Options for reducing nitrous oxide emissions from dryland cropping in the southern NSW grains region

Dr Guangdi Li and **Dr De Li Liu** NSW DPI, Wagga Wagga; **Dr Graeme Schwenke** NSW DPI, Tamworth

Key findings

- » Nitrous oxide (N_2O) emissions respond to large rainfall events.
- » Most N_2O emissions were generated after the crop was harvested.
- » Tillage did not increase N_2O emissions significantly in the first two years under wheat and canola.
- » Including perennial grass into legume-based pastures would reduce N_2O emissions.

Introduction

A four-year rotational experiment with wheat–canola–legumes–wheat in sequence was established at Wagga Wagga in 2012. The soil is a red kandosol and the long-term average rainfall at the site is 541 mm.

The objectives were to:

1. reduce nitrous oxide emissions from dryland grains cropping.
2. improve nitrogen use efficiency.
3. validate and develop process-based biogeochemistry models.
4. simulate net greenhouse gas emission under current and projected future climate scenarios.

This article reports on the N_2O emissions from different crops under different tillage systems.

Treatment and design

The crop sequence was wheat–canola–legumes–wheat from 2012 to 2015. The experimental area was divided into four quadrants. The gas emissions equipment was installed in one quadrant and moved to another quadrant each year (Figure 1).

The experimental design was a randomised split-plot design with tillage (tilled vs. no-till) for the whole plot and nitrogen rates (0, 20, 50 and 100 kg N/ha) as subplots in 2012 (year 1) and 2013 (year 2), or legume types as subplots in 2014 (year 3).

In 2014, grain legumes (field pea and lupins) were either harvested for grain or brown manured. Forage legumes (vetch and annual legumes) were either cut for hay or brown manured.

In 2015 (year 4), a wheat crop was sown to capture any residual nitrogen fixed from the legume crops. The N_2O emission from legume-derived nitrogen was measured during the final crop (wheat).

Measurements

An automated gas chromatograph system was setup on the site (Figure 2). The system consisted of 12 pneumatically operated static chambers linked to an automated sampling system to measure N_2O, CH_4 and CO_2 eight times a day over 24 hours for three years. Manual chambers (24 chambers) were also installed to cover more treatments than the automated system allowed.

