Determination of the N_2O emission factor for animal dung applied in late autumn in three regions of New Zealand

MAF Technical Paper No: 2011/93

Report prepared for Ministry of Agriculture and Forestry
By AgResearch
June 2009

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ISSN 2230-2794 (online)
ISBN 978-0-478-38749-0 (online)

November 2011

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

BIOSECURITY NEW ZEALAND

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Publisher

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Final report prepared for MAF

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Final report prepared for Ministry of Agriculture & Forestry (MAF)

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

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1. Executive summary

Objective

- To refine the N_2O emission factors from autumn application of animal dung on 6 different soil types throughout New Zealand.
- To compare these emission factors with those for cattle urine.
- To determine the effects of the use of the nitrification inhibitor DCD on N_2O emissions from application of cow dung.

Context

Previous MAF-funded studies suggested that the N_2O emission factor (EF3) for animal dung ranged between 0.1 and 0.5%. This is lower than the current New Zealand-specific EF3 of 1% applied to all animal excreta N. We have conducted 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.

Approach

This report presents findings from a field study conducted to determine the N_2O emission factors from application of animal excreta, following application in late autumn 2008 in three regions of New Zealand. Excreta included dairy cow dung, beef cow dung, sheep dung and cow urine. Excreta was applied as a series of plot trials to 6 different soil types throughout New Zealand (Waikato: Horotiu free draining silt loam and Te Kowhai poorly draining silt loam, Southern Hawkes Bay: Ngamoko free draining silt loam and Wilford poorly draining hill soil, Otago: Wingatui free draining silt loam and Otokia poorly draining silt loam) (Table 1). An additional treatment, "cow dung + DCD (a nitrification inhibitor)", on the two poorly-drained soils (Waikato Te Kowhai and Otago Otokia soils) was also included to determine the effects of the DCD use on N_2O emissions from application of cow dung.

Treatments were applied on 20 May 2008. N_2O emission measurements were made twice per week for the first month following the application. The

measurements were then made once per week until the background levels were reached at the end of September 2008.

Table 1: Regions, soil types and treatments used for autumn-applied excreta study.

Region	Soil drainage class	N source
Waikato	Free and poorly draining	Dairy Cow dung
	Free and poorly draining	Sheep dung
	Free and poorly draining	Dairy Cow urine
	Poorly draining only	Dairy Cow dung + DCD
Southern Hawkes Bay	Free and poorly draining	Beef Cow dung
	Free and poorly draining	Sheep dung
	Free and poorly draining	Dairy Cow urine
Otago	Free and poorly draining	Dairy Cow dung
	Free and poorly draining	Sheep dung
	Free and poorly draining	Dairy Cow urine
	Poorly draining only	Dairy Cow dung + DCD

Outcomes

- The N_2O emissions from this late autumn application of animal dung were much lower than those from application of dairy cow urine on all 6 soils, with most sampling occasions showing emissions from dung plots being similar to those from control (untreated) plots.
- Results from this late autumn study found that EF3 decreases as follows: cow urine > cow or cattle dung = sheep dung. The average EF3 for cow urine, cow dung and sheep were estimated at 0.30%, 0.05% and 0.04% of excreta N applied, respectively.
- The EF3 for cow urine was significantly greater ($P<0.05$) than those for dung in this late autumn study. There was no significant difference ($P>0.05$) in EF3 for cattle and sheep dung.
- EF3 for urine in this late autumn study was lower than the average estimated from previous MAF studies.
- Soil drainage class within regions did not have a consistent effect on EF3 values for different excreta types.

- EF3 for cow dung was not significantly (P>0.05) reduced with the application of DCD.
- These results support a disaggregation of EF3PRP between dung and urine. However, further disaggregation of dung into animal type may not be warranted. Further research focusing on excreta deposition in spring is being currently conducted to confirm these conclusions.

2. Introduction

2.1 Background

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 trials, funded by MAF, were 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 (or 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 N_2O inventory.

This report presents the results of a study, which commenced in May 2008 in three regions of New Zealand, testing the hypothesis that EF3 from different animal and excreta types decreases as follows:

Cow urine > cow or cattle dung > sheep dung.

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.

[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

2.2 Study objectives

- To determine N_2O emission factors from an autumn application of dairy urine, dairy cow dung, beef cow dung and sheep dung on 6 different soil types in three regions of New Zealand.
- To determine the effects of DCD (a nitrification inhibitor) use on N_2O emissions from an autumn application of cow dung on two poorly-drained soils.

3. Materials and methods

3.1 Study design

A series of plot trials were 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 2). The application of animal dung and urine was carried out on 20 May 2008.

Although this study aimed to refine the N_2O emission factor for cattle and sheep dung, a dairy cow urine treatment was 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) was also 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 2 The study design for determining N_2O emission factors for animal dung.

Region	Soil type	Drainage	Treatment	N application rate kg N ha^{-1}
Waikato	Horotiu silt loam	Free	Dairy cow dung	1039
			Sheep dung	449
			Dairy cow urine	496
			Control	0
	Te Kowhai silt loam	Poor	Dairy cow dung	1039
			Dairy cow dung + DCD	1039
			Sheep dung	449
			Dairy cow urine	496
			Control	0
Southern Hawkes Bay	Ngamoko silt loam	Free	Beef cow dung	654
			Sheep dung	273
			Dairy cow urine	504
			Control	0
	Wilford Hill soil	Poor	Beef cow dung	654
			Sheep dung	273
			Dairy cow urine	504
			Control	0
Otago	Wingatui silt loam	Free	Dairy cow dung	1169
			Sheep dung	351
			Dairy cow urine	499
			Control	0
	Otokia silt loam	Poor	Dairy cow dung	1169
			Dairy cow dung + DCD	1169
			Sheep dung	351
			Dairy cow urine	499
			Control	0

3.2 Approach

3.2.1 Waikato sites

The Waikato soils were 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" was also 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} was also used. The amount and method of urine N application were similar to those used in previous MAF funded NzOnet trials allowing direct comparison with the results of those trials. Each treatment was replicated four times in a randomised block design. Plots with no dung and urine applied were also included (control) with four replicates. Thus, there were 36 plots at the Waikato study sites.

