Refining the N_2O emission factor for animal dung: Initial N_2O results

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June 2008

Jiafa Luo, Tony van der Weerden, Coby Hoogendoorn, Cecile de Klein

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1. Introduction

Direct and indirect N_2O emissions from animal excreta deposited during grazing contribute over 80% of the total agricultural N_2O emissions in New Zealand. In recent years, seasonal field studies have been conducted to estimate the N_2O emission factor (EF3) for animal urine – mainly dairy cow urine – which confirmed a New Zealand specific value for EF3 of 1% (compared to the IPCC default value of 2%). However, these studies also included a limited number of dung treatments, with the results suggesting that EF3 for cow dung ranged between 0.1 and 0.5%, while N_2O emissions from sheep dung were (close to) zero[1]. Yet, the current New Zealand-specific EF3 of 1% applies to both animal urine and dung N. The partitioning of N in dung and urine largely depends on the N content of the herbage consumed and can range from 50:50 (dung N : urine N) in animals on a low N diet to 25:75 in animals on a high N diet[2]. A disaggregation of EF3 between urine N and dung N would therefore have a significant impact on the N_2O inventory. In addition, such a disaggregation would enable the effect of feeding strategies that partition more N in dung than urine (e.g. use of condensed tannins, high sugar grass and maize silage) to be accounted for in our national inventory.

We are conducting a field study to test the hypothesis that EF3 from different animal and excreta types decreases as follows: cow urine > cow or cattle dung > sheep dung. The field study commenced in May 2008. Late autumn/winter is the season when high N_2O emissions from animal excreta can be expected and could provide a good indication of the upper level of N_2O emissions from animal dung. If dung emissions are zero or close to zero in this season, it is likely that they will be low in other seasons too. A second trial starting in spring/early summer (warm/wet) could then be conducted to verify this. However, if autumn/winter emissions from dung are significantly above zero, it is intended that this study will be conducted in all four contrasting seasons.

[1] de Klein, C.A.M., Li, Z., Sherlock, R.R (2004) Determination of the N_2O and CH_4 emission factors from animal excreta and urea following a winter application in 2 regions of New Zealand. Report for MAF Policy, Wellington. Pp. 27

[2] Ledgard, S.F., Luo, J., Monaghan, R.M (2003). Partitioning of excreta nitrogen from grazing animals into urine and dung nitrogen. Report for MAF Policy, Wellington. Pp16.

2. Objectives

- To determine N_2O emission factors from application of dairy cow dung, beef cow dung and sheep dung on 6 different soil types throughout New Zealand.
- In addition, we will use this opportunity to determine the effects of DCD (a nitrification inhibitor) use on N_2O emissions from application of cow dung on two poorly-drained soils.

3. Outcome

- To provide scientific evidence to refine the N_2O emission factors for cattle and sheep dung.

4. Materials and methods

4.1 Overall study plan

A series of plot trials are being conducted to determine the N_2O emission factors from application of dairy cow dung, beef cow dung and sheep dung on 6 different soil types throughout New Zealand (Table 1). The application of animal dung was carried out on 20 May 2008.

Although this study aims to refine the N_2O emission factor for cattle and sheep dung, a dairy cow urine treatment is being included as a 'reference' treatment to ensure that the dung results can be directly compared to the urine emission factor results from previous MAF funded NzOnet trials[3]. An additional treatment, "cow dung + DCD (a nitrification inhibitor)", on the two poorly-drained soils (Waikato Te Kowhai and Otago Otokia soils) is also being included to determine the effects of the DCD use on N_2O emissions from application of cow dung.

[3] de Klein, C.A.M., Li, Z., Sherlock, R.R (2004) Determination of the N_2O and CH_4 emission factors from animal excreta and urea following a winter application in 2 regions of New Zealand. Report for MAF Policy, Wellington. Pp. 27

Table 1 The overall study plan for determining N_2O emission factors for animal dung.

