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NITROUS OXIDE EMISSIONS FROM FERTILISER AND URINE FOLLOWING FULL INVERSION TILLAGE AUTUMN PASTURE RENEWAL

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Abstract

The use of full inversion tillage (FIT) during a pasture renewal event provides an opportunity to manipulate the soil carbon (C) stratification and provide an opportunity to increase the total SOC stock. However, there is considerable concern that the manipulation of the SOC within the soil profile during and after this tillage will result in increased nitrogen losses.

We assessed the emissions of nitrous oxide (N_2O) following application of urine and fertiliser at two field trials established using FIT during pasture renewal. The trial design for both field experiments consisted of autumn pasture renewal following FIT, no tillage (NT) or continuous pasture (CP, no renewal). In each cultivation renewal, subplots were established whereby the N_2O emissions where quantified after application of urine (600 kg N ha^{-1}), fertiliser (50 kg N ha^{-1}) or control (0 N) treatments using sealed gas chambers. Emissions were measured across 2 subsequent years (approximately 4 months and 16 months post FIT renewal). Emission factors (EF) for both years were derived for the urine and fertiliser treatments under the various tillage practices.

A reduction in the N_2O emissions and EF were observed in the first year following FIT when compared to the continuous pasture. The NT treatments had greater losses of N_2O in the first year but these emissions typically reduced to levels similar to the CP treatment in the second year. Overall, the N_2O emission factors across both years for all treatments were lower than the default inventory reporting values.

Introduction

Soils have the ability to sequester large amounts of carbon (C). However, soils under long term pasture typically have high concentrations of C in the topsoil and the opportunity to sequester C is greater in the subsoil (Beare et al., 2014). Full inversion tillage (FIT) has been proposed as a method to overcome this limitation by manipulating the C in the soil profile and provide a large potential for C gain (Lawrence Smith et al., 2015). This manipulation would bury C rich topsoil and bring C depleted subsoil to the surface where it would be in greater contact with fresh C inputs from plants.

While this manipulation of the soil profile, using FIT, is an attractive option for increasing soil C, there are concerns about the effect this practice may have on nitrogen losses, in particular nitrous oxide (N_2O), a potent greenhouse gas (GHG). It is essential to ensure no pollution swapping or adverse effects occur as a result of this tillage. Since N_2O emissions from livestock farming represent approximately 22% of New Zealand's reported agricultural emissions (MfE, 2019) it is important to quantify any changes to these emissions caused by change in tillage practices. FIT may directly change the availability of N in the cultivated soil, or leave a legacy of soil physical change that influences denitrification reactions associated with additions of fertiliser or deposition of urine to the new pasture.

The objective of this study was to quantify the N_2O emission factors after addition of fertiliser or urine on pasture renewed by full inversion tillage.

Methods

Two established and on-going field trials (Lincoln, Canterbury and Palmerston North, Manawatu; Beare et al., 2020) were used for the purpose of measuring the N_2O emission factors following fertiliser and urine addition. These existing field trials, including treatment structure and number of replicates, have been described by McNally et al., (2019) and Calvelo Pereira et al., (2019). An overview of the Lincoln site is presented in Figure 1. Briefly, at each field site pasture was renewed following two different tillage practices including full inversion tillage (FIT) and no tillage (NT). A continuous pasture treatment (CP) was also included as a control. At each site, subplots were established in each replicate of the three treatments (CP, NT, FIT), for the purpose of N_2O measurement. Each subplot contained three sub-treatments representing the nitrogen addition rates: control (0 kg N ha^{-1}), fertiliser (50 kg N ha^{-1} applied as urea) and urine (600 kg N ha^{-1}, synthetic urine) as depicted in Figure 2. Measurements were performed over two periods at both sites: Winter-Spring 2018 and Winter-Spring 2019.

Static head space chambers were used for the measurement of N_2O following the methodology recommended by de Klein and Harvey (2015). For each measurement, gas samples were collected immediately after chambers were sealed and at two further occasions within a one hour period (i.e. 0, 30, 60 min). Gas measurements were taken frequently over several months until the N_2O emissions from the fertiliser and urine plots returned to baseline emissions. Gas sampling always occurred between 10:00 am and 12:00 pm NZ standard time.

Head space gas samples were collected through septa in the top of the chambers using a gas tight syringe. Gas samples were then injected into evacuated vials (Labco, Exetainer 6 mL) for transportation from field to laboratory prior to analysis by gas chromatography (Agilet 7890B). The N_2O flux (mg N m^{-2} hr^{-1}) was calculated for each sampling period and the average flux between two sampling periods was applied to the time elapsed between the sampling periods to calculate a measure of the cumulative N_2O emission per treatment. The cumulative emissions of N_2O were used to calculate the emission factor (EF) which was represented as the proportion of applied N (i.e. from fertiliser or urine) emitted as N_2O and expressed as a percentage.