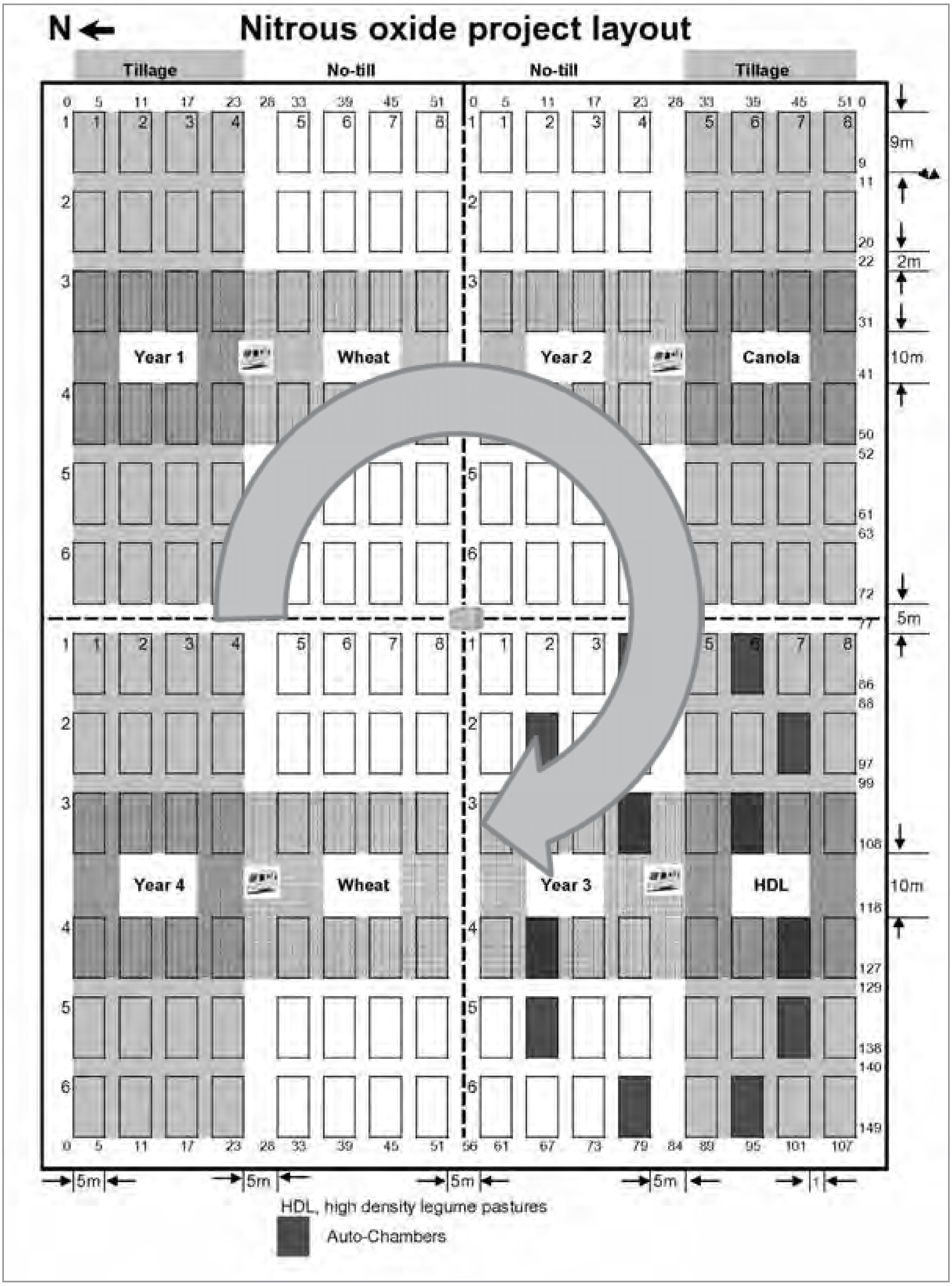

Figure 1. Crop sequence and treatment layout for the N_2O project.

Figure 2. An automated greenhouse gas measurement system setup with solar power supply. Dr Yantao Song is taking gas samples in the field (bottom right).

Results

N_2O emission under crops

Total N_2O emitted was 81–343 g N_2O-N/ha for a wheat crop in 2012 and 154–354 g N_2O-N/ha for a canola crop in 2013 (Table 1). The daily N_2O emission rate was relatively low ranging from −0.81 to 6.71 g N_2O-N/ha/day measured from auto-chambers on canola in 2013. These losses are comparable with those recorded for rain-fed wheat in other temperate regions of south-eastern Australia.

The emission factor (%N emitted as N_2O compared with N applied in fertiliser) averaged 0.06% based on data over two years. This was nearly identical to that measured from a canola crop grown on a sandy soil (0.06%) in Western Australia, but only a quarter of the current emission factor for all non-irrigated N-fertilised crop in Australia (0.2%).

There was no significant difference in N_2O emissions between tillage and no-till treatment in any year. However, applying N fertiliser at a higher rate increased N_2O emissions compared with nil nitrogen treatments (Table 1).

In a wheat crop in 2012, the nitrogen inhibitor Entec® significantly reduced N_2O emissions compared with normal urea, but no difference was detected between normal urea and Green Urea™ (urease inhibitor). For the canola crop in 2013, there was no difference in N_2O emissions between nitrogen rates when Entec® was used.

There was no yield benefit from using N inhibitors. As a result, the gross margin was lower when N inhibitors were used simply due to the higher input costs.

Table 1. N_2O emissions and emission factors.

