Tillage-Induced Soil Nitrous Oxide Fluxes from Two Soils in the Manawatu

A THESIS PRESENTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE
OF

MASTER OF APPLIED SCIENCE
IN
AGRICULTURAL ENGINEERING

INSTITUTE OF TECHNOLOGY AND ENGINEERING
MASSEY UNIVERSITY, PALMERSTON NORTH
NEW ZEALAND

AKMAL AKRAMKHANOV

April, 2000

Abstract

Enhanced greenhouse gas emissions of nitrous oxide (N_2O) induced by agricultural practices is believed to be the major anthropogenic source. Studies conducted in New Zealand generally from pasture suggest low N_2O emission, however, there is little information for arable farming systems. Therefore, there is a need for a site-specific assessment of the impact of tillage practices on N_2O fluxes.

This paper evaluates tillage system and land use effects on N_2O emissions at two sites using a closed chamber technique. Sites included a Kairanga silt loam where maize/barley was grown continuously for either 17 (K17) or 34 (K34) years, with a conventional tillage system (Kairanga), and an Ohakea silt loam where winter oats and summer fodder maize was double-cropped for five years with conventional (CT) and no-tillage (NT) systems (Massey). At both sites permanent pasture (PP) soil was used as a control.

Spatial measurements for all treatments at Massey site showed large inherent variations in N_2O fluxes (a mean CV=119%) which reflected natural soil heterogeneity, and perhaps the measurement technique used rather than the real differences due to the tillage and cropping systems evaluated. N_2O emissions measured from December 1998 to September 1999 from the PP were significantly lower (1.66 kg N_2O-N/ha/year) than the CT and NT plots at 9.20 and 12.00 kg N_2O-N/ha/year respectively. However, there were no differences in N_2O emission rates between the CT and NT treatments. Cumulative coefficient of variation (CV) of treatments ranged from 39 to 140% .

Seedbed preparation using power-harrow which was done within few days of ploughing the CT plots reduced N_2O emissions by 65% within the first hour after power-harrowing. However, N_2O emission rates returned to the pre-power harrowing levels one month after power-harrowing.

There was strong relationship between log-transformed values of soil moisture content (SMC) and N_2O emissions in all treatments, PP (r = 0.73), CT (r = 0.75) and NT (r = 0.86). Seasonal variation in N_2O emission from the PP was in the order of winter=autumn>summer. Although fluxes in the CT were higher in winter than in the autumn season, there were no differences between the summer and autumn data. Similar

to the PP, the seasonal variations in N_2O emission in the NT treatment were in the order of winter>autumn=summer.

The estimated annual N_2O emissions from the PP, K17 and K34 (calculated as the mean of all individual closed cover chamber measurements between November 1998 and September 1999) from Kairanga site were similar at 3.24, 3.42 and 2.37 kg N_2O-N/ha/year, respectively. There were large variations in N_2O emissions during the year with the mean flux rates ranging from 0.175 to 13.32, 0.175 to 16.91 and 0.088 to 30.05 kg N_2O-N/ha/year in the PP, K17 and K34 fields, respectively.

Although overall comparison of treatment means did not show any discernible differences between management practices, there were signs that the K34 had lower emissions compared to the PP.

N_2O fluxes from the K17 and PP field appeared to be influenced by SMC. There is clear indication that low or negligible emissions occur when gravimetric soil water content is less than 30% in the PP. Although N_2O fluxes did not follow the rainfall patterns in the K17 and PP, linear regression analyses indicated low but significant relationship r = 0.46 and 0.53 (0.72 when log-transformed), respectively.

In the K34 field, SMC did not seem to govern fluxes which were especially apparent during wet months of April and May. The linear regression analysis using the measured data revealed no relationship (r = 0.12) between the SMC and N_2O fluxes in the K34 treatment.

Seasonal grouping of monthly log-transformed N_2O emissions showed significant differences in all treatments. Summer season N_2O emissions in the PP were the lowest than other seasons whereas no discernible differences were observed among other seasons. Although N_2O fluxes during spring and summer were similar in the K17 field, they were significantly lower than the winter and higher than autumn fluxes. There were considerably higher emissions in summer than in autumn in the K34 but seasonal variation between winter and spring was less profound.

Spatial variability in N_2O fluxes was large during the year with coefficients of variation (CV) ranging from 10 to 82%, 12 to 99% and 9 to 137% for the PP, K17 and K34 fields, respectively.

Acknowledgements

I wish to express my sincere thanks to my chief supervisor Assoc. Prof. Ashraf Choudhary and co-supervisor Dr. S. Saggar of Landcare Research for their time, advice, supervision, encouragement and providing ideas during the course of this study.

Many thanks to staff and post-graduate students in Agricultural Engineering, Massey University, for their help and friendship including Leo Bolter, Joane Brooks, Roanna Moore and my post-graduate colleagues Edmundo Viegas, Khurshid Anwar and Val de Villa.

I also acknowledge assistance from Landcare Research, Palmerston North, for the use of laboratory facilities. Special thanks are due to Messrs Brian Daly, Graham Shepherd, Carolyn Hedley and Jaque for their help and guidance during laboratory experiment.

