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Assessing the sensitivity of fertilizer types and soil variables on nitrous oxide emissions in permanent grasslands using the DNDC model

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Introduction

- Robust accounting of agricultural greenhouse gases (GHGs) is a global concern.
- It is to estimate their emission factors (EFs) and identify mitigation options.
- Nitrous oxide (N$_2$O), a potent GHG, plays a key role in the climate change.
- Data on N$_2$O EFs are limited due to measurements and associated difficulties.
- The use of improved methodologies and models is essential to assess the:
  (i) long-term impact of management practices on N$_2$O fluxes and EFs,
  (ii) sensitivity of model outputs to key soil variables and management practices.

Materials & Methods

- We used a long-term grassland experiment established in 1970 at Hillsborough, Northern Ireland, UK.

  - The soil is classified as a clay loam overlying Silurian shale-greywacke (Dystric Gleysol), and poorly drained with high runoff rates.

  - This experiment has eight nutrient treatments:
    (i) Unfertilized control (NO)
    (ii) NPK @ 200 kg N (as urea), 32 kg P, 160 kg K, ha$^{-1}$ yr$^{-1}$ (NU)
    (iii) Pig slurry at low (PL=50), medium (PM=100) and high (PH=200), m$^2$ ha$^{-1}$ yr$^{-1}$
    (iv) Cattle slurry at the same three rates (CL, CM and CH, resp.), m$^3$ ha$^{-1}$ yr$^{-1}$

- Simulation of N$_2$O emissions from grassland silage plots managed for 45 years was performed using the DeNitrification-DeComposition (DNDC95) model.

- Sensitivity of the model for total N$_2$O flux and its emission factors (EFs) to soil and management variables was analyzed.

- Standard errors were calculated, and ANOVA was used for elucidating significant differences in total N$_2$O fluxes and the corresponding EFs.

Results and Discussion

- Over the 45 years, the DNDC95 simulated value for N$_2$O flux on average increased with increasing rates of applied inorganic or organic N (Fig. 1).

- The model predicted enhanced N$_2$O fluxes, probably through denitrification, by the application of C inputs coupled with N compared to inorganic N additions.

![Fig. 1. Annual total (45 years avg.) nitrous oxide (N$_2$O) fluxes (kg N ha$^{-1}$) of a permanent grassland managed with variable rates of inorganic & organic fertilizers.](image)

The DNDC performed well for urea, cattle slurry and pig slurry applied at variable rates, with EFs on-average of 0.35, 1.80 and 1.53%, respectively (Fig. 2).

![Fig. 2. Nitrous oxide (N$_2$O) emission factors (EFs, %) for a permanent grassland managed with variable rates of inorganic and organic materials.](image)

The model predicted higher N$_2$O-EFs with AS than CAN and urea fertilizers, and with urea-N at higher rates (Fig. 3).

![Fig. 3. Sensitivity of DNDC95 for N$_2$O EFs (%) of a permanent grassland to inorganic and organic N fertilizers. (NU)/AS25/AS25 CAN25 CAN25 = Similarly the 3rd split.](image)

The replacement of slurry either after the second or third silage cut by urea decreased EFs significantly.

There was a strong correlation between N$_2$O EFs and soil texture, bulk density, pH and organic carbon (R$^2$=0.96-0.99).

The resulting-EFs on-average for urea, cattle slurry, and pig slurry was 0.35±0.02, 1.74±0.17 and 1.39±0.12%, respectively.

![Table 1. Sensitivity of DNDC95 for N$_2$O emission factors (EFs, %) of a permanent grassland to various soil variables. (SE = Standard error).](image)

Conclusions

- The latest version of DNDC95 provides a good prediction of management-induced N$_2$O emissions from temperate permanent grassland and the resultant emission factors are comparable to the IPCC defaults.

- The model, although requiring more improvement, could provide an accurate representation of the effect of soils, climate and management practices on N$_2$O fluxes and subsequent estimates of disaggregated EFs.

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