Treatment	N rate (kg N/ha)	N_2O-N emission (g/ha)		Significance	Emission factor (%)	
		No-till	Till		No-till	Till
Wheat – 2012		**Manual chambers (219 days from 7/8/2012 to 14/3/2013)**				
Urea	0	81	130	Tillage, NS		
	100	179	294	N rate, P <0.01	0.10	0.16
Entec®	100	105	218	N type, P <0.05	0.02	0.09
Green Urea™	100	172	343		0.09	0.21
Canola – 2013		**Manual chambers (334 days from 23/5/2013 to 22/4/2014)**				
Entec®	0	250	332			
	25	305	354	Tillage, NS	0.05	0.02
	50	319	305	N rate, NS	0.07	-0.03
	100	300	306		0.05	-0.03
Canola – 2013		**Auto-chambers (366 days from 23/5/2013 to 22/4/2014)**				
Urea	0	154	196	Tillage, NS		
	100	186	263	N rate, P = 0.058	0.03	0.07

There was a distinct seasonal variation in N_2O emission rates that followed the rainfall pattern, though temperature changes could also have contributed. Significant rainfall events stimulated N_2O emissions, particularly summer storms delivering more than 10 mm of rain (Figure 3). Most N_2O emissions occurred after the crop was harvested.

Immediately after tillage and sowing operations (tillage on the tilled treatments was carried out one day before sowing), N_2O emission from both tilled and no-till treatments increased coinciding with two significant rainfall events in late May and June (Figure 3). The N_2O emissions were slightly higher in the tilled treatment during winter, late spring, early summer and early in the following autumn compared with the no-till treatment. However, there was no overall significant difference in daily N_2O emitted between tilled and no-till treatments.

N_2O emission under legumes

There were no significant differences in N_2O emissions between different legume crops under different crop managements. However, N_2O emissions tended to increase after tillage compared with no-till treatments (P = 0.09) (Table 2). Averaged across all crops, the cumulative N_2O emission was 354 g N_2O-N/ha/day under tillage treatment and 280 g N_2O-N/ha/day under no-till treatment. No-till treatment reduced N_2O emission by 21% compared with tillage treatment (Table 2).

Table 2. N_2O emission under legumes.

Legumes – 2014	Manual chambers (279 days from 28/5/14 to 3/3/15)			
Crop type	No-till	Till	Significance	Emission reduction
Lupin (grain harvested)	255	335		23.9%
Pea (grain harvested)	280	353	Tillage, P = 0.09	20.6%
Vetch (hay cut)	262	334	Crop type, NS	21.5%
Pasture (hay cut)	321	394		18.4%
Mean	280	354		21.0%
Pasture – 2013–2015	**Manual chambers 658 days from 14/5/2013 to 3/3/15)**			
Treatment	**N_2O-N emission (g/ha)**		**Emission reduction**	
Lucerne monoculture (L)	517			
Subclover monoculture (S)	417		-19.3% (L vs S)	
Phalaris–lucerne mix (PL)	438			–15.2% (L vs PL)
Phalaris–subclover mix (PS)	405		-7.6% (PL vs PS)	–3.0% (S vs PS)
Significance	P = 0.057			

