the frequency of wetting/drying cycles. In most soils however, the amelioration process occurs more slowly, and in some it is difficult to detect, so a much larger proportion of paddock area is effectively "trafficked".

This project was designed to demonstrate the impact of CTF relative to non-CTF farming, so the experimental design focused on a greater number of sites and grain growing environments, rather than a greater intensity of monitoring. This means the ratios of results from different treatments (impact factors) are thus more reliable than the absolute value of emission changes, but consideration of these, together with accepted emission factors for grain production suggests that adoption of controlled traffic will provide substantial reductions in soil emissions.

The other important consideration is the impact of CTF on nitrogen loss. The average difference in N loss between random and bed treatments at these sites was only 0.4 kg/ha N_2O-N per year. This is insignificant, but N_2O-N loss typically represents only a small proportion of total denitrification loss, so the difference in total N loss between these 2 treatments is likely to be around 16 kg N/ha. The CTF effect on N loss reduction will – like the effect on emissions – depend on the reduction in trafficked area. This would also represent a useful reduction in fertiliser costs.

It is likely that emissions and N loss could be further reduced by more precise placement of nitrogenous fertilisers, avoiding trafficked soil. More precise placement – common overseas – is still relatively rare in Australian grain production, but most growers have the necessary base unit (the seeder air cart) and a few growers already do it. CTF has also been shown to reduce N loss in the sporadic run-off events that occur with varying frequency throughout the grain growing area.

Findings.

- Controlled traffic farming (CTF) reduces soil emissions of dryland grain production by 30 – 50%, and provided an estimated average reduction in GWP of >60kg CO_2-e /ha within the monitoring period.
- CTF also reduces N lost in denitrification by an estimated average of 5 -12 kg N/ha.
- Further work is required to develop and validate APSIM-based soil emission models to predict CTF effects in grain cropping.

PARTNER ORGANISATIONS

Lead : Australian Controlled Traffic Farming Association (ACTFA)
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PROJECT SUMMARY

This project has demonstrated that the traffic of farm equipment roughly doubles nitrous oxide emissions and reduces soil's ability to absorb methane from trafficked soil in a wide range of grain production environments. Average emissions from trafficked soil were more than twice those of soil in non-trafficked crop beds, so CTF should reduce soil emissions of grain cropping by 30 – 50% and also reduce loss of fertiliser nitrogen.

OBJECTIVES

To demonstrate that Controlled Traffic Farming (CTF) is an effective mechanism for reducing soil emissions of nitrous oxide and methane from Australian dryland grain production.

KEY ACTIVITIES

Soil emissions of nitrous oxide and methane were monitored during the production of 15 grain crops across a wide range of grain growing environments in Queensland, Victoria and Western Australia. The project followed the plan outlined in the original application, with the following exceptions:

- The central Queensland site proved impractical, so a 2nd site was established in S. Queensland.
- The first Queensland winter crop was drought affected to the point that it had to be abandoned.
- Winter crop monitoring was completed for 2, rather than of the planned 1 year in W. A.
- With financial input from ACTFA's GRDC project on "CTF in the low rainfall zone", an additional winter crop winter crop was monitored near Swan Hill, in northern Victoria.

The loss of the Queensland winter crop was a setback, however all other changes from the original plan are significant enhancements, increasing the range of environments under which CTF impacts on soil emissions have been assessed.

OUTCOMES

This project has applied standard procedures, good experimental design and rigorous statistical analysis to demonstrate the impact of field traffic on soil emissions and nitrogenous fertiliser loss. The results show that even in the relatively arid environments of Australian grain production, Controlled Traffic Farming can provide environmental and economic benefits. This will be a further incentive for growers considering the adoption of CTF - no-till, and for equipment manufacturers to facilitate this process.

Results from this work have already been presented to Australian growers at GRDC updates, conferences and field days. They will also be published in the scientific literature, and used as the basis for modelling to extend the usefulness to other environments.

IMPLICATIONS

For grain growers: CTF is already used on about 22% of the Australian grain growing area, but adoption is generally much lower in the southern region. These results show that it is this environment where the greatest benefit is achieved in terms of both emissions and reduction in nitrogen loss.

For policymakers: in addition to the soil emissions benefits demonstrated by this work, CTF also reduces fuel consumption and N loss in run-off. In terms of emissions reduction fund value, these effects might be relatively small from an individual grower's perspective, but with 22 Mha grain growing, organisations such as the regional farming systems groups might be able to make a case for ERF support for CTF adoption programs.

The other important implication of this work is the much greater effect that could be expected in more intensive, irrigated crop production. It indicates the importance of further investigation of traffic effects in these cropping systems, which could more easily justify ERF support for individual growers in overcoming the technical issues of controlled traffic. These issues are simple in concept (use of modular operating and track gauge widths) but much more challenging in practice.

Consent to use photographic images and audiovisual recordings

Consent

I, Chris Bluett……………………………………………………………………[name], being at least 18 years of age,

of ……………………………………………………………………………………….................. [address]

Email: ……………………………………………. Telephone:0419336113 ....

Child's name, if applicable: ....

a) consent to and release the Commonwealth of Australia (the **Commonwealth**) acting through the Department of Agriculture to use and publish photographic images and audiovisual recordings (the **Material**) of me or my child for informational and promotional purposes without remuneration;

b) acknowledge that the Material is the property of the Commonwealth and release the Commonwealth from any infringement of any personal or property rights arising from use of the Material;

c) acknowledge the Commonwealth will store my details with the images and may identify my name or my child's name in conjunction with use of the Material; and

d) acknowledge the Commonwealth will not use Material in a manner that may be deemed adverse or defamatory to me or my child and will not use the Material for any political advertising campaign.

Material

Description of images or video recording: Photograph of Emission Sampling Site ....

....

Do you agree to your name being published with image/video? Yes ☐ No ☐ ....

Photographer/cinematographer:..Staff or Contractor:..

Date of image/video: June, 2015..

Location image/video taken: Inverleigh, Victoria ....

Image/video identification number/s: ....

Department of Agriculture contact officer: Zaman Nuruzzaman ....