3.2.2 Southern Hawkes Bay sites

The Southern Hawkes Bay soils were located in hill country. Stock was excluded from the sites for at least 6 weeks before the commencement of the study. The treatments and measurement procedures for the hill country soils were the same as those for the Waikato soils, except that in this trial fresh beef cow dung instead of dairy cow dung was used (Table 2). The lower N content of the beef dung, compared to dairy cow dung, meant that the beef cow dung N application rate was approximately 60% that of the dairy cow dung applied at the Ruakura and Otago sites (see 3.2.3). The "cow dung and DCD" treatment used at the Waikato site was not included. Sheep dung was applied at a rate of 273 kg N ha^{-1}, which was approximately 60 and 80% of the N application rate of the sheep dung applied at the Ruakura and Otago sites respectively. There were 32 plots at the southern Hawkes Bay study site

3.2.3 Otago sites

The Otago soils were 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 were the same as those for the Waikato soils (Table 2). The N content of the dairy cow dung was similar to that at the Ruakura site and thus dairy cow dung at the Otago site was applied at a similar N rate to that at the Ruakura

site. Sheep dung was applied at a rate of 351 kg N ha^{-1}, which was approximately 80% of the N application rate of the sheep dung applied at the Ruakura site. There were 36 plots at the Otago study sites.

3.2.4 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 urine was stored overnight at 4^{o}C or transported overnight as refrigerated airplane cargo to Southern Hawkes Bay and Otago. The dairy cow urine was applied at all study sites on 20 May 2008. A dairy cow urine sample was taken immediately after collection 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. Characteristics were analysed at the time of application.

	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

3.2.5 Animal dung and urine application

The cow 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 were made from the entire dung pat plus a small area of un-amended soil. The gas emission rates were corrected to adjust for this un-amended area during calculation, employing the correction method used previously in a MAF study for treatments that are smaller than the chamber area[4]. Adjacent to this circular plot, two separate areas (0.2 $\times$ 0.5 m each area, leaving 0.1 m buffer in between) were 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 were taken in the middle of each plot and soil samples were taken from the rest.

[4] 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

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[5]. Gas samples were taken in the middle of each plot and soil samples were taken from the rest.

3.3 N_2O measurements and calculations

A soil chamber technique was used to measure N_2O emissions and the methodology was based on that from the previous MAF funded NzOnet studies on excreta N_2O emissions[6].

Gas samples were taken on one occasion several days before the treatments were applied to determine if there was any pre-existing between-plot variability. If evident, this between-plot variability could then be taken into account during the statistical analysis of the treatment effects. Following treatment application on 20 May 2008, gas samples were collected twice per week for the first month and then once per week until background levels were reached at the end of September 2008.

On each sampling day, N_2O measurements were carried out once between 12 noon and 2 p.m. For the first month three headspace gas samples were 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 was transferred into a 6 ml septum-sealed screw-capped glass vial. Once a linear relationship between N_2O concentration and time was verified, two headspace gas samples were taken at times t_0 and t_{60} from each chamber for the remaining period of the trial.

Gas samples were analysed for N_2O concentrations by gas chromatograph at AgResearch Grasslands, Palmerston North, and at the Analytical Services laboratory, Lincoln University. At AgResearch Grasslands, analysis was conducted using a Hewlett Packard gas chromatograph equipped with a ^{63}Ni-electron capture

[5] Haynes, R.J., Williams, P.H. (1993) Nutrient cycling and soil fertility in the grazed pasture ecosystem. *Advances in Agronomy* 49: 119-199

[6] 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

detector with oxygen-free N as a carrier gas. At Lincoln University, a SRI 8610 automated gas chromatograph was used.

Due to technical difficulties with gas analysis at the Grasslands laboratory in July 2008, analysis of samples collected after this date was delayed by, typically, three months, although several batches were stored for up to five months. Sample quality was maintained, however, by testing sample vials for a positive pressure using a double-ended hypodermic needle. One end of the needle was placed just below the surface of some water in a small beaker while the other end pierced the exetainer® septum. A brief flow of bubbles resulted and when these ceased, the exetainer® gas contents were at ambient air pressure. Expelling the excess sample through water provided a visual indication that no leakage had occurred. It was also necessary to bring samples back to ambient air pressure for GC analysis.

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

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

where, δN_2O is the increase in head space N_2O concentrations 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).

Hourly emissions were integrated over time, for each enclosure, to estimate the total emission over the measurement period.

Total emissions from dung treatments in this study were often very low: in several cases, lower than the total emissions measured from control treatments, resulting in net negative emissions from specific treatments (suggesting N_2O deposition had occurred). Consequently, the previous method used for calculating average Emission Factors, where the geometric mean of the emission factors for each

excreta type is presented[7], could not be employed here as it is not possible to calculate the log of a negative number.

An alternative method was employed in this study, where total emissions were transformed using the *log(a+x)* transform, with *a* = 0.76 estimated by optimizing the Anderson-Darling statistic for normality. Transformed data were analysed by residual maximum likelihood, with plot within block within location as random effects, and the factorial interaction of region, soil drainage class and excreta treatments as fixed effects. Each cell in the resulting table of estimates of fixed effects then had $\frac{\sigma^2}{2}$ added to it, as the variance inflation appropriate for the lognormal distribution, and was then back-transformed using the exponential function. Emission factors were then calculated from the difference in total emissions from each excreta treatment and the control treatment, divided by the rate of urine N or dung N applied, as described by equation 2:

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

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}). Standard errors were calculated using the variance of function formulae as in Kendall and Stuart, Volume 1 (1969) [8].

3.4 Soil and climatic parameters

Soil samples (7.5 cm deep, 25 mm diameter) were taken from all plots for determination of soil nitrate, ammonium and water content. Immediately after sampling the hole was back-filled with sealed PVC tubes to minimise any effects on soil aeration. Back in the laboratory on the same day or the following day, the

[7] 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

[8] Kendall, M.G., Stuart, A. (1969) The Advanced Theory of Statistics, Volume 1, Third Edition. Griffin: London

samples were thoroughly mixed and about 15 g of fresh soil (about 10 g dry soil equivalent) was extracted for 1 hour in 50 mL of 0.5 *M* K_2SO_4. The filtered (using filter paper No 42 or equivalent) solutions were then frozen until analysed for nitrate (plus nitrite) and ammonium in the Ruakura laboratory. The remainder of the mixed soil was dried at 105ºC for 24 hours, to determine gravimetric soil water content. Water-filled pore space (WFPS) was calculated by dividing volumetric water content by total porosity (Linn and Doran, 1984)[9]. 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 were monitored on each sampling day at the study sites.

