NITROUS OXIDE EMISSIONS DURING MAIZE CROPPING

Stuart Lindsey, Jiafa Luo, Justin Wyatt, Stewart Ledgard

Ruakura Research Centre, AgResearch Limited, Private Bag 3123, Hamilton, New Zealand

Introduction

In recent years the strategic use of supplementary feeds on New Zealand (NZ) dairy farms has contributed to intensification and increased productivity. Maize silage is the dominant source of NZ produced supplementary feeds on farms, as it provides a low cost source of starch and fibre for dairy cattle (Kolver *et al.*, 2001). Maize silage is often used to increase and maintain cow condition, extend lactation and overcome feed shortages. The production of maize as a supplementary feed results in considerable soil disturbance and extensive use of fossil fuels during establishment, harvesting and transport (Ledgard *et al.*, 2007). Therefore, gains in farm production could be offset through an increased environmental footprint. Little is known about the effect of use of feed supplements on greenhouse gas (GHG) emissions and nutrient losses particularly at the whole farm scale. The few NZ studies to date, examining the effects of supplementary feeding on environmental emissions (Luo *et al.*, 2008a), have rarely adequately accounted for all sources of emissions. This applies particularly to emissions specifically associated with the production of these feeds, which have generally been ignored (Beukes & Dynes, 2012). Because of this, there is a need to measure the GHG emissions resulting from maize production compared to the ryegrass/white clover pastures that form the dietary staple of NZ ruminant livestock. This experiment investigates changes in soil nitrous oxide (N_2O) emissions and soil carbon due to the cultivation of permanent pasture and planting of a maize crop.

The amount of N_2O emitted is affected by many soil factors, such as mineral N content, soil aeration, soil water and availability of degradable organic material (Choudhary *et al.*, 2002). These factors are all affected by soil cultivation. Greater N_2O fluxes have been measured from cultivated soil compared to permanent pasture (Choudhary *et al.*, 2002) and also when grazed pastures are renovated (Luo *et al.*, 2010). However, it has also been suggested that cultivation increases aeration and thereby reduces soil N_2O flux (Choudhary *et al.*, 2001). Studies which examine the cultivation of permanent pasture to maize and its effect on N_2O emissions are few.

For this study a trial was set up to examine N_2O emissions during the establishment and growth of a maize silage crop. Field measurements of N_2O emissions were conducted through various stages during the production of maize silage when converted from permanent pasture following standard practice in New Zealand. Treatments were also included to examine the effect of application of N fertiliser during the production of maize silage when converted from permanent pasture.

Materials and Methods

Site Description and Preparation

An area located on the former Ruakura Number 1 Dairy farm, near Hamilton, was fenced to exclude cattle grazing on 12 October 2012. The site was on a Horotiu silt loam soil and had formerly been used for dairy grazing. The pasture consisted of well-established perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). About half of the fenced area was sprayed with herbicide to kill pasture plants in preparation for cultivation and planting of maize. The other half of the fenced area remained in pasture to act as a control.

The maize trial area was cultivated on 24 October to a depth of between 150 and 200 mm. Immediately after cultivation, 6 static chambers were installed in the cultivated area and gas samples were taken on 25 and 30 October for N_2O analysis prior to application of any treatments.

Field Trial Layout
The trial was divided into two time periods: the maize growth period from October 2012 to March 2013 and the pasture re-establishment period from March 2013 to June 2013.

The trial used a randomised block design with 4 treatments replicated 6 times. Each individual plot measured 2.4 m × 2.4 m, with no buffers between plots. During the maize growing period the treatments were: fertilized permanent pasture (80 kg N ha^{-1}), permanent pasture control (0 N), fertilized maize (177 kg N ha^{-1}) and maize control (0 N). During the pasture re-establishment period the treatments were: maize area and permanent pasture area. Both treatments received 25 kg N ha^{-1}.

Maize Area
Urea was applied to the fertiliser treatments in the maize growth area On 31 October 2012 at a rate of 40 kg N ha^{-1}. After fertiliser was applied, each plot was individually cultivated to a depth of 150 - 200 mm.

The maize area was then manually planted with Corsons early maturing Delitop CRM 78 maize silage seed to a depth of 5 cm, at seed spacings of 150 mm, in rows 600 mm apart. Each plot contained four rows of maize and therefore a total of 64 plants. After sowing, gas sampling chambers were installed between the central two rows of maize in each plot, immediately adjacent to the base of the maize plants (see Figure 2 for approximate chamber location). The first gas sampling after treatment application was undertaken on 2 November 2012. Gas sampling then occurred twice weekly until 17 January 2013 when it reduced to once a week.