Region	Soil type	Drainage	Treatment
Waikato	Horotiu silt loam	Free	Dairy cow dung
			Sheep dung
			Dairy cow urine
			Control
	Te Kowhai silt loam	Poor	Dairy cow dung
			Dairy cow dung + DCD
			Sheep dung
			Dairy cow urine
			Control
Southern Hawkes Bay	Ngamoka silt loam	Free	Beef cow dung
			Sheep dung
			Dairy cow urine
			Control
	Wilford Hill soil	Poor	Beef cow dung
			Sheep dung
			Dairy cow urine
			Control
Otago	Wingatui silt loam	Free	Dairy cow dung
			Sheep dung
			Dairy cow urine
			Control
	Otokia silt loam	Poor	Dairy cow dung
			Dairy cow dung + DCD
			Sheep dung
			Dairy cow urine
			Control

4.2 Approach

4.2.1 Waikato sites

The Waikato soils are located on a flat dairy farm. Stock was excluded from the sites for at least one month before the commencement of this study. Dairy cow dung was applied at a rate of 1039 kg N ha^{-1} and sheep dung at a rate of 449 kg N ha^{-1} (Table 2). Another treatment "cow dung + DCD (a nitrification inhibitor) applied to the poorly-drained Te Kowhai soil" has also been included (Table 2), and DCD was applied at a rate of 10 kg ha^{-1}. A reference treatment with real dairy cow urine at an application rate of 496 kg N ha^{-1} has also been used. The amount and method of urine N application are similar to those used in previous MAF funded NzOnet trials allowing direct comparison with the results of those trials. Each treatment has been replicated four times in a randomised block design. Plots with no dung and urine applied have also been included (control) with four replicates. Thus, there are 36 plots at the Waikato study sites.

4.2.2 Lower North Island hill country sites

The lower North Island soils are located in hill country in the Southern Hawkes Bay. Stock was excluded from the sites for at least one month before the commencement of the study. The treatments and measurement procedures for the hill country soils are the same as those for the Waikato soils, except that in this trial fresh beef cow dung (at an application rate of 654 kg N ha^{-1}) instead of dairy cow dung is used (Table 2). The "cow dung and DCD" treatment used at the Waikato site is not included. There are 32 plots at the southern Hawkes Bay study sites.

4.2.3 Otago sites

The Otago soils are located on a flat sheep farm and stock was excluded from the sites for at least one month before the commencement of the study. The treatments (including the dung and DCD treatment) and measurement procedures for the Otago soils are the same as those for the Waikato soils (Table 2). There are 36 plots at the Otago study sites.

Table 2 Rates of dung or urine applied per treatment (kg N/ha).

	Treatments					
Sites	Dairy cow dung	Dairy cow dung +DCD	Beef cow dung	Sheep dung	Cow urine	Control
Waikato free draining	1039			449	496	0
Waikato poorly draining	1039	1039		449	496	0
Southern Hawkes Bay free draining			654	273	504	0
Southern Hawkes Bay poorly draining			654	273	504	0
Otago free draining	1169			351	499	0
Otago poorly draining	1169	1169		351	499	0

4.2.4 Animal dung and urine collection

On 19 May 2008, fresh dung from dairy cows, beef cows and sheep was collected from local commercial farms in Waikato, Southern Hawkes Bay and Otago. The fresh dung was stored in cool-rooms at 4^{o}C overnight and applied on 20 May 2008. Subsamples of each dung type were taken for chemical analysis (Table 3).

For the cow urine treatment, fresh cow urine was collected at the AgResearch Ruakura No. 1 Dairy farm. The dairy cow urine from this farm was used for all three sites. Immediately after collection, the dairy cow urine was stored at 4^{o}C and transported overnight as refrigerated airplane cargo to Southern Hawkes Bay and Otago. In the Waikato, the dairy cow urine was stored overnight at 4^{o}C. The dairy cow urine was also applied at all study sites on 20 May 2008. A dairy cow urine sample was taken for chemical analysis (Table 3) at AgResearch and NZlabs. These analyses revealed that the N concentration of the dairy cow urine was relatively low (3.61 g N/L) compared to that used in previous MAF trials (4.5 to 6.0 g N/L). To ensure consistency with previous MAF trials, it was therefore decided to increase the total N concentration of the collected urine to about 5 g N/L by adding urea just prior to treatment application.