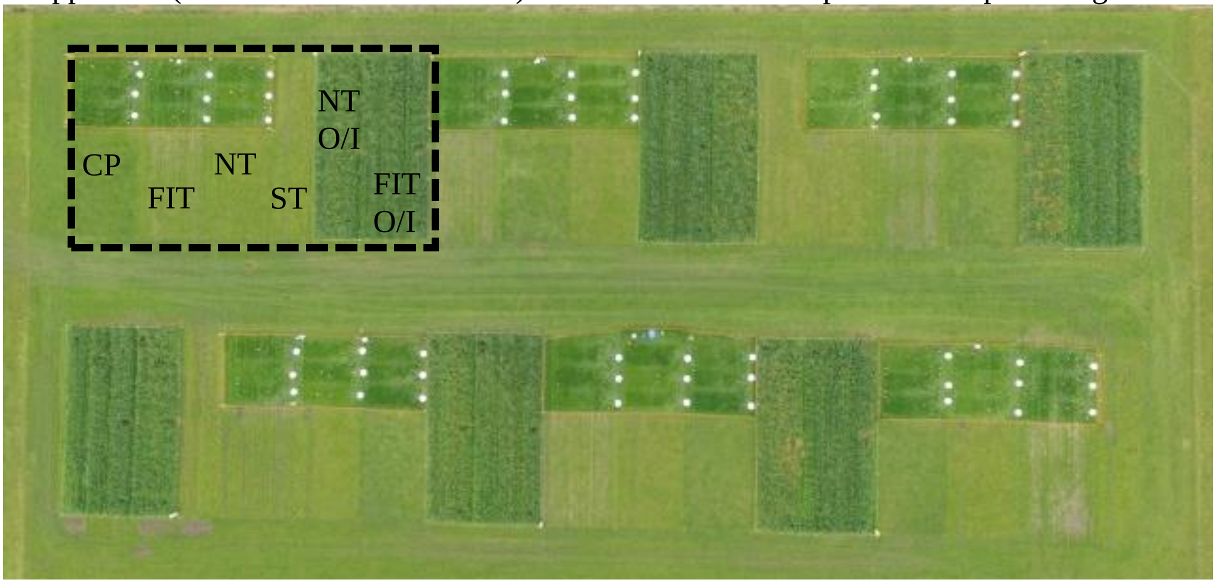

Figure 1 Aerial view of the Lincoln trial site demonstrating the general layout of the trial and blocking of the 6 replicates. The dashed box indicates 1 block with the respective treatments. CP = continuous pasture, FIT = full inversion tillage, NT = no tillage, ST = shallow tillage, O/I = oats/Italian ryegrass. Note that the ST only has 4 replicates.