Prior to maize emergence the site was sprayed with residual herbicides to control annual grasses and broadleaf weeds. Emergence of the maize plants occurred on about 8 November 2012. On 9 November the trial area was covered with bird netting to reduce the risk of bird damage. The netting was removed on 5 December 2012, once the maize had reached the four leaf stage of maturity. The maize site was hand weeded on 10 December 2012. On 12 December 2012 a side dressing of urea fertiliser was broadcast to the fertiliser plots at a rate of 137 kg N ha^{-1}.

Maize silage was harvested on 4 March 2013 when the plants were determined to be visually dry as a consequence of drought conditions, and close to the two-thirds milk stage. On 15 March 2013, weeds and summer grasses within the harvested maize trial were spot sprayed using Roundup at a rate of 10 ml per litre of spray solution. The maize growing area was re-sown with 22.5 kg ha^{-1} of ALTO AR37 perennial ryegrass, 1.5 kg ha^{-1} of Kotare white clover and 1.5 kg ha^{-1} of Weka white clover on 22 March 2013, using a direct drill system at row spacing's of 15 mm.

On 24 April 2013 urea was applied at a rate of 25 kg N ha^{-1}, following typical best practice guidelines for new pasture. The new grass in the maize trial area received its first artificial grazing (mowing) on 14 May 2013 and then again on 7 June and 5 July 2013.

Permanent Pasture Area

Urea was surface applied to the fertiliser treatment in the permanent pasture area on 31 October 2012 and again on 12 December 2012 at a rate of 40 kg N ha^{-1}. Following fertiliser application to the pasture area on 31 October 2012, the static chambers for gas sampling were installed in the centre of each plot. As with sampling in the maize growth area, the first N_2O sampling was undertaken on 2 November 2012. Gas sampling then occurred twice weekly until 17 January 2013 after which it was reduced to once-weekly.

Pasture cuts were undertaken on the pasture trial on 19 November 2012, 12 December 2012, 27 December 2012, 11 March 2013, 14 May 2013, 7 June 2013 and 5 July 2013. Pasture was cut at about 45 mm to replicate a typical height after grazing. The extended period between cuts in December and March was a consequence of a summer drought for the 2012/13 period, which resulted in low pasture growth. As for the new grass in the maize growing area, urea was applied on 24 April at a rate of 25 kg N ha^{-1}.

Figure 1: Trial site showing maize area and permanent pasture area in foreground with gas sampling chambers.

Nitrous oxide sampling

A static soil chamber technique was used to measure N_2O emissions and the methodology was based on previous Pastoral Greenhouse Gas Research Consortium studies on N_2O emissions (Luo *et al.*, 2008b). Briefly, stainless steel chamber bases were inserted 100 mm into the soil (Figure 2). On each sampling day, insulated aluminium chamber tops were fitted to the bases and gas samples were collected at 0, 30 and 60 minutes between 11a.m. and 1p.m. The samples were analysed for N_2O content using a gas chromatograph fitted with an electron capture detector. From these results N_2O emission rates and emission factors (% of applied fertiliser N lost as N_2O, EF_1) were calculated.

Figure 2. Gas sampling chamber in use in maize plot.

Climate Parameters

Rainfall and ambient air temperature were measured at the Ruakura meteorological station, which is within 1 km of the trial site. Soil temperature, to 5 cm depth, was measured on site using a hand probe during each N_2O sampling occasion.

Statistical Analysis

Analysis of variance total N_2O emissions and N_2O emission factors was carried out using the statistical software package GenStat (13th edition). Standard error of the mean was calculated for N_2O flux.

Results & Discussion

Nitrous Oxide Emissions

N_2O fluxes were generally higher from the cultivated maize area than from the permanent pasture area for about 2 months following initial cultivation ($P<0.05$) (Figure 3).

The three peaks in N_2O flux, on 19 November, 3 December and 27 December 2012 (Figure 3), corresponded with peaks in soil water filled pore space as a result of significant rainfall events. During these times, soil water filled pore space in the pasture treatments was generally lower than the cultivated treatments (data not presented).