Table 3 Characteristics of animal dung and urine used in the trials.

	Total N (%)	NH_4^+ (mg N L^{-1})	Organic C (%)	Dry matter (%)	pH
Waikato					
Dairy cow dung	0.367	0	5.87	15.3	7.5
Sheep dung	0.898	8	9.50	20.2	7.4
Dairy cow urine	0.496	244		1.8	8.1
Southern Hawkes Bay					
Beef cow dung	0.231	38	6.13	16.3	7.2
Sheep dung	0.545	57	9.43	25.4	8.0
Dairy cow urine	0.504	182		1.8	8.4
Otago					
Dairy cow dung	0.413	0	5.20	12.9	7.7
Sheep dung	0.702	8	10.8	25.9	7.9
Dairy cow urine	0.499	207		1.8	8.1

4.2.5 Animal dung and urine application

The dung was applied in 20 cm diameter "pats" for gas sampling. Fresh dung (0.89 kg) was evenly spread to the entire circle (equivalent to 28.3 kg m^{-2}). The gas measurements are made from the entire dung pat plus a small area of un-amended soil. The gas emissions will be corrected to adjust for this un-amended area. Adjacent to this circular plot, two separate areas (0.2 $\times$ 0.5 m each area, leaving 0.1 m buffer in between) are used for soil sampling, and 2.83 kg of fresh dung was applied to each area. For the dung and DCD treatment a 1 g L^{-1} solution of DCD was applied onto the cow dung at a rate of 10 kg DCD ha^{-1}.

Sheep dung was applied to 0.25 $\times$ 1 m plots. Fresh sheep dung (1.25 kg) was evenly distributed over the entire plot (equivalent to 5 kg m^{-2}). Gas samples are taken in the middle of each plot and soil samples are taken from the rest.

The dairy cow urine was evenly spread onto 0.5 x 1 m plots at a rate of 10 L m^{-2} which is a typical urination rate for cattle[4]. Gas samples are taken in the middle of each plot and soil samples are taken from the rest.

4.3 N_2O measurements and calculations

A soil chamber technique is being used to measure N_2O emissions and the methodology is based on that from the previous MAF funded NzOnet studies on excreta N_2O emissions[5].

Gas samples were taken on one occasion a couple of days before the treatments were applied (May 2008) and taken again immediately after the treatments were applied. Gas samples are currently being collected twice per week for the first month and then will be collected once per week until background levels are reached (the maximum period is anticipated to be 5 months).

On each sampling day N_2O measurements are carried out once between 12 noon and 2 p.m. Three headspace gas samples are taken during a cover period of 60 minutes at times $t_{0,}$ t_{30} and t_{60} from each chamber with syringes and 12 ml of the gas sample is transferred into a 6 ml septum-sealed screw-capped glass vial. (Depending on initial data we may reduce the three gas samples per enclosure to two during each sampling occasion, decision to be made in June 2008.)

Gas samples are being analysed by AgResearch Grasslands using a gas chromatograph equipped with a ^{63}Ni-electron capture detector with oxygen-free N as a carrier gas.

The hourly N_2O emissions are calculated for each chamber from the increase in head space N_2O over the sampling time. The hourly N_2O emissions (mg N m^{-2} h^{-1}) are calculated as follows:

[4] Haynes, R.J., Williams, P.H. (1993) Nutrient cycling and soil fertility in the grazed pasture ecosystem. Advances in Agronomy. 49: 119-199.
[5] de Klein, C.A.M., Li, Z., Sherlock, R.R (2004) Determination of the N_2O and CH_4 emission factors from animal excreta and urea following a winter application in 2 regions of New Zealand. Report for MAF Policy, Wellington. Pp. 27

$$N_2O\ flux = \frac{\delta N_2O}{\delta T} * \frac{M}{Vm} * \frac{V}{A} \quad (1)$$

where, δN_2O is the increase in head space N_2O over time (μL/L); δT is the enclosure period (hours); *M* is the molar weight of N in N_2O; *Vm* is the molar volume of gas at the sampling temperature (L/mol); *V* is the headspace volume (m^3); and *A* is the area covered (m^2).

