CAN WE IMPROVE INTERPOLATION OF N_2O EMISSION MEASUREMENTS BY USING ENVIRONMENTAL FACTORS?

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Abstract

Determining nitrous oxide (N_2O) emissions is highly uncertain due to their large spatial and temporal variability. This variability is caused by the many biological processes involved, each responding in a different way to environmental conditions. Also the various processes are often associated with non-linear relationships to gaseous emissions. The objective of this study was to analyse N_2O emission from a recently compiled New Zealand N_2O database and to verify the possibility of using environmental factors to improve the currently used linear interpolation of measurements. The database comprises a collection of data from 21 trials carried out in New Zealand since 2000, under different climates, with different soils and N loads and sources. Gaseous and soil data collection were performed according to NZ's Ministry of Agriculture and Forest (MAF) protocols. In this work, we analyzed all data from urine patches treatments (N application ranging from 49 – 1,000 kg/ha) using stepwise multiple regression to select significant variables and to determine their relationship with N_2O emissions. Daily measurements of soil water-filled pore space, volumetric water content, soil porosity, sum of rain recorded in the two previous days of gas measurement, soil temperature, air temperature, solar radiation as well as soil organic carbon content and inorganic soil N content were used as environmental variables. Prediction of N_2O emissions using environmental parameters resulted in a poor agreement when fitting was done using the whole dataset (R^2=0.16). Improvement of fitting (R^2=0.39) was achieved after filtering the data according to the soil's nitrate content (soil NO_3 content higher than 70% of total inorganic N). This separates the N_2O values obtained when denitrification was the dominating process on the production of N_2O. For the remaining data, the emissions come from both nitrification and denitrification, and could not be related to environmental factors in a more precise way. Next the data were analysed region specific. For the Waikato region, stepwise regression indicated four variables as significant: rainfall, air temperature, radiation, soil's clay content, and NO_3 amount; while for Otago only rainfall and NO_3 amount were significant. Predictive functions based on these variables were used to interpolate N_2O emissions and these were compared with the Intergovernmental Panel on Climate Change (IPCC) interpolation approach. Preliminary results suggest that the above procedure is promising and specific tests will be carried out in the future. The relationship between estimated gaseous emissions and environmental factors at the time of high ammonium contents also need to be further investigated.

Introduction

Greenhouse gas (GHG) emissions from agriculture have become a national concern since New Zealand's ratification of the Kyoto protocol. The majority of the country's GHGs come from agriculture, mainly in the form of methane (CH_4) and nitrous oxide (N_2O). N_2O is one of the most powerful greenhouse gases, with a warming potential around 300 times higher than CO_2 and its scale is closely related to the management of N deposited onto soils, from both, animal excreta and fertilizer. It is recognised that a reduction i N_2O emissions can only be accomplished by improving farm management allied with the use of mitigation actions (de Klein and Ledgard, 2005; Leslie et al., 2008).

Nitrous oxide production is a complex oxidation-reduction reaction driven by soil microorganisms and controlled by factors such as soil moisture, temperature, pH, and N availability. It can be produced during both nitrification and denitrification processes. A clear separation of the most important process at any time is not simple and possibly highly affected by variations in environmental conditions.

In order to evaluate the impact of excreta and fertiliser on N_2O emitted from soil, IPCC established protocols to calculate emission factors (EF) from various N sources. Emission factor is defined as the fraction of the N applied to the soil that is emitted as N_2O. The EF is determined experimentally by measuring N_2O emissions in standard trials, which are carried out until N_2O from plots that received the treatments returns to background level (i.e. becomes equal to the measurements from control plot). The measurements are taken as often as few hours in the beginning of the trial up to intervals of 15 days or more at the end of the experiment. To obtain the total amount emitted, daily values are summed up over the trial period. Linear interpolation is used to obtain values for the days not measured. A series of trials looking at the effects of animal (e.g. sheep, beef and deer) excreta deposition (urine and dung) on soil nitrous oxide (N_2O) emissions have been carried out across the country to produce and refine estimated of EF for New Zealand conditions (de Klein et al., 2003; Hoogendoorn et al., 2008; Luo et al., 2007; Luo et al., 2008; Saggar et al., 2007).

This work describes the preliminary results of a study to use some environmental factors as ancillary information in the interpolation of N_2O emission from soils. The work was done by analysing a dataset that comprises results from a series of 21 trials carried out all across New Zealand since 2000, under different soil and climate conditions.

Materials and Methods

New Zealand's N_2O emission database (Vogeler et al, 2012) is a compilation of results from 21 trials carried out in New Zealand since 2000. These trials comprise treatments with different N sources (i.e. fertilizer, urine, dung) and at various N loads across a variety of soils and climates. The majority of the trials were performed to determine N_2O emission factors from different N sources specific for New Zealand. Information on soil and climate have been added to the database, which is organized in an easy-accessible spreadsheet allowing filtering or sorting data according to several factors.