I thank Mr. Duncan Hedderley for his assistance in computer analysis of the data.

I am grateful to the New Zealand Official Development Assistance (NZODA) Programme, Ministry of Foreign Affairs and Trade, Wellington for the postgraduate student scholarship.

Last, but certainly not least, I thank my parents, family and friends for continuing support and patience throughout my studies.

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Chapter 1

General Introduction

There is a growing concern world-wide about climate change. Atmospheric warming which is known to be caused by so-called "greenhouse gases" mainly include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) and to a lesser extent chlorofluorocarbons (CFCs) (IAEA, 1992). Presently, the increase in greenhouse gases other than CO_2 in changing the climate is similar in importance as CO_2. One such gas is N_2O which despite its low concentration in the atmosphere, about 310 ppb (IPCC, 1995), on a molecule per molecule basis has a radiative force about 200 to 300 times that of CO_2 (Jaques, 1992) and an average atmospheric lifetime of about 150 years (IAEA, 1992). It is widely accepted that the main source of N_2O is agriculture.

Most N_2O originates with soil processes, as intermediate product from microbial nitrification and denitrification (Delwiche, 1981). Increased emissions of N_2O from soils are associated with fertilisation of soils with mineral nitrogen (N), animal manure, N derived from biological N_2 fixation, and enhanced N mineralisation (MacKenzie et al., 1998). With fertiliser usage predicted to grow worldwide at 6-7% per annum (Peoples et al., 1995) and low N utilisation efficiency in agricultural systems, the potential of soils to form and emit N_2O increases. This increased N_2O emission to the atmosphere is of great concern and need quantification.

Amounts of N_2O emitted depend on complex interactions between soil properties, climatic factors and agricultural practices (Granli and Bockman, 1994). Main factors in the soil controlling N_2O emissions are soil content of NH_4 and NO_3 (Ball et al., 1997; Castaldi and Smith, 1998; Seneviratne and Van Holm, 1998); soil aeration status and soil water content (Carran et al., 1995; Teira-Esmatges et al., 1998; MacKenzie et al., 1998); presence of degradable organic material which promotes microbial activity (Ineson et al., 1998; Kaiser et al., 1998); soil pH (Anderson and Poth, 1998; Sitaula and Bakken, 1993; Burth and Ottow, 1983) and soil temperature (Mahmood et al., 1998). Although these are known interacting factors they are not always strongly correlated with N_2O fluxes. Due to complexity of interactions between various factors, N_2O emissions have very high spatial and temporal variations.

Agricultural practices alter soil properties which influence the extent of N_2O emissions. Intensive use of cultivation practices, both internationally and locally in New Zealand, hugely impact soil properties. In the Manawatu region heavier textured soils used for continuous maize production result in loss of soil organic matter (SOM) (Saggar et al., 2000) and deterioration in soil structure (Shepherd et al., 2000). Even short term tillage operations can affect SOM levels and microbial biomass (Aslam et al., 1999) which are of particular interest in nutrient transformations. Conversion of pastures to arable cropping in New Zealand results in depleting of SOM and soil fertility over time and additional N fertilisers are applied to compensate for the loss of organic N reserves.

Since N fertilisation is considered as a major practice on increasing N_2O emission from soil by providing an additional N source (Ryden and Rolston, 1983), careless N application on such soils may contribute to increased loss of N either as NO_3 through leaching or as N_2O emissions.

An alternative to conventional tillage system is conservation tillage system which aims for sustainable agricultural production. Its growing acceptance is due to reduced soil erosion and runoff (Choudhary et al., 1993; Unger and Vigil, 1998; Myers and Wagger, 1996), enhanced moisture retention and infiltration (Baumhardt and Lascano, 1996), lower summer temperatures (Prihar et al., 1996) and possible increased net return to the farmer (Reicosky, 1994). However, the impact conservation tillage has on N_2O emission is not known for these Manawatu soils.

In the past 20 years, research of N_2O emissions has concentrated on enhancing an understanding of N_2O production processes and its controlling factors. Despite this it is not possible to predict the fate of a unit of N that is applied on a specific arable field (Mosier et al., 1996). Both short- and long-term in-situ measurements are needed to assess N_2O emissions from soils.

Studies by Ruz-Jerez et al. (1994) and Carran et al. (1995) from both poorly and well drained grazed pastures in the Manawatu region suggest low N_2O emission from these low fertility hill lands. However, there is little information for arable farming systems. Therefore, there is a need for site-specific assessment of the impact of tillage practices on N_2O fluxes.

1.1 Research Objectives

To evaluate long-term and short term impacts of different tillage systems and land use on N_2O emissions selected farming practices were chosen in the Manawatu region of New Zealand. The overall aim was to characterise land use practices and their effect on N_2O emissions. This study is a part of a wider project on soil nitrogen recycling.

The specific objectives of this study were as follows:

- To quantitatively determine the rates of N_2O emissions from fields sown with the conventional tillage (CT), no-tillage (NT) and compare these with permanent pasture (PP) fields throughout one management cycle.
- To measure the response of soil N_2O emissions to various cultural practices and selected environmental parameters such as changes in soil moisture and soil temperature.
- To measure soil physical and chemical properties and asses their interactions with N_2O emissions.