The influence of liquid organic fertilization on nitrous oxide and dinitrogen emissions from agricultural soils

Reinhard Well & Balázs Grosz

- **Although incorporating liquid organic fertilizer into the soil is recommended to reduce ammonia emissions, our results showed that this increased dinitrogen (N_2) and nitrous oxide (N_2O) emissions by 170 to 800%.**
- **It is unclear how the application of liquid organic fertilizers can be optimized, as data on N_2 emissions are lacking and current models are not suitable for taking into account the spatial distribution of manure in the soil.**
- **The injection of cattle manure compared to surface application was investigated in laboratory incubations with two soils. The results showed that injection increased N_2 and N_2O emissions by 170 to 800%.**
- **We developed and calibrated a model that takes into account spatial hot spot effects in manure application and can be used to develop site-specific management recommendations.**

Background and objective

Fertilizing agricultural soils with liquid manure affects gaseous nitrogen losses such as nitrous oxide (N_2O), dinitrogen (N_2), ammonia (NH_3), and nitrogen monoxide (NO), as well as nitrate leaching. These emissions reduce nitrogen use efficiency and contribute to the greenhouse effect, ozone depletion, and water pollution. While the effects of slurry fertilization on nitrogen transformations are generally known, predicting them is difficult because many studies do not quantify N_2 flux and models do not take into account the spatial distribution of slurry components. Previous studies have shown that injecting manure reduces NH_3 emissions, but the effects of this NH_3 reduction measure on $N_2$and N_2O fluxes were unclear.

Our research questions in the MOFANE project were:

- Are anaerobic processes and N_2 and N_2O emissions enhanced by injecting manure into the soil compared to homogeneous incorporation?
- Are N_2 and N_2O emissions reduced by increased uptake of the mobile phase of manure into the soil matrix?
- Do current biogeochemical models underestimate N_2 and N_2O emissions induced by manure fertilization due to the lack of model routines for taking into account the inhomogeneous distribution of manure in the soil?
- Can this problem be solved by implementing additional compartments for manure fractions in the models?

Approach

Our project investigated how manure application and application techniques influence N_2O and N_2 flows and how models can be improved.

Our specific objectives were as follows:

- Compilation of existing data sets and development of new data sets for testing and calibrating existing and improved models.
- Investigating the effects of manure fertilization on N transformations, N_2 and N_2O emissions, and the respective control factors by varying the pH value in the soil and using different application techniques.
- Use of the project data sets to evaluate and calibrate selected biogeochemical models with regard to the influence of application technique on N_2 and N_2O emissions.
- Improvement and calibration of the model modules for nitrification and denitrification, taking into account the effects of slurry fertilization.
- Application and validation of the models with existing field data from other projects.
- Testing of strategies for reducing greenhouse gas emissions through optimized fertilization with liquid organic fertilizers using the calibrated and improved models.

The work program began with laboratory experiments to compare the effects of different manure application techniques on N_2O and N_2 emissions and to develop and test empirical and process-based models (fig. 1). In the next step, existing models were improved and calibrated to simulate the dynamic effects of manure application, the spatial distribution of manure components, and the interactions between soil, manure, and the atmosphere. Finally, the effects of manure in arable farming and possibilities for reducing greenhouse gas emissions were evaluated under realistic conditions using improved models.

Figure 1: Preparation of soil samples for ^{15}N gas flux experiments. Manure application via defined above-ground or below-ground application is carried out using the special device in the foreground (source: Balázs Grosz).

Results

In batch experiments with different slurry concentrations, kinetic parameters for nitrification and denitrification were determined for the first time. In incubation experiments with soil columns with slurry application to the surface or as an injection, N gas fluxes and the depth distribution of moisture, NO_3^-, NH_4^+, labile carbon, and pH in the soil were determined. The results showed that manure injection increases N_2 and N_2O fluxes (Fig. 2). A special hotspot submodule was integrated into the DyMaN model, which takes into account the application of manure, NH_4^+ and labile carbon. This has already achieved a good fit with the measurement data for emissions in sandy soil. Further model tests are planned as part of the second phase of the MOFANE project.

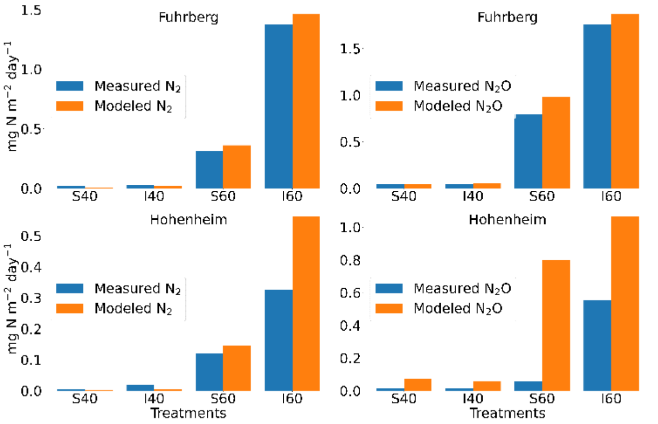

Figure 2: Average daily fluxes of measured and modeled N_2O and N_2 (in mg N per m² and day) over a 10-day laboratory incubation of sandy (Fuhrberg) and silty (Hohenheim) soils with two soil moisture contents (40% and 60% water-filled pore space) and two application techniques (surface application, S; injection, I) - (Source: modified after Grosz et al., 2022).

Conclusion

The project results will contribute to the development and evaluation of optimized application techniques for organic fertilizers. Our test results confirm previous findings on increased N_2O fluxes from manure injection and show the same for N_2 fluxes. In follow-up projects, the newly developed model will be further refined and ultimately used to investigate scenarios that combine climate, soil, and crop effects with different application modes for organic fertilizers. Specific recommendations for agricultural practice will be derived from this.

Further information

Contact

[1] Thünen Institute of Climate-Smart Agriculture

Reinhard.Well@thuenen.de

www.thuenen.de/ak

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Publications

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