These hourly emissions will be integrated over time, for each enclosure, to estimate the total emission over the measurement period. Emission factors (EF, N_2O-N emitted as % of N applied) will be calculated. The EF will be calculated for each block using equation 2. Thereafter, an average emission factor will be calculated for each soil type by taking the mean of the emission factors calculated for the 4 blocks per soil.

$$EF = \frac{N_2O \text{ total (urine/dung)} - N_2O \text{ total (control)}}{\text{Urine/Dung N applied}} \times 100\% \quad (2)$$

where EF is emission factor (N_2O-N emitted as % of urine-N or dung-N applied), N_2O total (urine/dung) and N_2O total (control) are the cumulative N_2O emissions from the urine/dung and control plots, respectively (kg N ha^{-1}), and Urine/Dung N applied is the rate of urine N or dung N applied (kg N ha^{-1}).

For all sites, the 95% confidence interval of the EFs will be calculated.

The measurement period will extend beyond 30 June 2008. It is anticipated, however, that by 30 June 2008 some early indication will be available about the relative differences in N_2O emissions between the different types of dung and soils. However, completion of the 5 month measurement period is critical for fully assessing the N_2O emission factors for the animal dung. The N_2O emission factors will be compared with those measured from the reference urine treatment in this trial and with those measured in the previous NzOnet trails.

4.4 Soil and climatic parameters

Soil sampling (7.5 cm deep, 25 mm diameter) from all plots for determination of soil soluble carbon, nitrate, ammonium and water content is being carried out. Immediately after sampling the hole is back-filled with sealed PVC tubes to minimise any effects on soil aeration. Back in the laboratory on the same day or the second day, the samples are thoroughly mixed and about 15 g of fresh soil (about 10 g dry soil equivalent) is extracted for 1 hour in 50 mL of 0.5 *M* K_2SO_4. The filtered (using filter paper No 42 or equivalent) solutions are then frozen until analysed for nitrate (plus nitrite), ammonium and soluble carbon in the Ruakura laboratory. The remainder of the mixed soil is dried at 105ºC for 24 hours, to determine gravimetric soil water content. Water-filled pore space (WFPS) will be calculated by dividing volumetric water content by total porosity (Linn and Doran, 1984)[6]. Total porosity is calculated as follows: 1–(bulk density/particle density). Volumetric water content is calculated by multiplying gravimetric water content by bulk density.

Air and soil temperatures (at 5 cm depth) and rainfall are monitored on each sampling day at the study sites.

5. Milestones

- Define the N_2O study plan for the project by 31 March 2008. (Achieved)
- Prepare and submit the study outline and plan (framework report) to MAF by 30 April 2008. (Achieved)
- Complete the set-up phase for the N_2O measurements and start the initial N_2O measurements before treatments are applied by 19 May 2008. (Achieved)
- Collect animal excreta and apply the treatments by 21 May 2008. (Achieved)

[6] Linn, D.M., Doran, J.W. (1984) Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and non-tilled soils. *Soil Science Society American Journal* 48: 1267-1272.

- Prepare and submit a draft report to MAF by 30 May 2008. (Achieved)
- Evaluate initial N_2O emissions from the application of animal dung and urine and produce a report for MAF by 30 June 2008. (This report)
- Complete the analysis of the soils and estimate the total N_2O emissions by 24 December 2008.
- Complete the evaluation of N_2O emissions and produce a final report for MAF by 30 January 2009.

6. Initial N_2O results

- Figures 1-3 show initial hourly N_2O fluxes for the various treatments on the 6 soils at the different sites. Please note the differences in scales of the Y-axes for different soils.

- The N_2O fluxes from each individual soil were similar among all gas sampling chambers before the treatments were applied.

- The N_2O fluxes from the control treatment (no urine and dung) remained low over the sampling periods on all measured soils.

- Dairy cow urine application sharply increased N_2O fluxes above those of the control treatment on all measured soils. At most sampling times, the N_2O fluxes were higher than those from the control treatment.

- At sampling times up until 26 May for the Waikato sites, up until 9 June for the Southern Hawkes Bay site and up until 3 June for the Otago site), the N_2O fluxes from cow dung treatments and sheep dung treatments were not different from those from the control treatments on all measured soils apart from the Otago Wingatui soil.

