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Comparison of APSIM and DNDC when predicting N_2O emissions from urine patches

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Extended Abstract

Agricultural greenhouse gas (GHG) emissions, including nitrous oxide (N_2O), are a major contributor to total GHG emissions, and animal excreta deposited onto pastures are a main source of this. To reduce N_2O emissions better understanding of the factors driving emissions and evaluation of mitigation strategies is required. Computer simulation models can provide an effective tool for these. We compared two process-based models simulating C- and N-cycling in agricultural soils: APSIM[1] and NZ-DNDC[2], an adapted to New Zealand grazed pasture conditions. The aim was to identify primary differences in simulated nitrogen transformation rates in soils under varying environmental conditions including temperature (T), soil water content (θ), soil organic carbon (SOC), pH, and NH_4 and NO_3 concentration.

Model descriptions

APSIM is a framework of biophysical modules that simulate biological and physical processes in farming systems. The SoilN module simulates the dynamics of N and C on a daily time-step in soil layers, with C and N mineralisation, C and N immobilisation, N nitrification, N denitrification and nitrate and ammonium adsorption and movement explicitly described in each layer. These N processes are controlled by soil water content, temperature and pH and water flow which are simulated within either the SoilWat (tipping bucked model) or SWIM (based on Richards equation) modules.

DNDC consists of several sub-models for simulating thermal-hydraulic flows, plant growth, aerobic decomposition, fermentation and denitrification. The model usually operates on a daily time-step, except following a rainfall event where denitrification is calculated on an hourly time-step. To allow nitrification and denitrification to occur simultaneously in aerobic or anaerobic microsites, a dynamic 'anaerobic balloon' balloon' is used[3]. Substrates such as carbon, NH_4 and NO_3 are split into aerobic and anaerobic soil micro-sites.

Methods

Firstly, to compare N transformations from APSIM and DNDC, simulations were set up with simplified conditions (no plant cover, constant temperature, uniform soil properties with depth). In separate simulations environmental conditions were altered: the initial N concentration (100 or 500 kg NH_4/ha, or 100 kg NO_3), θ of 0.3, 0.45, 0.55 m^3 m^{-3}, soil T of 10, 15 and 30°C, SOC of 3 and 6%, pH of 6 and 8, and +/- rainfall of either 20 mm on day 1, or at 5 mm/day).

APSIM and DNDC were then compared to a series of field measurements of soil mineral N (NH_4 and NO_3) and N_2O emissions following urine application, with different soil types, different climates and urine application timings[4].

Results

Simulations under the simplified conditions revealed that soil T had a larger influence on the nitrification rate in APSIM than NZ-DNDC, while NH_4 concentration and soil water content had more influence on the nitrification rate in NZ-DNDC than in APSIM. NZ-DNDC showed a higher sensitivity of denitrification rate to T and organic carbon than APSIM[5].

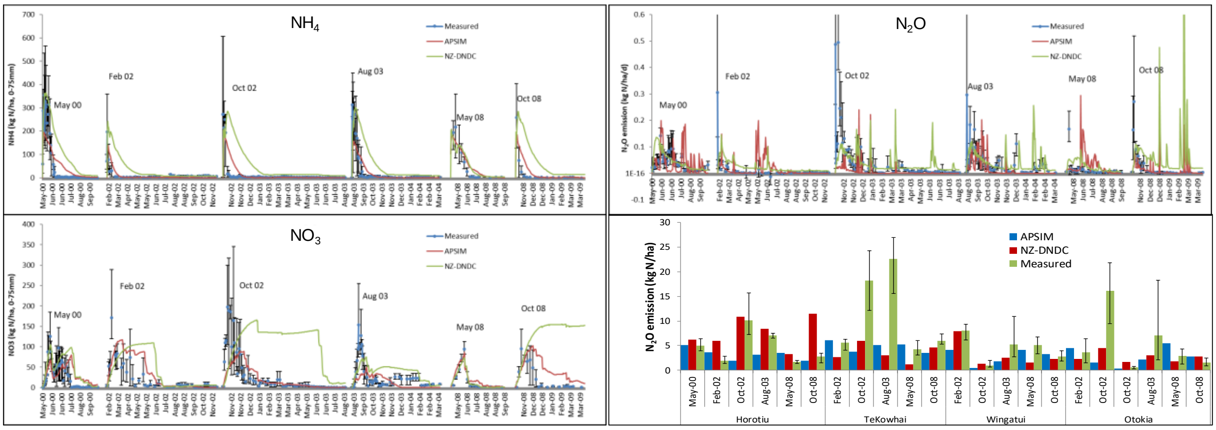

Figure 1. APSIM and NZ-DNDC model results compared with measured values of NH_4, NO_3, and N_2O following urine application for six trials on the Horotiu soil, New Zealand. Also shown are the measured and predicted cumulative emissions.

The two models predict N transformation from the urine patches quite differently, with APSIM in general predicting faster nitrification, an example is shown for the time series of the Horotiu soil, a well-drained allophanic soil (Fig.1). The daily measurements of N_2O emissions (replicates) show high spatial variability, indicating the sensitivity of N_2O emissions to variability in soil properties over short distances. Both models frequently produced results outside the measured range, with both over- and underestimation. Total N_2O emissions also show mixed results by the two models, with some measurements predicted well by both models, as well as over- or underpredictions. Statistical analysis suggests that APSIM is better at predicting trends between soil types, whereas NZ-DNDC is better at predicting seasonal differences in N_2O emissions. In New Zealand a specific emission factor (EF3) of 1% for deposited urine, is employed within the national agricultural greenhouse gas inventory[6]. The two process-based models performed less well than the compared to when calculating cumulative N_2O emissions based on the EF3 method.

An initial sensitivity analysis, in which various model parameters were varied, indicated, that while changing some of the default model parameters improved the agreement in some cases (e.g. for APSIM when denitrification rate was decreased or the fraction of nitrified N emitted as N_2O was increased, and for DNDC when microbial activity was decreased or volatilization increased), so far none of the model parameters investigated could produce emissions that agreed reasonably with all datasets. A sensitivity analysis, which includes more parameters and model functions, as well as changing various parameters simultaneously, is needed.

One reason for the difficulty in modeling N_2O emissions is that they are small compared to other N fluxes (e.g. plant uptake, leaching, NH_3 volatilisation). So, simulating these other N transformation processes with low error is required to accurately simulate N_2O emissions. There have been some subsequent improvements to the simulation of NH_3 volatilisation in NZ-DNDC[7], which have not been tested in these comparisons.

Conclusions

This paper presents a comparison of the two different models, APSIM and DNDC to simulate nitrogen transformation rates, including nitrification, denitrification and N_2O emissions in soils. The two models predicted showed quite different responses to environmental factors.
It should be stressed that for both models only default values for the many model parameters were used. Fine tuning of model parameter values based on measurements and improved understanding is likely to increase the prediction capability of the models, and maybe also the agreement between the two models.

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