After the side-dressing of fertiliser urea was applied to the cultivated fertiliser treatment (137 kg N h^{-1}) and application to pasture fertiliser treatment (40 kg N ha^{-1}) on 12 December 2012

N_2O flux increased and peaked two weeks later on 27 December 2012 at the rates of 0.173 mg N m^{-2} hr^{-1} from the cultivated fertiliser treatment and 0.0212 mg N m^{-2} hr^{-1} from the pasture fertiliser treatment (Figure 3).

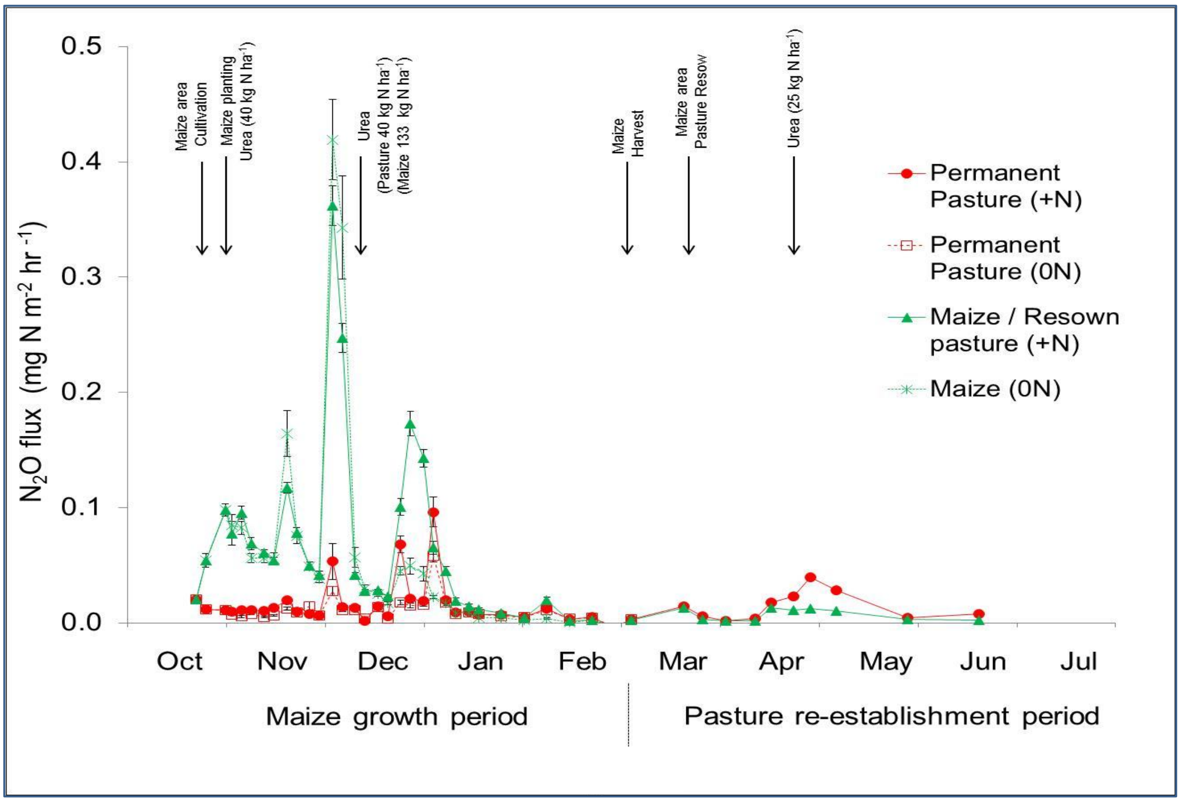

Figure 3: Nitrous oxide emissions from maize and permanent pasture areas with and without fertiliser.

The N_2O emission factors (EF_1)) over the maize growing period were 0.10% and 0.16% for the maize and permanent pasture areas, respectively. The EF1 values obtained were below the default NZ IPCC value of 1% for applied fertilisers.

After 27 December 2012, N_2O flux decreased and by 24 January 2013 there was no difference in the flux between fertilized treatments in the cultivated maize area or pasture area and the controls ($P<0.05$). The N_2O fluxes from all treatments remained low until maize harvest date on 4 March 2013.

Low N_2O fluxes were generally observed from the cultivated and pasture control areas after maize harvest on 4 March 2013. After 12 April 2013 there was a small peak in N_2O flux for the pasture area (Figure 3), which corresponded with increased soil moisture levels (Data not presented).