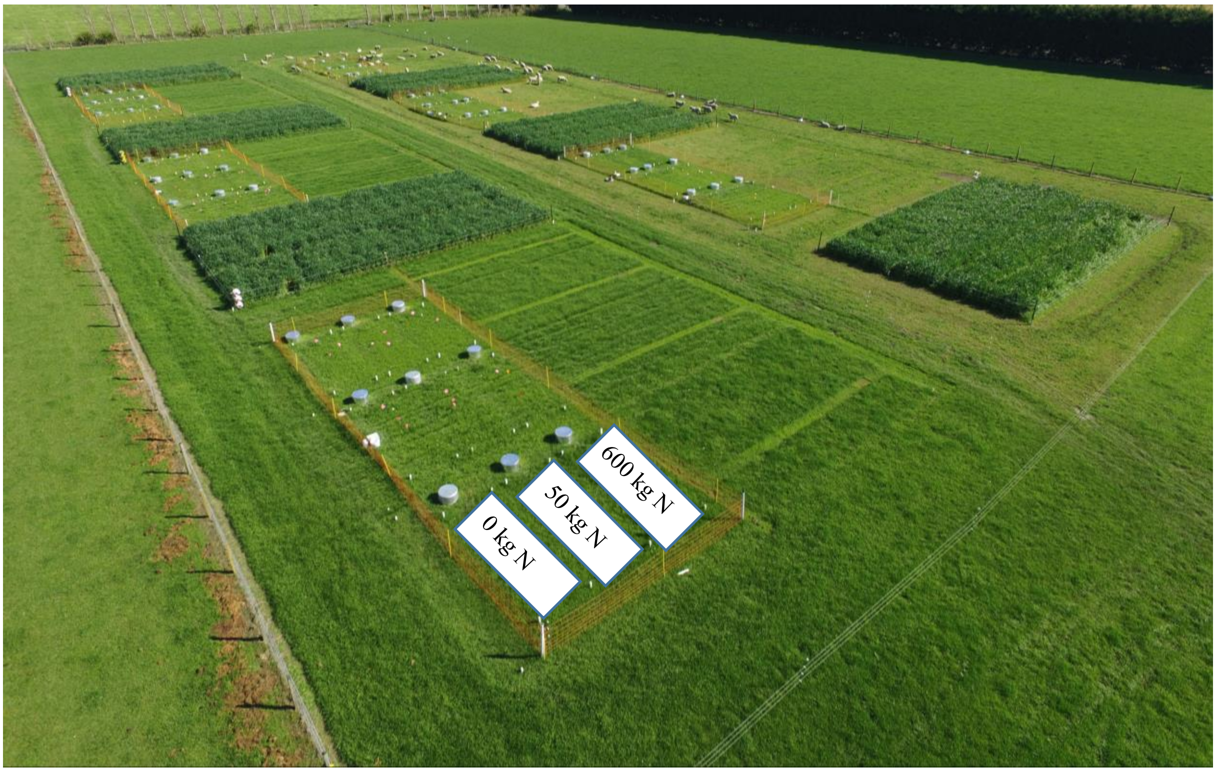

Figure 2 Diagram showing the indicative layout of the subplots within a tillage treatment, where nitrogen was applied at rates of either 0, 50, or 600 kg N ha^{-1} *equivalent. The layout of all nitrogen treatments within each subplot was randomly allocated.*

Results and Discussion

The estimated N_2O emission factors for urine applied N (EF_3) ranged between 0.10% (Massey 2018) and 0.22% (Lincoln 2019) for the FIT treatment (

Table 1 Summary of emission factors (N_2O-N emitted as a percentage of applied N) for N_2O losses after addition of fertiliser-N (EF_1) or urine-N (EF_3). Values reported are means.

). These EF_3 values were generally lower than both the NT and CP treatments across both sampling years except for the Lincoln site in 2019 when the EF_3 values were not different across all treatments. The FIT plots at the Massey site had lower EF_3 values than the plots established by NT or the CP plots across both years. The EF_3 values reported in the current study, for all treatments, are much lower than the default EF_3 value recommended for New Zealand’s inventory reporting (i.e. 1.0 %, MfE, 2019). Therefore, there is evidence to suggest that the action of FIT may result in short term reductions in N_2O emissions from urine and the corresponding EF_3 values.

The N_2O emissions from the fertiliser applied N were lower than the emissions derived from the urine derived N, largely reflecting the lower N loading. However, the emission factors derived from the fertiliser N displayed different responses to the tillage depending on the year of measurement or the site ( ). In the 2018 measurement period, the Lincoln site had large EF_1 values in the NT treatment (1.05 %) compared to the CP and FIT treatments which were not statistically different. However, in the same year at the Massey site, the NT treatment had fluxes that were difficult to detect from the background and as such the EF_1 value could not be derived. For the 2019 measurement period, the Lincoln site had EF_1 values that were not different between any of the treatments, whereas the Massey site had high EF_1 values measured in the CP treatment and the lowest EF_1 values derived in the FIT treatment. In general, with the exception of the NT treatment in 2018 (Lincoln site) and the CP treatment in 2019 (Massey site), the EF_1 values estimated from all the treatments across both sites and measurement years were lower than the $EF_{1\text{-urea}}$ default value of 0.6% used for inventory reporting (MfE, 2019).

Table 1 Summary of emission factors (N_2O-N emitted as a percentage of applied N) for N_2O losses after addition of fertiliser-N (EF_1) or urine-N (EF_3). Values reported are means.

	EF_1 (50 kg N, Urea)				**EF_3 (600 kg N, Urine)**			
	CP	NT	FIT	L.S.D.	CP	NT	FIT	L.S.D.
Lincoln 2018	0.19	1.05	0.23	0.36	0.30	0.44	0.18	0.15
Lincoln 2019	0.02	0.03	0.03	0.03	0.27	0.16	0.22	0.17
Massey 2018	0.10_{a}	n.d.	0.07_{a}		0.14_{b}	0.24_{a}	0.10_{b}	
Massey 2019	0.92_{a}	0.47_{ab}	0.17_{b}		0.45_{b}	0.42_{b}	0.20_{a}	

n.d. = not detectable.

L.S.D. = least significant difference at the 5% significance level. Reported for the Lincoln site only. Massey trial: Means with different letters in the same year indicate statistical difference ($P<0.05$) among treatments following a one-way ANOVA.

The emissions of N_2O at both the Lincoln and Massey sites in both years increased when rainfall raised soil moisture (an example of emission flux for the Lincoln site across both years in Figure 3). As expected, the largest emissions in both the fertiliser and urine addition plots were observed in the first few of weeks following the addition of the nitrogen and the intensity of the emission typically increased following rainfall events.