4. Results and discussion

4.1 Hourly N_2O emission rates

- The hourly N_2O fluxes for the various treatments at the different sites are given in Figures 1-6. Please note the difference in scale of the Y-axis between Figures. Soil and climatic conditions are also shown in these figures.
- For each site, the N_2O fluxes from the individual plots were similar prior to treatment application and thus pre-existing between-plot variability was not evident.
- Following excreta application, N_2O fluxes were greater than that of control plots for up to 132 days.
- Dairy cow urine treatments resulted in the largest fluxes, followed by dung and control treatments.
- The single largest flux was 1.4 mg N_2O-N m^{-2} hr^{-1}, measured from dairy cow urine applied to the poorly drained Te Kowhai soil at the Waikato site.

[9] 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

- The largest fluxes measured in the other two regions (South Hawkes Bay and Otago) were half of this, at about 0.7 mg N_2O-N m^{-2} hr^{-1}, both from dairy cow urine.
- On all 6 soils, N_2O fluxes from application of animal dung were much lower than those from dairy cow urine application with most sampling occasions showing fluxes from dung plots being similar to control (untreated) plots.
- N_2O fluxes were greater from cow dung compared to sheep dung on all soils, apart from the poorly drained Otokia soil in Otago, where sheep dung emissions were slightly higher.
- During three sampling occasions in early June on the Te Kowhai soil in the Waikato, DCD applied to cow dung significantly reduced the N_2O emission. This is reflected in the soil mineral N data, where DCD application resulted in higher soil ammonium-N and lower nitrate-N levels compared to the non-DCD dung plots, suggesting nitrification of ammonium in the soil beneath the dung pat was inhibited by DCD.
- There was no effect of DCD on N_2O fluxes from dung in Otago. This may have been due to fluxes from dung at this site being close to zero. Soil mineral N data also suggest no inhibition of nitrification by DCD occurred in the soil beneath the dung pats, as ammonium-N levels were similar for the "cow dung" and "cow dung + DCD" treatments.
- The initial N_2O peaks from the urine treatments from both the Horotiu and Te Kowhai soils were possibly due to an increase in soil pH immediately following urine application resulting in the mineralisation of soil N and release of available C. This could increase nitrification and denitrification rates. Following the initial peak, N_2O fluxes from both soils at the Waikato sites were generally lower than previously measured from urine applications[10,11,12]. This could have be due to the relatively low amount of rainfall during the first month after treatments were applied, resulting in low soil WFPS (WFPS<65%). The N_2O fluxes were then increased from the

[10] Sherlock, R.R., de Klein C.A.M., Li, Z. (2003a) Determination of the N_2O and CH_4 emission factors from animal excreta, following a summer application in 3 regions of New Zealand. Report for MAF Policy, Wellington. pp. 27

[11] Sherlock, R.R., de Klein C.A.M., Li, Z. (2003b) Determination of the N_2O and CH_4 emission factors from animal excreta, following a spring application in 3 regions of New Zealand. Report for MAF Policy, Wellington. pp. 28

[12] 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

poorly-drained Te Kowhai soil, probably due to increased soil WFPS as a result of the frequent rainfall. However, N_2O fluxes remained low in the well-drained Horotiu soil, presumably due to the frequent rainfall in late June having a minor effect on WFPS while moving a significant amount of nitrate down the soil profile, thereby reducing the denitrification potential and rate.

- As for the Waikato site, the sites in the Southern Hawkes Bay also produced low N_2O fluxes. This is also possibly due to the low soil WFPS resulting from the low rainfall during the first month following application of treatments. The N_2O fluxes from cow urine were greater from the well drained Ngamoko soil compared to the poorly drained Wilford hill soil. The higher soil nitrate N results from the Ngamoko soil suggest that the Ngamoko soil has a higher nitrification potential than the Wilford soil, potentially leading to relatively higher N_2O emissions, even when the Wilford soil had a higher WFPS (consistently about 10% greater than the Ngamoko soil over the study period).
- N_2O fluxes measured from cow dung-amended soil at the Otago site in the current study are comparable to those found in past studies[8,9,10]. However, N_2O fluxes from urine-amended soil in the current study are generally lower than those previously found. This is possibly due to the relatively low WFPS for the first two months after treatments application, particularly for the poorly drained Otokia soil. N_2O peaks from the urine-amended soil were observed in the Otokia soil during the first two months following rainfall events. For the Wingatui soil, N_2O emissions were elevated after urine application for about 4 months, presumably due to the higher WFPS of this soil. The Wingatui soil is well structure recent soil, with good water holding capacity and tends to remain moister than the Otokia under low rainfall conditions. The same finding was observed in a previous MAF funded study (summer trial)[13], i.e. higher N_2O emissions from the well drained Wingatui soil compared to poorly drained Otokia soil at the Otago site.

[13] Sherlock, R.R., de Klein C.A.M., Li, Z. (2003a) Determination of the N_2O and CH_4 emission factors from animal excreta, following a summer application in 3 regions of New Zealand. Report for MAF Policy, Wellington. pp. 27

4.2 N_2O emission factors

- Table 4 provides an overview of estimates of the N_2O emission factors for autumn-applied dung and urine. The emission factors have been estimated using emissions measured over a period of 132 days, up to the end of September 2008. Also shown in Table 4 are emission factors for dung and urine, as calculated in previous studies and summarised by Kelliher et al. (2005)[14]. Table 5 presents the results on an excreta type basis, with annual averages from previous studies also shown.

Key points about N_2O emission factors:

- Results showed that average EF3 decreases as follows:

  Cow urine > cow or cattle dung = sheep dung

  0.30 > 0.05 = 0.04.

- EF3 for urine was significant greater ($P<0.05$) than that for dung, presumably due to two major factors. Firstly, the readily available N in urine (urea-N + ammonium-N) was greater than that applied in dung pats, resulting in significantly higher soil ammonium- and nitrate-N levels under urine patches. Secondly, urea hydrolysis following urine application to the soil potentially increased the soil pH, releasing organic matter into a soluble form available as a microbial food supply for denitrifying bacteria.
- There was no significant ($P > 0.05$) difference in EF3 for cattle and sheep dung.
- An analysis of previous NzOnet seasonal EF3 studies[15] showed the following trend of EF3: cow urine (0.9) > cow dung (0.2) > sheep dung (0.0).