- For the Otago Wingatui soil, N_2O fluxes from cow dung and sheep dung treatments were greater than those of the control from 26 May onwards (Fig. 3).

- The N_2O fluxes from animal dung application were lower than those from dairy cow urine application at most sampling times on all 6 soils.

- The magnitude of the N_2O fluxes varied between soils. At the Waikato site, N_2O fluxes from application of animal excreta appear to be higher from poorly-drained soils than from the well-drained soils at most sampling times (Fig. 1).

- At the Southern Hawkes Bay site, N_2O fluxes from application of animal excreta appear to be similar for the two soils at most sampling times (Fig. 2).

- At the Otago site, N_2O fluxes from application of animal excreta appear to be higher from freely-drained soils than from the poorly-drained soils at most sampling times (Fig. 3).

- To date, the DCD application to cow dung on the poorly-drained soils at the Waikato and Otago sites has not reduced N_2O fluxes from this source.

- It appears that unusually dry conditions nationally in New Zealand during the measurement period affected the magnitude of the N_2O fluxes.

- Measurements are being continued, and N_2O emission factors from application of dairy cow dung, beef cow dung and sheep dung will be determined.

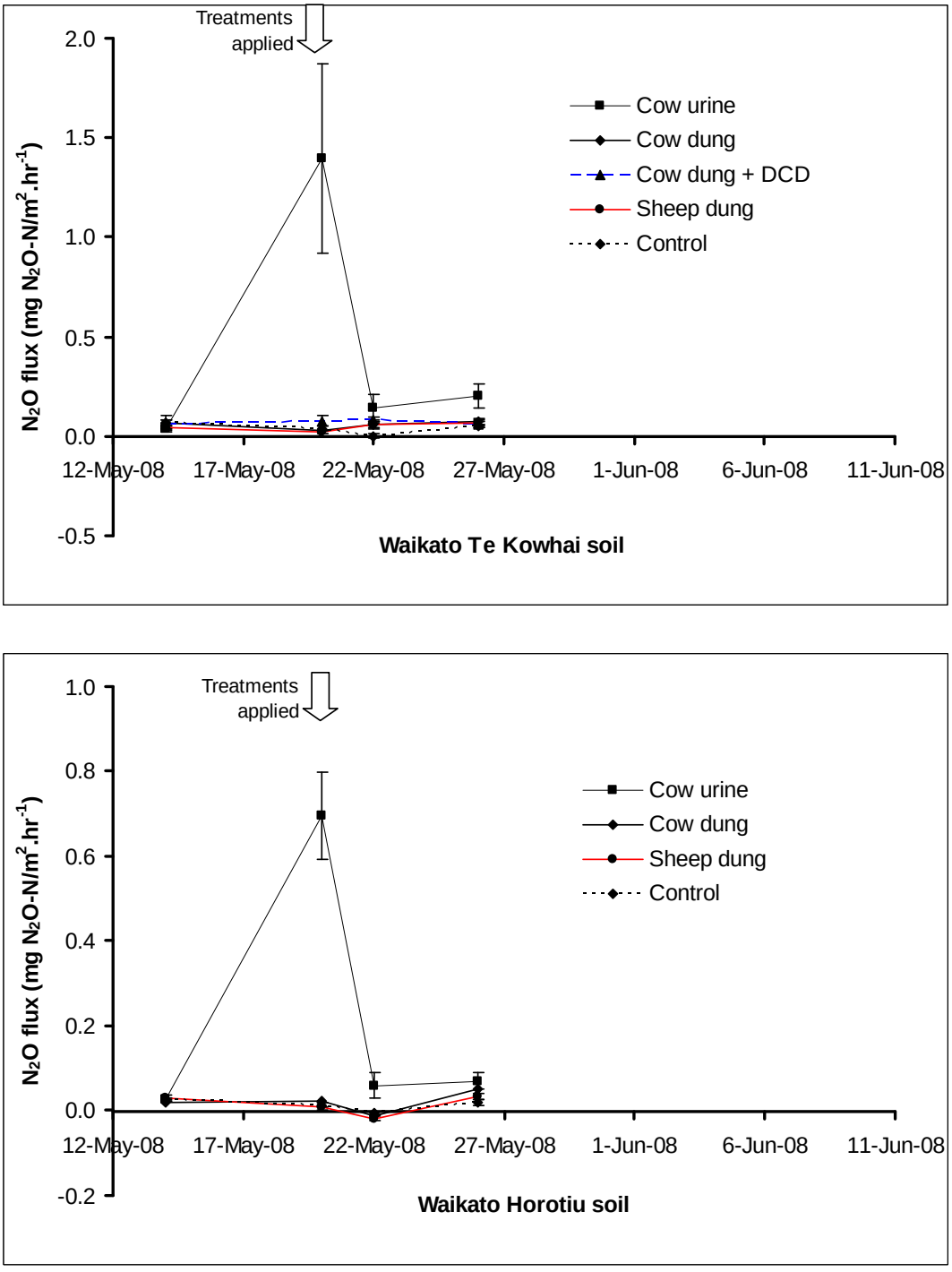
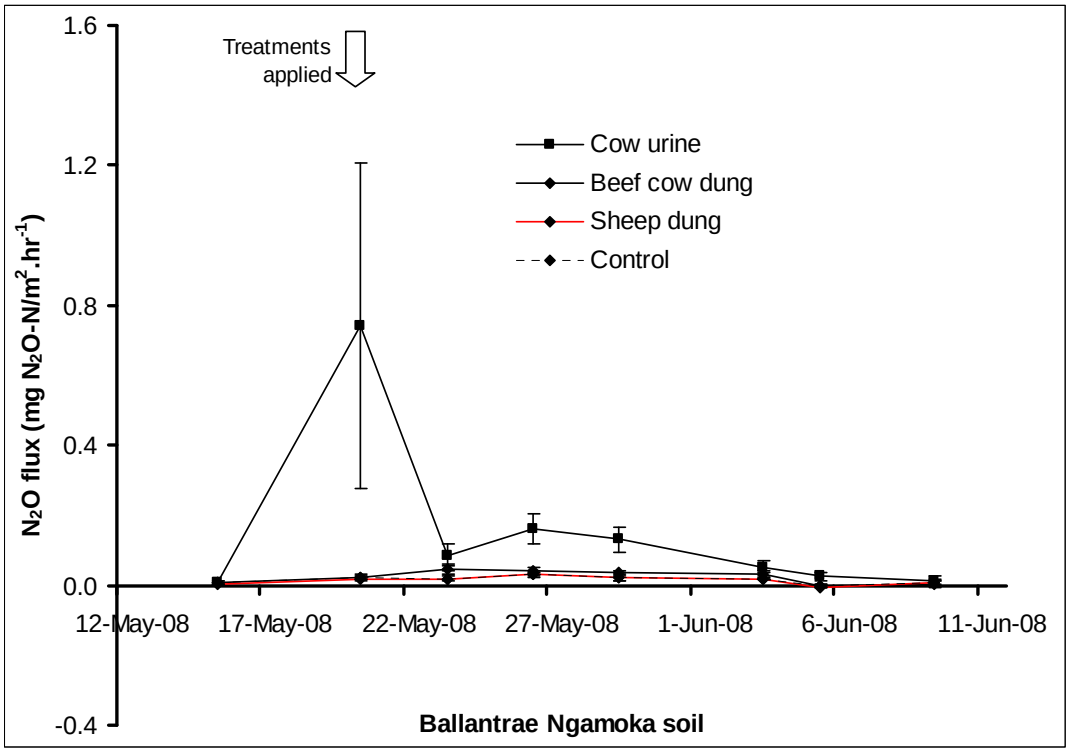


Fig. 1 Nitrous oxide fluxes following excreta application (bars represent SE, n=4) at the Waikato site. Excreta were applied on 20 May 2008. The gas fluxes from the dung treatment have not been corrected to adjust for small un-amended area inside the gas sampling chambers.