To consolidate the dataset unique experiment identification was created using region, location, soil type and slope, time of application and N source. For each treatment and measuring day, replicate N_2O measurements were averaged using a log-transformation according to van der Weerden et al. (2011). From these the values from control plots were subtracted, thus yielding the net N_2O emissions for a given day. Prior to this a conservative inspection for data consistency and outliers using descriptive statistics was performed.

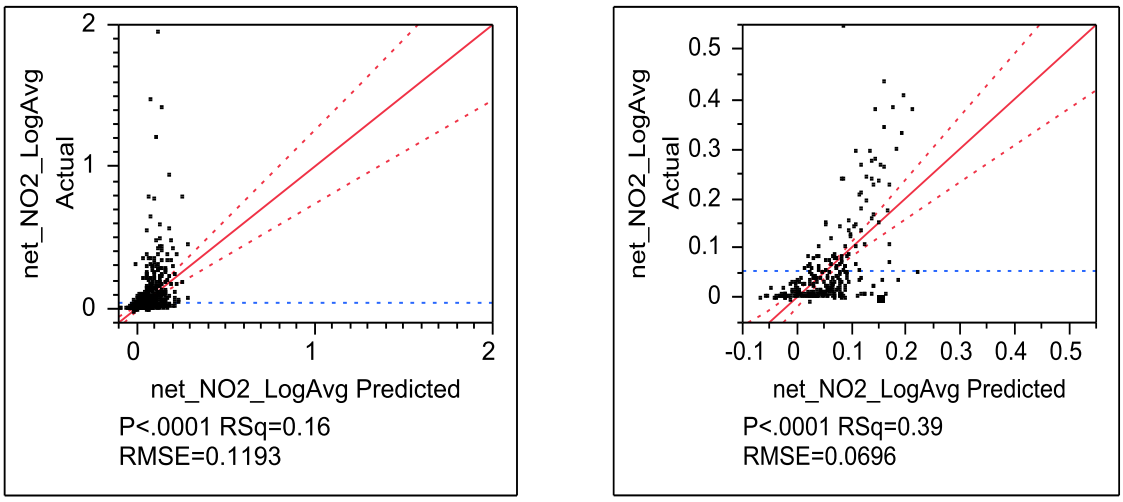
In the analyses presented here only data where urine was applied is used. Stepwise multiple correlation approach was employed to identify those environmental conditions that lead to high N_2O emissions. Due to the natural high variability of N_2O emissions, a significance level of 10% was used to retain any variable in the predictive model. Multiple regression analyses were performed in order to find a single equation describing the effect of those variables on gaseous emissions. N_2O measurements were then interpolated using the obtained equations across dates and compared to linear interpolation. The EFs calculated based on both methods is shown for selected treatments.

Results and Discussion

The first approach was made using all datasets (21 trials, 1089 measurements), but excluding the dung treatments. Exclusion of dung treatments was done because its N content is not readily available compared to N deposited via urine, and N_2O emissions are thus likely to be driven by other environmental conditions than those from urine patches.

Using the whole dataset, the agreement between N_2O emissions predicted the regression model and those measured was poor (Figure 1a). Next the data was restricted so that only measurements where soil nitrate content higher than 70% of the inorganic N was used. The model performance increased considerably (Figure 1b), even though the dispersion was still high. The selection of data at high NO_3 contents attempted to focus on emissions occurring when denitrification is the dominant process. This removed the data from the beginning of the trials, when both NH_4 is nitrifying in substantial amount and thus the contribution of nitrification to the total N_2O emission is likely to be significant. This is important because environmental factors affect nitrification and denitrification differently, and thus a relationship between N_2O and the environmental factors is much more complicated, or impossible, to attain. For the data restricted to high NO_3 content, the environmental factors that were significant to explain the variation of N_2O were the rainfall recorded in the two previous days of gas measurement (RF_prior2), daily average of solar radiation (Radn), soil temperature at 100 mm depth, clay content an soil inorganic nitrogen amount (N-inorg).

Performing the same analyses for the data split by region improved the model performance further, indicating that the relative importance of environmental factors varies for different climates. Splitting the data by soil type resulted in mixed results. For some soils the fraction of N_2O variance described by the model increased considerably, however for other soils this was not the case, even when choosing different environmental factors to enter in the model.



(a) (b)

Figure 1 – Measured versus predicted soil N_2O emission using all data available in the NZ database (a) and using only data where soil nitrate was higher than 70% of total soil inorganic N (b)

The interpolation using environmental factors and the standard IPCC approach is shown in Figure 2 for two soils in Hamilton and Mosgiel. Both with approximately the same amount of N urine applied (500 kg N/ha). Using environmental factors as ancillary information to interpolate N_2O emission had a good agreement for Horotiu soil in Hamilton, however not for the Wingatui soil in Mosgiel. Nonetheless the approach was able to describe the bulk variation in the data and is a promising approach to identify the days between measurements where emissions might have been higher, or smaller, than the simple average of the two measurements around it. In both examples the EF calculated using the interpolation based on environmental factors was slightly smaller than the standard IPCC. While this approach, using environmental factors for more accurate interpolation, needs to be refined and tested, it can potentially be used to . improve experimental procedures and especially to improve management practices leading to lower N_2O emissions

Clearly more detailed analyses are needed to understand the variation in performance in different regions and soils. All the analyses so far considered linear responses and the use of non-linear functions might improve the description of N_2O emissions. This work is carried out in parallel with farm systems simulations, whose results may be used to improve the interpolation and to better understand the emission processes.