[14] Kelliher F.M., de Klein, C.A.M., Li, Z., Sherlock, R.R. (2005) Review of nitrous oxide emission factor (EF3) data. Report for MAF Policy, Wellington. Pp. 20

[15] Kelliher F.M., de Klein, C.A.M., Li, Z., Sherlock, R.R. (2005) Review of nitrous oxide emission factor (EF3) data. Report for MAF Policy, Wellington. Pp. 20

- EF3 for urine in the present study was lower than the average calculated from previous studies, primarily due to relatively dry soil conditions in combination with the cool soil temperatures during this study period.
- The results for EF3 for dung from the Waikato soils in the present study were below values found in previous studies, where dung was applied in the spring, while the results from Otago were greater in the present study to previous studies where dung was applied in the winter and spring.
- EF3 for dung was not significantly ($P > 0.05$) reduced with the application of DCD to the surface of dung.
- Dung EF3 was not significantly influenced by region nor by drainage class ($P > 0.05$).
- The results suggest that pooling data into drainage class alone is not sufficient, due the variation between regions. Therefore, disaggregation of urine EF3 will need to be on a 'region' x drainage class basis, where 'region' is represented by local climatic conditions (soil temperature, rainfall).
- The EF3 for urine was largest in Otago, presumably due to soil WFPS being greater than for the other regions, which were relatively dry for the winter.
- Urine EF3 from the poorly drained soils were higher than those of the well drained soils in the Waikato. However, the reverse was found in Otago and Southern Hawkes Bay. This is partly explained by the soil mineral N levels at each soil within each region. For instance, at the Southern Hawkes Bay site, while WFPS was always higher for the poorly drained than that for well drained soil (average WFPS over the 132 day trial was 70.5 vs. 61.3 %), soil NO_3^--N concentrations were lower for all of the excretal types on the poorly drained soil. This could suggest that the Wilford soil has a lower nitrification potential than the Ngamoko soil.

Table 4. Estimates of autumn N_2O emission factors (N_2O-N emitted as % of dung or urine-N applied). Values in brackets are the SEM. Average and range of N_2O emission factors from previous trials are also given[16].

Location	Soil (description)	Treatment	Current autumn trial	Previous NZ work [average, (range across seasons)]
Waikato	Te Kowhai	Dairy Cow dung	0.07 [0.03]	0.43 (spring)
	(poorly draining)	Dairy Cow dung + DCD	0.03 [0.09]	-
		Sheep dung	0.04 [0.05]	-
		Dairy cow urine	0.50 [0.09]	1.74, (0.75 - 2.70)
	Horotiu	Dairy Cow dung	0.03 [0.02]	0.24 (spring)
	(free draining)	Sheep dung	0.03 [0.05]	-
		Dairy cow urine	0.10 [0.05]	0.47 (0.07 – 1.22)
Southern Hawkes Bay	Wilford	Beef Cow dung	0.01 [0.02]	-
	(poorly draining)	Sheep dung	0.01 [0.06]	-
		Dairy Cow urine	0.07 [0.04]	-
	Ngamoko	Beef Cow dung	0.05 [0.03]	-
	(free draining)	Sheep dung	-0.01 [0.06]	-
		Dairy Cow urine	0.14 [0.04]	-
Otago	Otokia	Dairy Cow dung	0.0 [0.01]	0.10 (winter)
	(poorly draining)	Dairy Cow dung + DCD	0.0 [0.01]	-
		Sheep dung	0.03 [0.05]	0 (spring)
		Dairy cow urine	0.49 [0.08]	1.41 (0.58 – 2.95)
	Wingatui	Dairy Cow dung	0.17 [0.03]	0.10 (winter)
	(free draining)	Sheep dung	0.12 [0.05]	0.01 (spring)
		Dairy cow urine	0.91 [0.12]	1.15 (0.9 – 1.46)

[16] Kelliher F.M., de Klein, C.A.M., Li, Z., Sherlock, R.R. (2005) Review of nitrous oxide emission factor (EF3) data. Report for MAF Policy, Wellington. Pp. 20

Table 5. Estimates of N_2O emission factors (N_2O-N emitted as % of urine or dung-N applied), as affected by excreta type, region and soil drainage class. Also shown is the annual average emission factor for each excreta type, as reported previously[17].

Excreta type	Region	Drainage class (soil type)	Season: Autumn	Average (per excreta type x region)	Average (per excreta type)	Annual Average (previous research)
Dairy Cow urine	**Waikato**	Poor (Te Kowhai)	0.50	**0.26**	**0.30**	**0.90**
		Free (Horotiu)	0.10			
	Hawkes Bay	Poor (Wilford)	0.07	**0.10**		
		Free (Ngamoko)	0.14			
	Otago	Poor (Otokia)	0.49	**0.68**		
		Free (Wingatui)	0.91			
Dairy Cow dung* **Hawkes Bay used Beef Cow Dung*	**Waikato**	Poor (Te Kowhai)	0.07	**0.05**	**0.05**	**0.18**
		Free (Horotiu)	0.03			
	Hawkes Bay	Poor (Wilford)	0.01	**0.03**		
		Free (Ngamoko)	0.05			
	Otago	Poor (Otokia)	0.00	**0.06**		
		Free (Wingatui)	0.17			
Sheep dung	**Waikato**	Poor (Te Kowhai)	0.04	**0.04**	**0.04**	**0.0**
		Free (Horotiu)	0.03			
	Hawkes Bay	Poor (Wilford)	0.01	**0.00**		
		Free (Ngamoko)	-0.01			
	Otago	Poor (Otokia)	0.03	**0.07**		
		Free (Wingatui)	0.12			

[17] Kelliher, F.M., de Klein, C.A.M., Li, Z., Sherlock, R.R. (2005) Review of nitrous oxide emission factor (EF3) data. Report for MAF Policy, Wellington. Pp. 20