Total Emissions "Standard Practice"

The data presented in Figure 4 represents N_2O emissions from "standard" maize and pasture management practices in NZ during the study period (239 days). The total from the cultivated "standard" practice was the sum of N_2O emissions from the cultivated fertiliser treatment from initial cultivation until maize harvest and emissions from the cultivated control from maize harvest, including the establishment of new pasture until N_2O measurements ceased. The total N_2O emissions from the pasture "standard" practice was the sum of emissions from the permanent pasture fertiliser treatment until maize harvest and emissions from the pasture control from maize harvest until measurements ended.

The "standard" cultivated maize growth area produced more total N_2O emissions than the pasture area (1.78 kg N_2O-N ha^{-1} compared to 0.74 kg N_2O-N ha^{-1}) (Figure 4). Most of the N_2O production in the cultivated area occured during the maize growth period, which was the period of significant land use change from permanent pasture to a maize system. However, during the post maize harvest period (from maize harvest to new pasture development) the pasture area produced more total N_2O emissions than the cultivated area with values of 0.319 and 0.162 kg N_2O-N ha^{-1}, respectively.

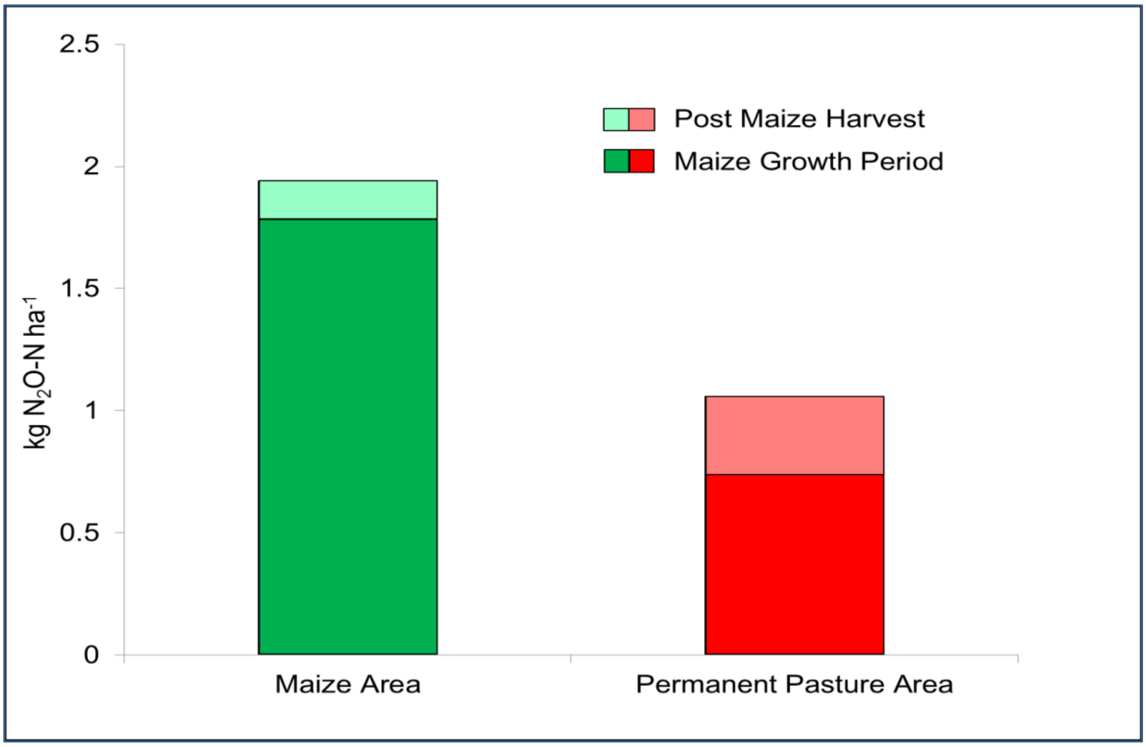

Figure 4: Total N_2O production from cultivation until completion of gas sampling (239 days) for the maize cultivated area and pasture area.

Conclusion

Using "standard" maize and pasture management practices in NZ, the total N_2O emission from the cultivated and fertilised maize growth area, including subsequent establishment of new pasture, was 1.78 kg N_2O-N ha^{-1}. This was higher than the 0.74 kg N_2O-N ha^{-1} emitted from the fertilised permanent pasture area over the same period ($P<0.05$).

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