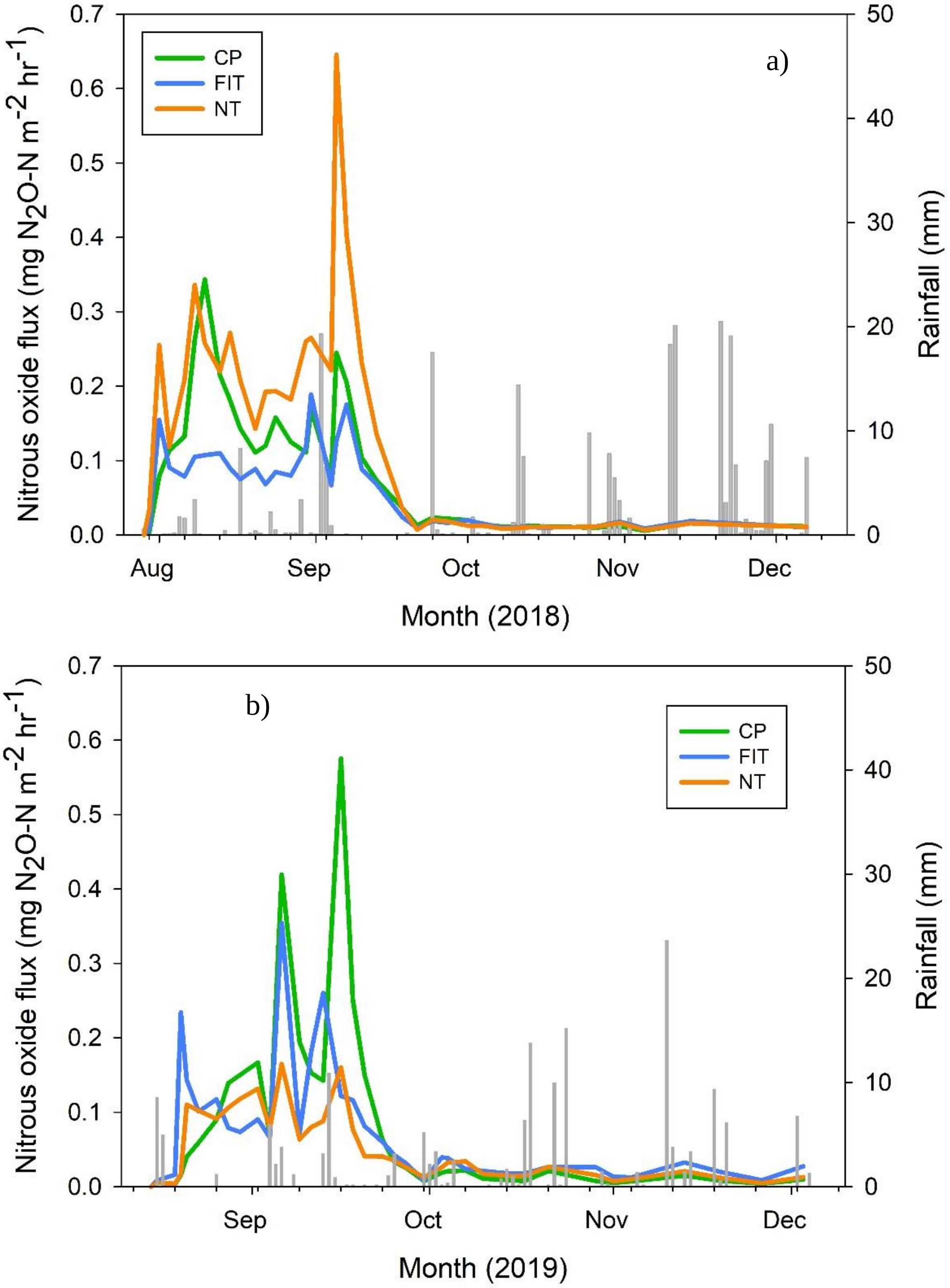

Figure 3 Nitrous oxide flux (mg N_2O-N m^{-2} hr^{-1}) following urine-N addition (600 kg N ha^{-1}, synthetic urine) in a) 2018 and b) 2019 for pasture renewal following full inversion tillage (FIT), no tillage (NT) or no renewal/continuous pasture (CP). Rainfall (mm) is represented by the grey bars.

Mechanisms that explain the observed reductions in EF_3 (and to a lesser extent EF_1) values after FIT currently require further investigation. Possible explanations for mechanisms driving these reductions include FIT altering the hydrological and physical soil properties (i.e. drainage, water filled pore space, and reducing compaction) or reducing the available carbon for denitrification processes due to the burial of carbon at depth.

Acknowledgements

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