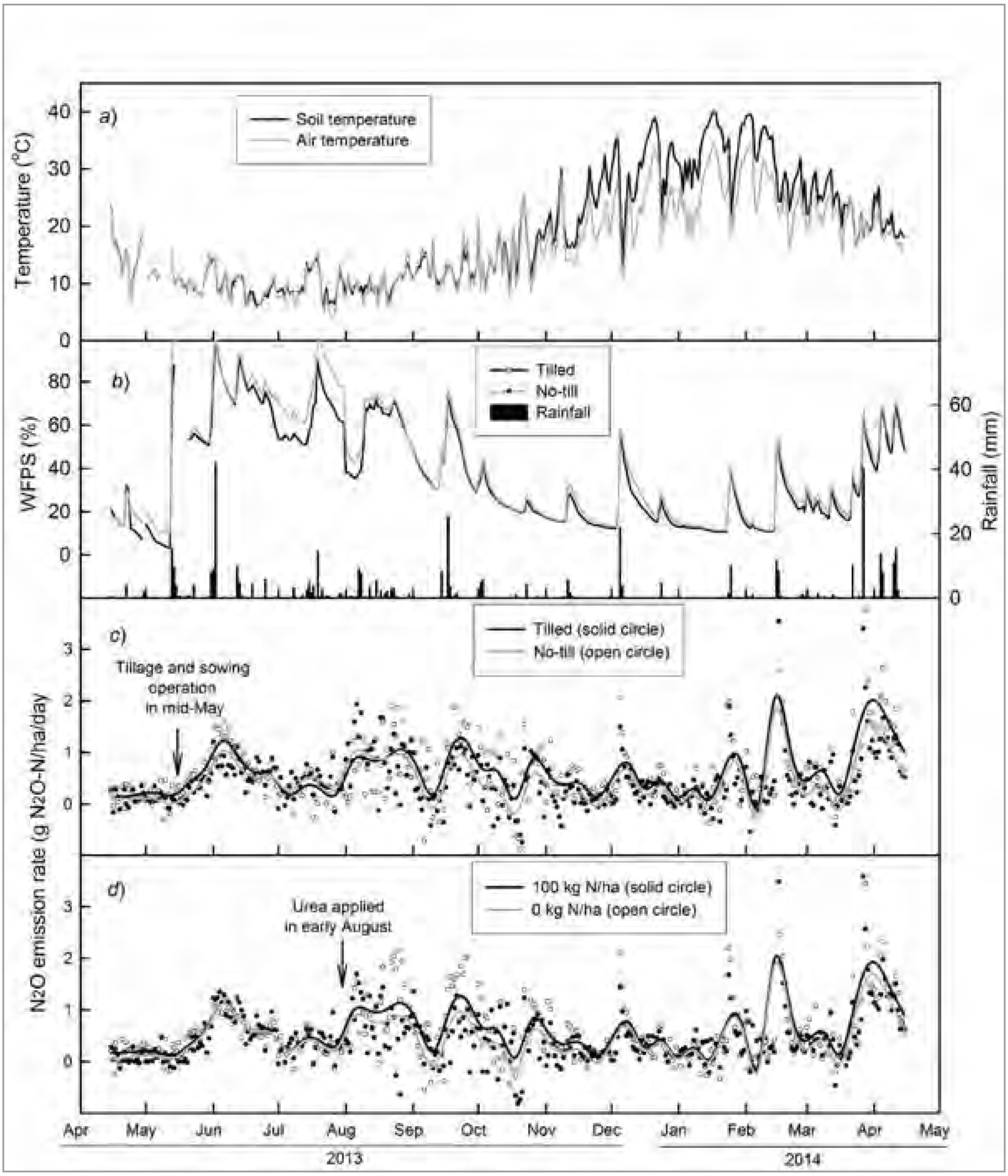

Figure 3. a) Air and soil temperatures (°C); b) Rainfall (mm) and water-filled pore space (WFPS, %) under tilled and no-till treatments; c) Daily N_2O emission rate (g N_2O-N/ha/day) under tilled and no-till treatments; d) Daily N_2O emission rate (g N_2O-N/ha/day) under 0 and 100 kg N/ha treatments for a canola crop in 2013. Lines on c) to d) are fitted splines for respective treatments.

At the perennial pasture site, the N_2O emission has been monitored over two years since May 2013. The pastures were sown in May 2012 and sprayed out in October 2014 in preparation for cropping in 2015. The rainfall events during the summer months stimulated N_2O emissions when subclover had died out or lucerne and phalaris were less active, compared with the growing season when all pasture species were actively growing (Figure 4). After the pasture was sprayed out, the N_2O emissions increased dramatically when large rainfall events occurred.