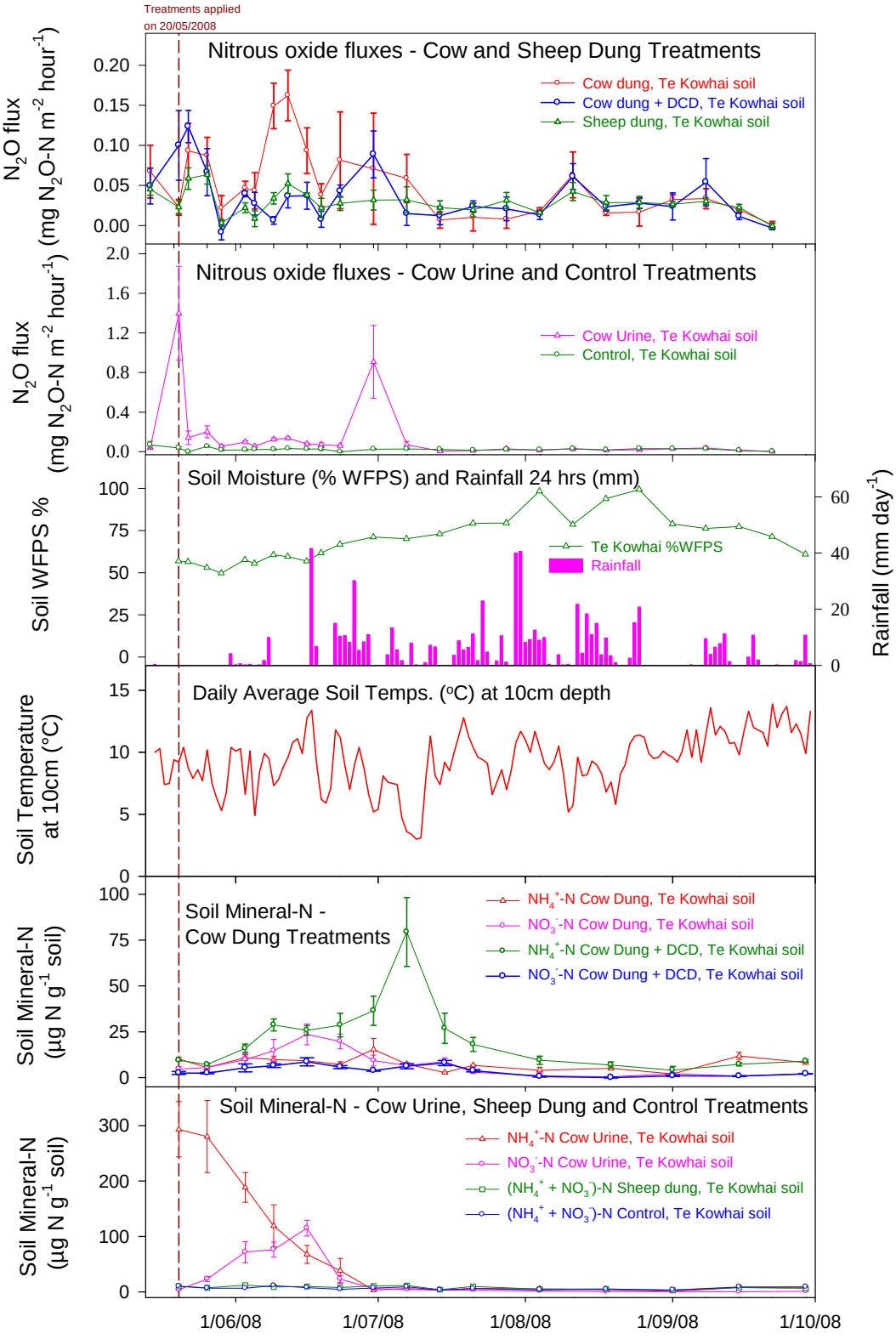

Figure 1: N_2O emissions and soil and climatic conditions for excreta amended Te Kowhai soil in Waikato. For N_2O flux and mineral N the data points represent arithmetic mean values ± SE (n=4).