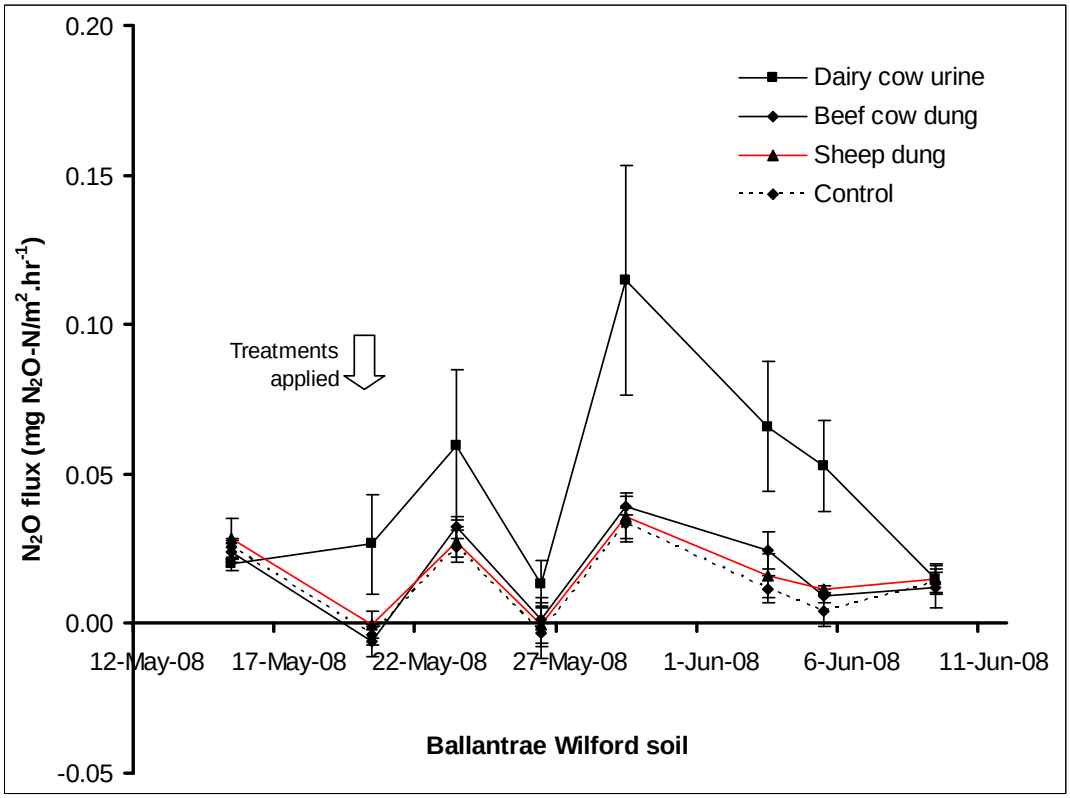
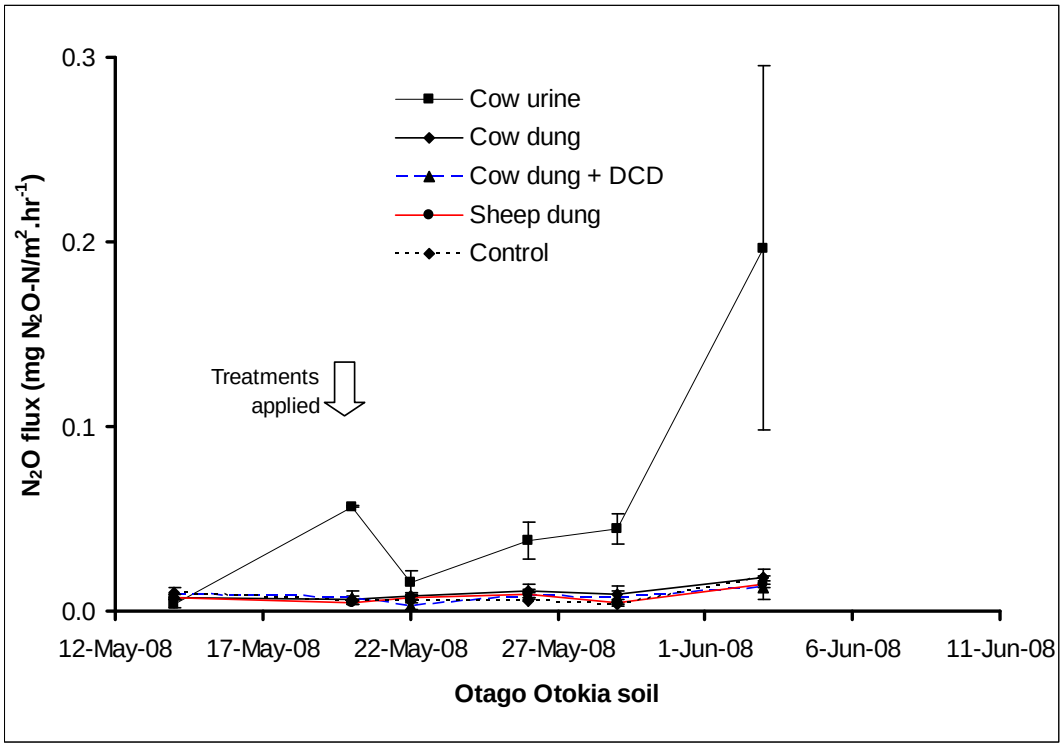