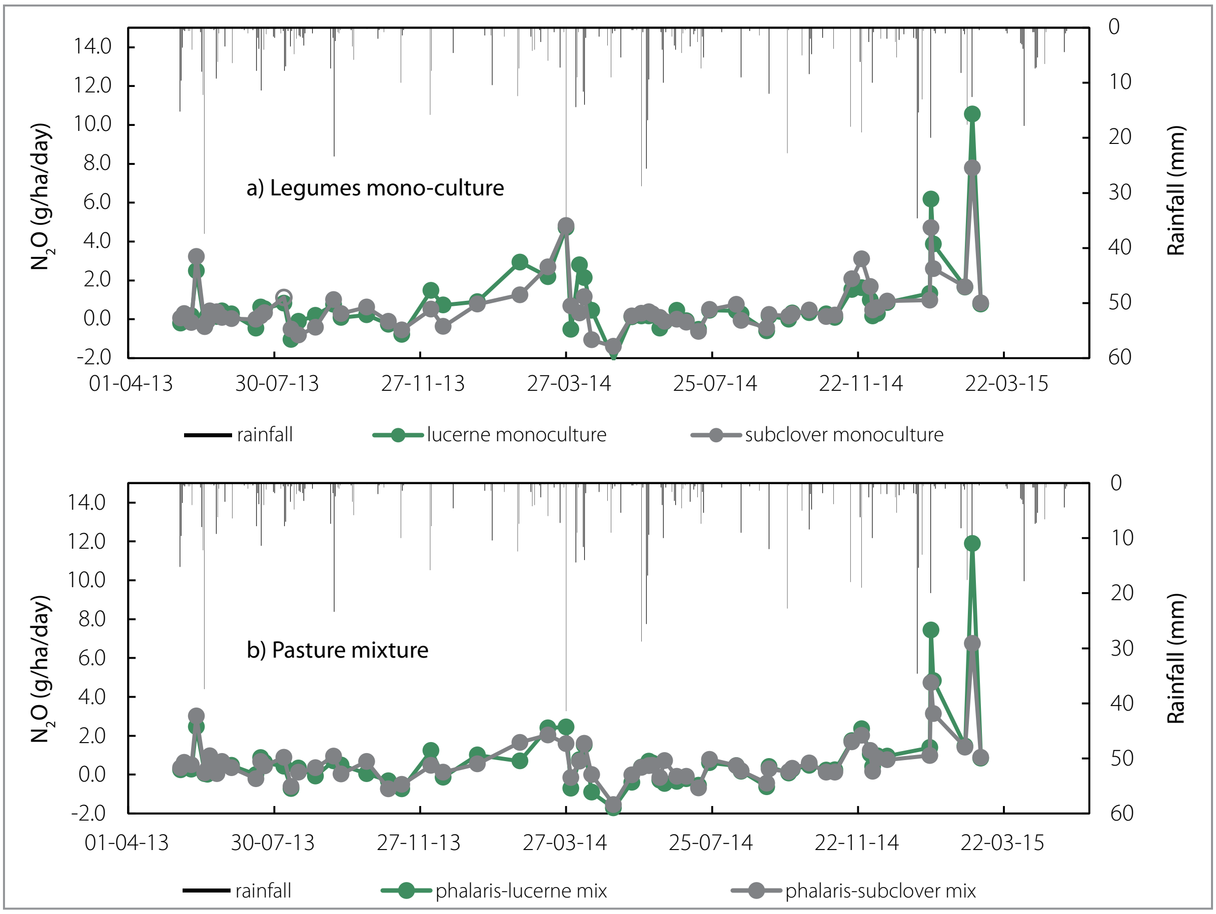

Figure 4. N_2O emissions under a) lucerne vs subclover, and b) phalaris mixed with lucerne and subclover over two years from May 2013 to May 2015; measured using manual chambers.

There was a significant difference in cumulative N_2O emissions between pasture types (P = 0.057). Over 658 days, lucerne monoculture had the highest N_2O emission (517 g N_2O-N/ha) and phalaris–subclover had the lowest emission (405 g N_2O-N/ha) (Table 2). When legumes were sown as a monoculture, the N_2O emissions were reduced by 19% compared with the annual system (Table 2). However, when legumes were mixed with phalaris, N_2O emissions were reduced compared with corresponding legume monocultures. For example, the N_2O emissions were reduced by 15% in phalaris–lucerne mixture swards compared with lucerne grown on its own (Table 2).

Acknowledgments

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