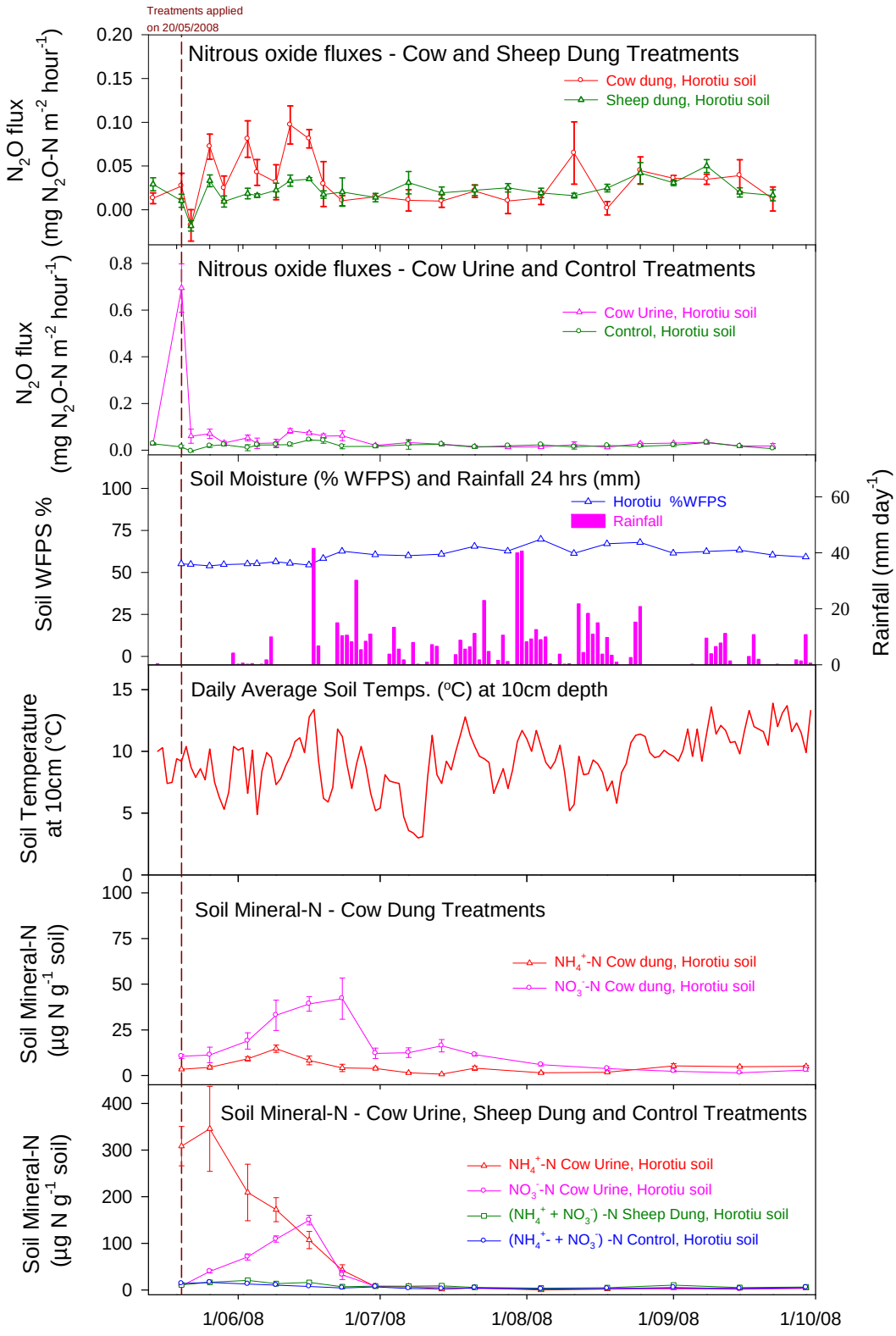

Figure 2: N_2O emissions and soil and climatic conditions for excreta amended Horotiu soil in Waikato. For N_2O flux and mineral N the data points represent arithmetic mean values ± SE (n=4).

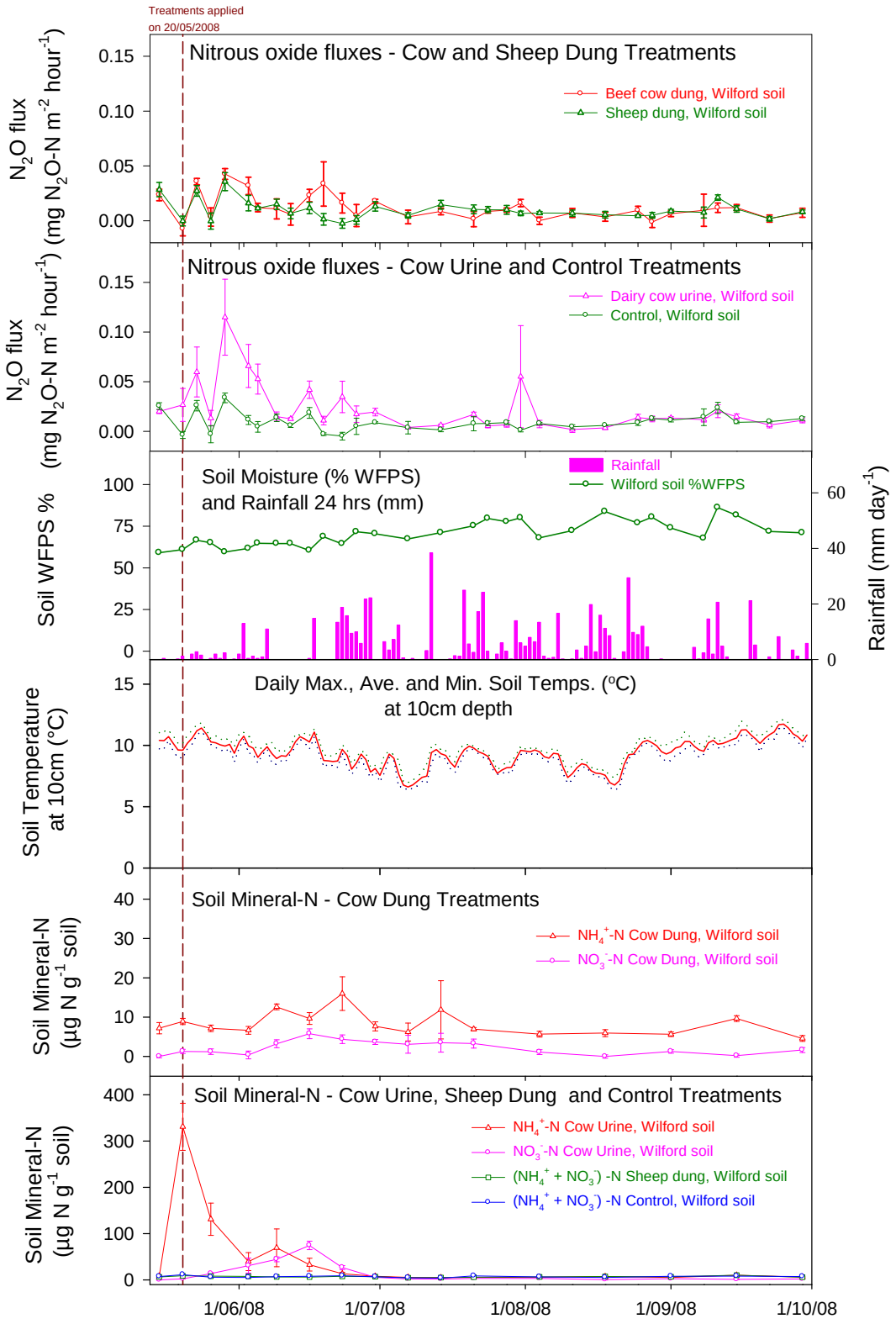

Figure 3: N_2O emissions and soil and climatic conditions for excreta amended Wilford soil in Southern Hawkes Bay. For N_2O flux and mineral N the data points represent arithmetic mean values ± SE (n=4).