Fig. 2 Nitrous oxide fluxes following excreta application (bars represent SE, n=4) at the Southern Hawkes Bay site. Excreta were applied on 20 May 2008. The gas fluxes from the beef dung treatment have not been corrected to adjust for small un-amended area inside the gas sampling chambers.



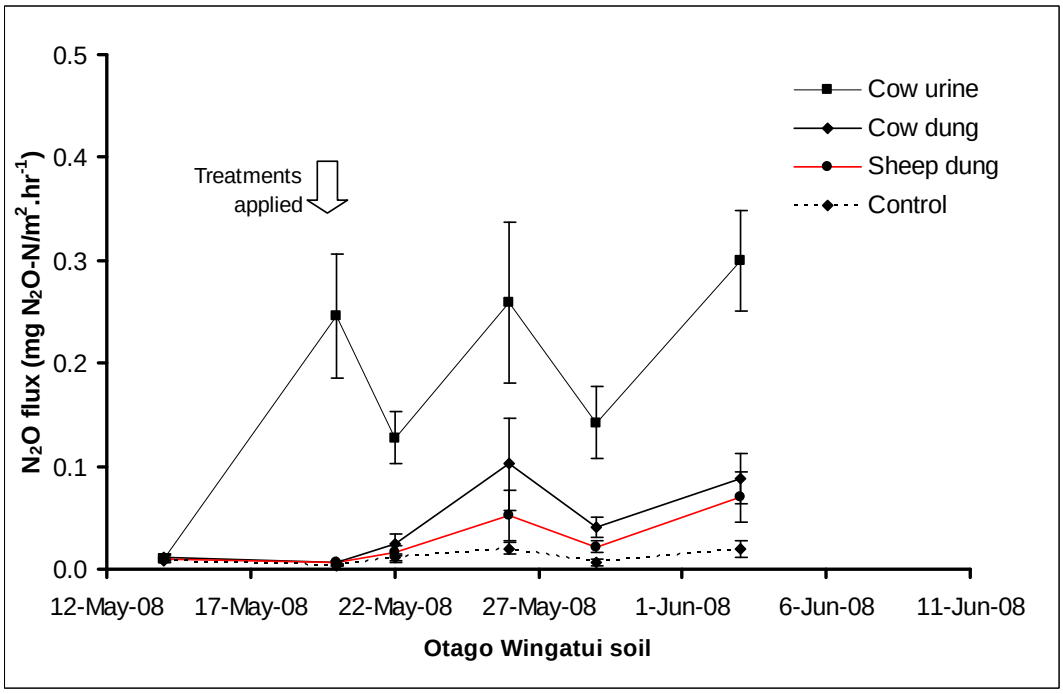


Fig. 3 Nitrous oxide fluxes following excreta application (bars represent SE, n=4) at the Otago site. Excreta were applied on 20 May 2008. The gas fluxes from the dung treatment have not been corrected to adjust for small un-amended area inside the gas sampling chambers.