Nitrous oxide emission from soil under pasture as affected by grazing and effluent irrigation

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Abstract

New Zealand's greenhouse gas inventory is dominated by the agricultural trace gases, CH_4 and N_2O instead of CO_2, which is dominant on a global scale. While the majority of the anthropogenic CH_4 is emitted by ruminant animals as a by-product of enteric fermentation, N_2O is mainly produced by microbial processes occurring in the soil. In grazed pastoral soils, N_2O is generated from N originating from dung, urine, effluent applied to land, biologically fixed N_2 and fertiliser. The amount of emission depends on complex interactions between soil properties, climatic factors and management practices.

Increased intensification of pastoral agriculture in New Zealand, particularly in dairying has led to an increased production of farm dairy effluent. Traditionally, direct disposal of nutrient rich farm dairy effluents (FDE) into water bodies was an acceptable practice in New Zealand, but with the introduction of the Resource Management Act (1991), discharge of effluents into surface waters is now a controlled activity and many Regional Councils encourage the land irrigation of effluents to protect surface water quality. While the impact of grazing and FDE irrigation on groundwater contamination through leaching and runoff of nutrients has been studied extensively, there has been only limited work done on the effect of these practices on air quality as affected by N_2O emission.

This thesis examines the effects of various factors, such as compaction due to cattle treading, and the nature, application rate and time of effluent application on N_2O emission in relation to the changes in the soil physical properties and C and N transformation from a number of small plot and field experiments. The results were then used, together with data from the literature, to predict the emissions from effluent irrigated pastures using a process-based model.

In grazed pastures, animal treading causes soil compaction, which results in decreased soil porosity and increased water filled pore space that stimulate the denitrification rate as well as influence the relative output of N_2O and dinitrogen (N_2) gases. A field plot study was conducted to determine N_2O emission from different N sources as affected by soil compaction. The experiment comprised two main treatments (uncompacted and compacted) to which four N sources (natural cattle urine, potassium nitrate, ammonium sulphate and urea at the rate of 600kg N ha^{-1}) and a control (water only) were applied. Compaction was obtained through driving close parallel tracks by the wheels of the vehicle. The changes in the soils physical properties (bulk density, penetration resistance (PR), soil matric potential and oxygen diffusion rate (ODR) due to the compaction created by the wheel traction of the vehicle were compared with the changes in these properties due to the treading effect of grazing cattle, which was monitored in another field experiment. The N_2O fluxes were measured using a closed chamber technique.

The compaction at the grazing trial and at the wheel traction experimental plot caused significant changes in soil bulk density, PR, soil matric potential and ODR values. Overall, the bulk density of the compacted soil was higher than the uncompacted soil by 6.7% (end of 3 weeks) and 4.9% (end of 1 week) for the field experiment and the grazing trial, respectively. Results suggest that maximum compaction occurred in the top 0-2 cm layer. Compaction caused an increase in N_2O emission, which was more pronounced in the nitrate treatment than in the other N sources. In the case of the compacted soil, 10% of the total N applied in the form of nitrate was emitted, whereas from uncompacted soil this loss was only 0.7%. N_2O loss was found to decrease progressively from the time of application of N treatments. Total N_2O emission for the three month experimental period ranged from 2.6 to 61.7 kg N_2O-N ha^{-1} for compacted soil and 1.1 to 4.4 kg N_2O-N ha^{-1} for uncompacted soil.

In the second field plot experiment, the results of N_2O fluxes from treated farm dairy effluent (TFDE), untreated farm dairy effluent (UFDE), treated piggery farm effluent (TPFE) and treated meat effluent (TME) applied to 2m x 1m plots for 'autumn' (February-April) and 'winter' (July-September) are described. Effluent irrigation resulted in higher emissions during both the seasons indicating that the supply of C and N through effluent irrigation contributed to increased N_2O emission. The highest emissions were observed from TPFE (2.2% of the applied N) and TME (0.6% of the applied N) during the autumn and winter seasons, respectively. Emissions generated by the TFDE application were the lowest of the four effluent sources but higher than the water and control treatments. The effect of effluent irrigation on N_2O emission was higher during the autumn season than the winter season. The effect of key soil and effluent factors such as water filled pore space (WFPS), nitrate, ammonium and available C in soil and effluents on N_2O emission was examined using regression equations.

The third field plot experiment examined the effect of four TFDE application rates (25mm, 50mm, 75mm and 100mm) on N_2O emission. Treatments were added to 2m x 1m plots lined with plastic sheet to restrict the flow of effluent. The N_2O emission increased with the increasing effluent loading rate, with the emission ranging from 0.8 to 1.2% of the added N. This can be attributed to the increasing addition of N and C in the soil with the increasing application rate of the effluent. Besides, providing C and N substrates, the effluent application increased the WFPS of the soil, thereby creating conditions conducive for dentrification and N_2O emission.

A field experiment was conducted at the Massey University No 4 Dairy farm in which N_2O emission and related soil and environmental parameters were monitored for two weeks following the TFDE applications over an area of 0.16 ha in September 2003 (21mm), January 2004 (23mm) and February 2004 (16mm). Emissions were measured by a closed chamber technique with 20 chambers for each treatment, in order to cover the variability present in the field. N_2O emissions increased immediately after the application of the effluent, and subsequently dropped after about two weeks. The total N_2O emitted from the effluent application after the first, second and third irrigation was 2%, 4.9% and 2.5%, respectively of the total N added through the effluent. The higher emission observed during the second effluent irrigation event was due to high soil moisture content during the measurement period. Moreover effluent was applied immediately after a grazing event leading to more N and C input into the soil through excretal deposition. In this experiment the residual effect of effluent application on N_2O emission was also examined by monitoring emissions 12 weeks after the effluent application. The emissions from the control and effluent irrigated plots were similar, indicating that there was no residual effect of the effluent irrigation on N_2O emissions. In a separate field study, N_2O emission was monitored at the Massey University No 4 Dairy farm to examine the effect of a grazing event of moderate intensity on N_2O emission. The treatments consisted of a grazed and an ungrazed control. The fluxes from the grazed site were much higher than for the ungrazed site with the total emissions from the former site being 8 times higher than the latter site for the entire experimental period.

A modified New Zealand version of denitrification decomposition model (DNDC), a process based model, namely "NZ-DNDC", was used to simulate N_2O emission from the TFDE application in the field experiment. The model was able to simulate the emission as well as the WFPS within the range measured in the field. But simulated emissions from the TFDE were slightly lower than measured values. Improvements in the parameterisation for effluent irrigation are likely to further improve the N_2O simulations.

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To my parents, I am indebted for their unconditional love, encouragement and believing in me throughout my life. Special thanks are due to my mother for coming to New Zealand and providing the much needed moral support and motivation for writing this thesis. The constant love and encouragement provided by my grandmother, brother, sister-in-law, uncles and aunts, Smita, Diksha and rest of the family members made living away from home possible and is highly appreciated.

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