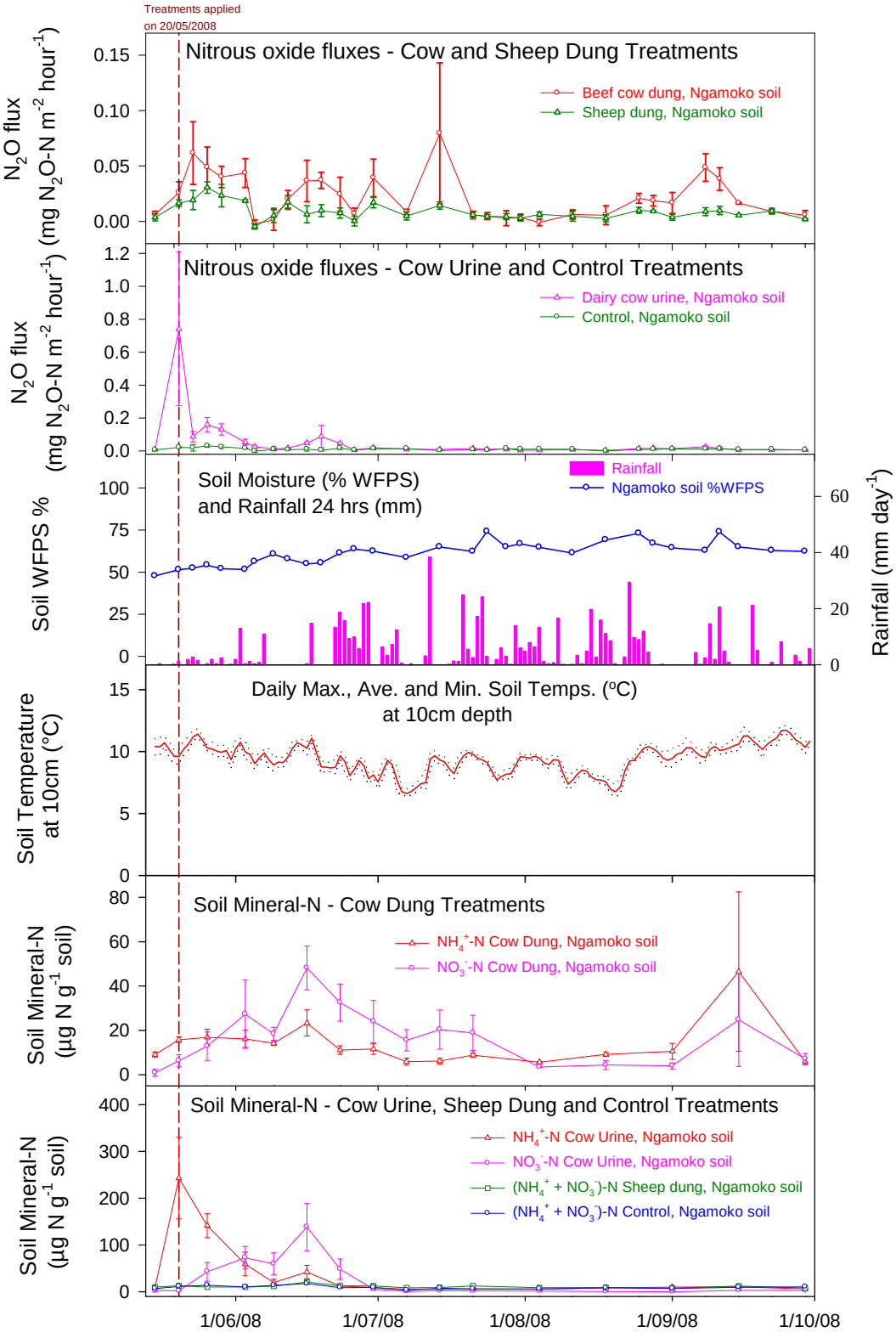

Figure 4: N_2O emissions and soil and climatic conditions for excreta amended Ngamoko soil in Southern Hawkes Bay. For N_2O flux and mineral N the data points represent arithmetic mean values ± SE (n=4).

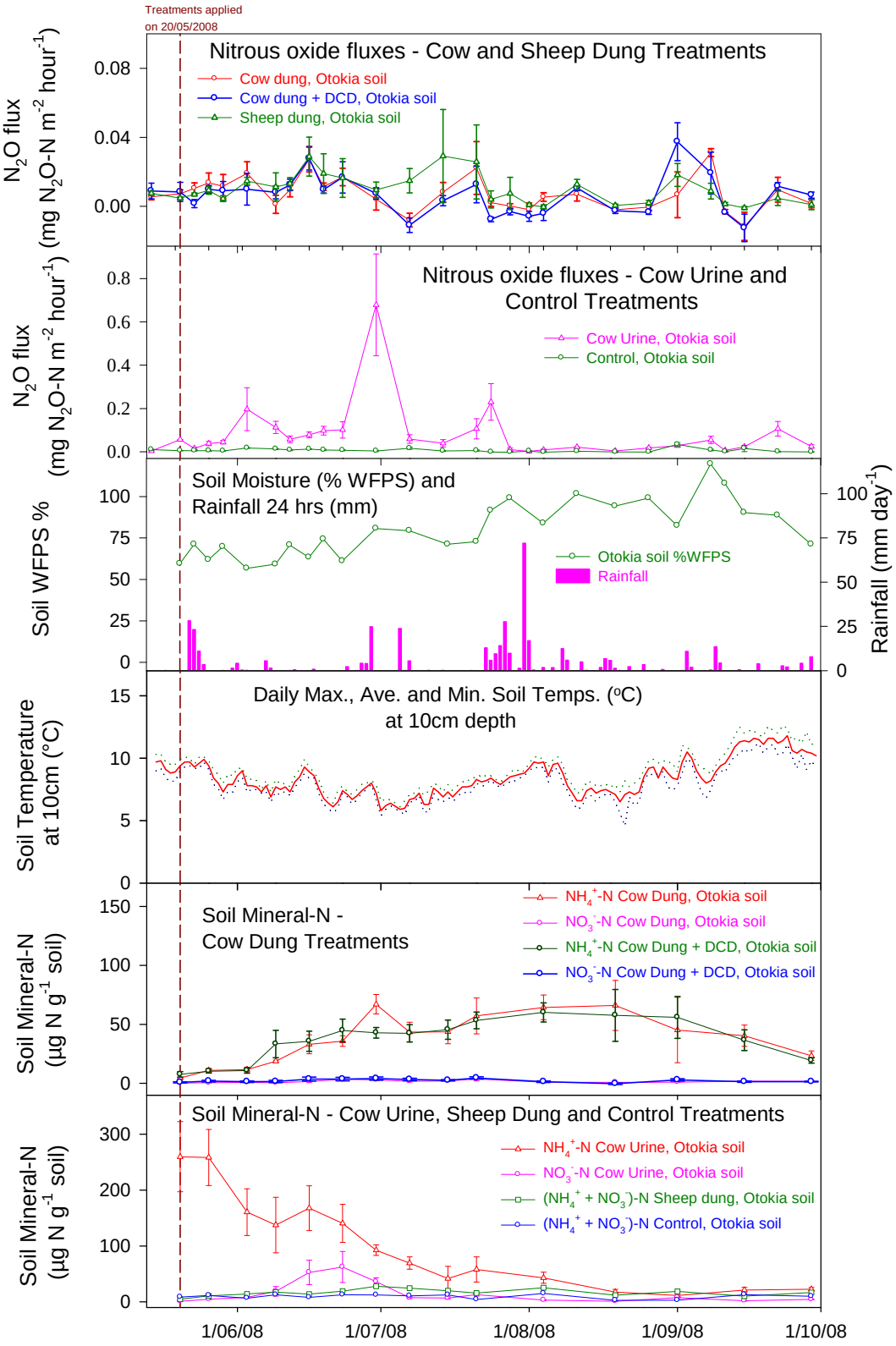

Figure 5: N_2O emissions and soil and climatic conditions for excreta amended Otokia soil in Otago. For N_2O flux and mineral N the data points represent arithmetic mean values ± SE (n=4).