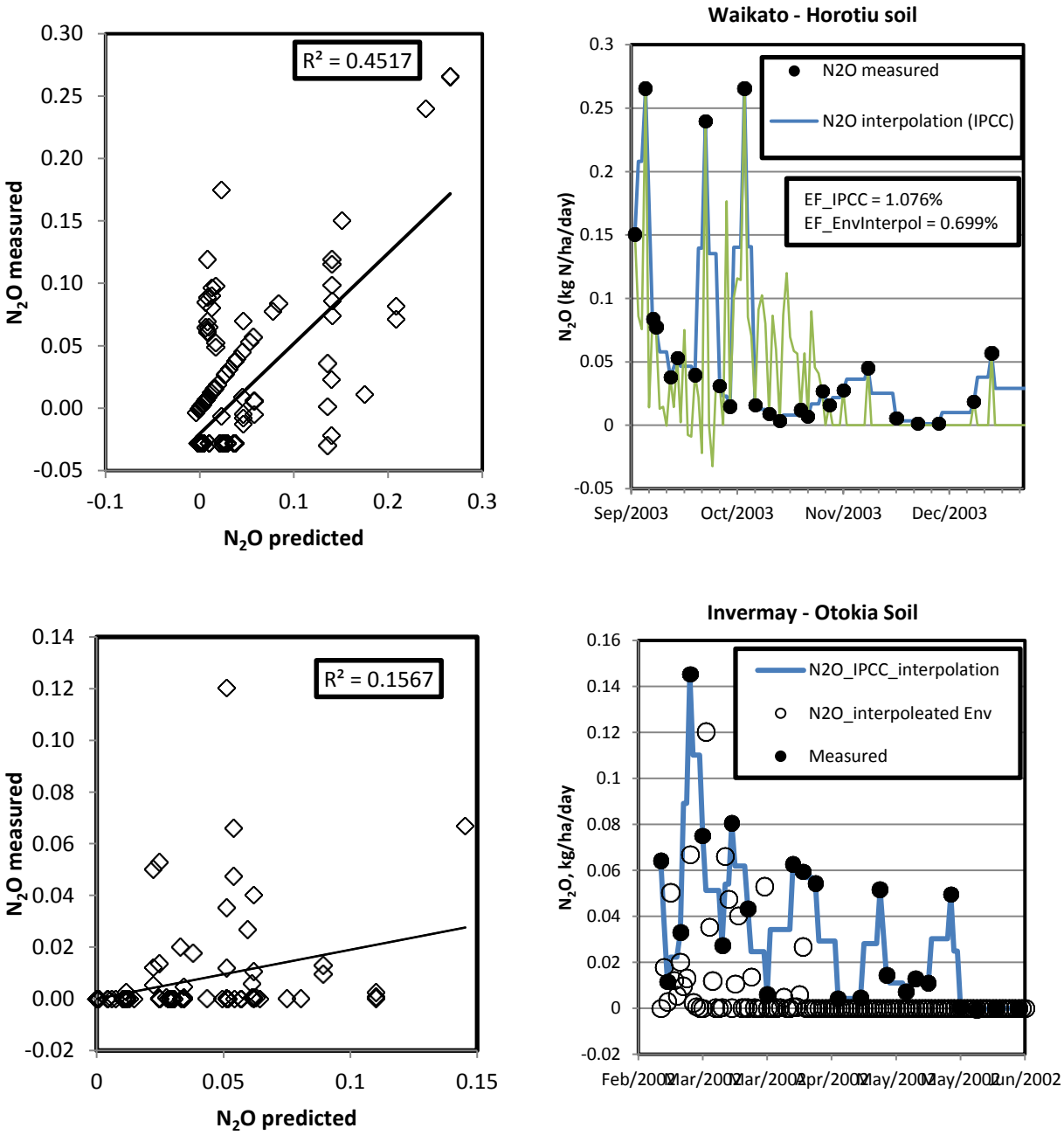


Figure 2 – Fitting performance and interpolation of nitrous oxide emissions from soil at Hamilton and Mosgiel after the application of urine at 500 kg N/ha.

Summary

This work presented some preliminary results of a study to use environmental factors as ancillary information to interpolate N_2O data. New Zealand N_2O database compiled from several trials carried out in pastoral systems across the country was analysed. Due to the high variability inherent to gaseous measurements and to the variation in climate conditions recorded during the trials, the use of the entire dataset did not produce a good model to describe the measured data. This agreement was much improved by considering only the

data where denitrification was the major loss process. Splitting the data by region or soil also improved the predictions. These results although preliminary are promising and further analyses will be carried to identify better functions to describe N_2O emissions as function of environmental factors.

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