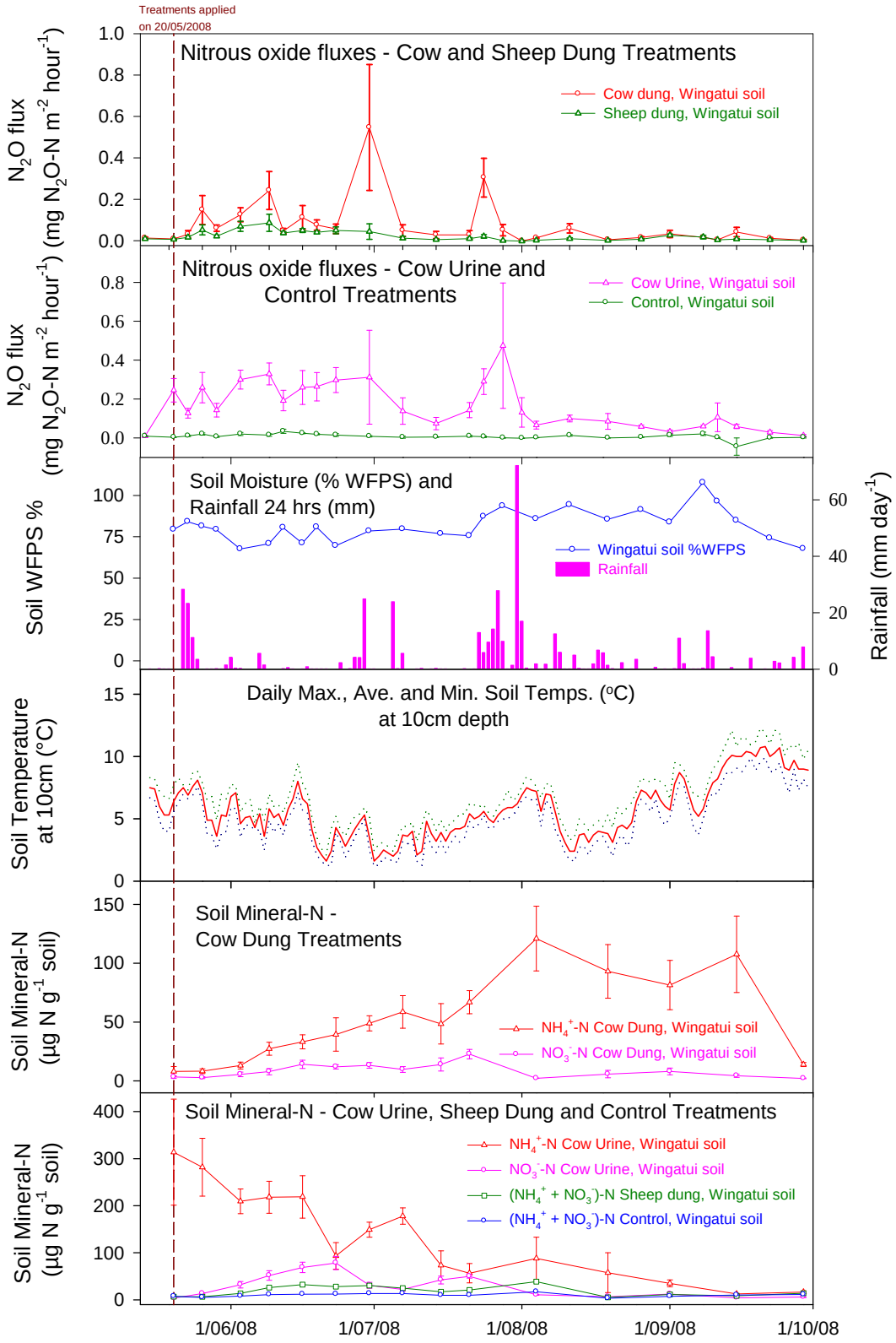

Figure 6: N_2O emissions and soil and climatic conditions for excreta amended Wingatui soil in Otago. For N_2O flux and mineral N the data points represent arithmetic mean values ± SE (n=4).

5. Conclusions

- The N_2O emissions from application of animal dung were much lower than those from application of dairy cow urine on all 6 soils, with most sampling occasions showing emissions from dung plots being similar to those from untreated plots.
- Results from this late autumn study found that EF3 decreases as follows: cow urine > cow or cattle dung = sheep dung. The average EF3 for cow urine, cow dung and sheep were estimated at 0.30%, 0.05% and 0.04% of excreta N applied, respectively.
- The EF3 for cow urine was significantly greater ($P < 0.05$) than those for dung in this late autumn study. There was no significant difference in EF3 for cattle and sheep dung ($P > 0.05$).
- EF3 for urine in this late autumn study was lower than the average estimated from previous MAF studies. This could be due to relatively dry soil conditions during the first two months of the study at both Waikato and Southern Hawkes Bay and relatively cool soil temperature at Otago.
- Soil drainage class within regions did not have a consistent effect on EF3 values for different excreta types.
- EF3 for cow dung was not significantly ($P > 0.05$) reduced with the application of DCD.
- These results support a disaggregation of EF3PRP between dung and urine. However, further disaggregation of dung into animal type may not be warranted. Further research focusing on excreta deposition in spring is being currently conducted to confirm these conclusions.

6. Acknowledgements

Stuart Lindsay, Bridget Wise and Martin Kear for field and lab work at the Waikato Ruakura sites; Brian Devantier, Barry Rolle and Jill Walcroft for field and lab work at the Hawkes Bay Ballantrae sites; Jane Campbell, Alison Rutherford, Jim Paton and Sonya Walker for field and lab work at the Otago sites. Dr Roger Littlejohn for statistical analysis.