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The effect of aggregates on N_2O emission from a drained peat soil

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Introduction

The temporal variabiltiy of nitrous oxide (N_2O) emissions is poorly understood. Thisis reflected in poor simulations of daily N_2O emissions.

In this research we studied the effect of soil aggregates on N_2O emissions with a mobile-immobile model concept. We hypothesized that denitrification preferably occurs inside the aggregates, while transport occurs in between the aggregates. Diffusion of N_2O out of the aggregate is hampered, leading to a **delay** in the emission. This longer storage time in the soil is expected to lead to extra N_2O reduction and therefore **lower** N_2O emissions.

The objectives of this study were 1) to determine the effect of aggregates on N_2O prodeuction, reduction and emissions; 2) to test the model performance to simulate observed fluxes; and 3) to explore the limiations of the model.

Mobile-immobile model concept

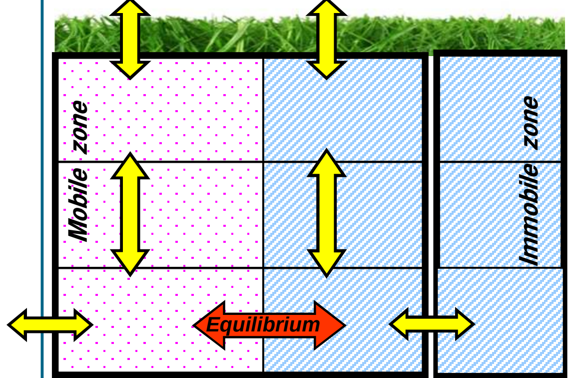
The mobile-immobile model concept was implemented for N_2O in SWAP-ANIMO. Here denitrification is located in the immobile part and all vertical transport in the mobile zone. The transfer rate R_{tr} between the mobile and immobile zone is estimated with a mass transfer coefficient, k (d^{-1}):

$$R_{tr} = k\,\theta_*\,(c_{IM} - c_{MO})$$

This equation is an approximation of diffusive transport in soil water and has often been used in mobile-immobile zone studies. For the description of the mass transfer coefficient k we follow Gerke and Genuchten (1993):

$$k = \frac{\beta}{a^2} D_{0,w}$$

Here c_{MO} and c_{IM} (kg N m^{-3} water) are the N_2O concentrations in the mobile and immobile zone, respectively, θ_* (–) is the moisture fraction of the zone with the highest concentration, β (–) is an aggregate shape factor, a (m) is the radius or half-widht of the aggregate and $D_{0,w}$ is the N_2O diffusion coefficient in free water. For a full description see Stolk et al. (2011).



Mobile zone
- Production by nitrification
- Transfer with immobile zone
- Vertical transport
- Emission
- Leaching

Immobile zone
- Production by denitrification
- Reduction
- Transfer with mobile zone

Figure 1 Mobile-immobile model concept

Site and data

Observed daily N_2O emission data were available for the site of Oukoop, a grassland site in the Netherlands used for intensive dairy farming. Fluxes were measured Augustus to November 2006 with the eddy covariance method.

Table 1 Characteristics of the Oukoop site

Soil type	clayey peat
Aggregation	Fine blocky to coarse prismatic
Ground water level (cm)	0-70
Fertilizer and manure (kg N ha^{-1})	353
Annual N_2O emission (kg N_2O-N ha^{-1})	17.8 ± 58%

Simulation results

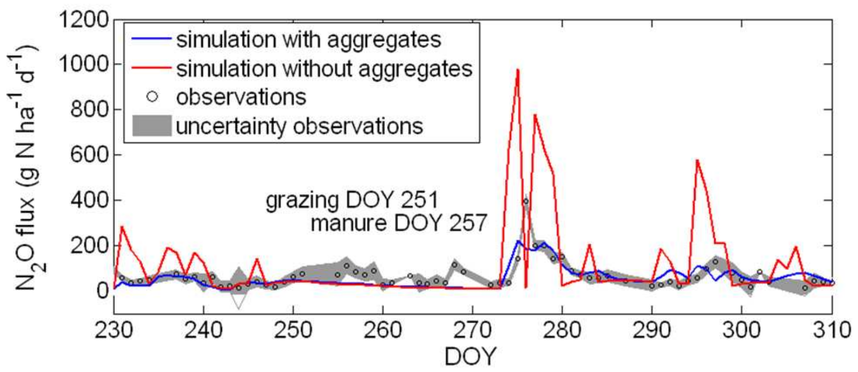


Figure 2 Comparison of simulated and observed N_2O fluxes

The results of this study showed that aggregates strongly affect N_2O emissions: peak emissions are lower, background emissions are slightly higher. The simulated annual emissions decreased more than 40 %. The model performance to simulate observed N_2O fluxes strongly improved.

Table 1 Model performance to simulate observed emissions.

Statistic	*Model with aggregates*	*Model without aggregates*
r^2	0.42	0.11
Model efficiency	0.30	< 0
RMSE	40	198
RMSE/ standard dev.	0.83	4.09
CRM [1]	0.03	1.18

[1] CRM = coefficient of residual mass : $\left(\sum \text{observed} - \sum \text{simulated}\right) / \sum \text{observed}$

Analysis

Aggregates mainly influence the reduction during denitrification events ('hot moments'). Larger aggregates generate in more reduction and lower emissions.

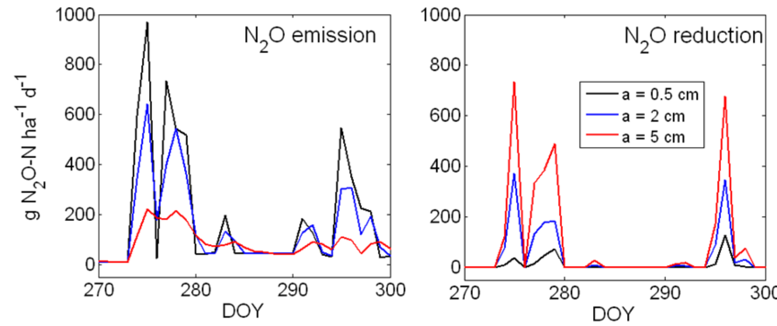


Figure 3 Effect of aggregate radius a (cm) on N_2O emission and reduction

A decrease of the hydraulic conductivity in the top soil and subsequent more anaerobic conditions have inconsistent effects on the N_2O emisisons. If there is enough nitrate to meet the potential electron production, this leads to higher emissions (DOY 283 and 291). If not, N_2O reduction is stimulated at the expense of N_2O production, leading to lower emissions (DOY 275, 278, and 296).

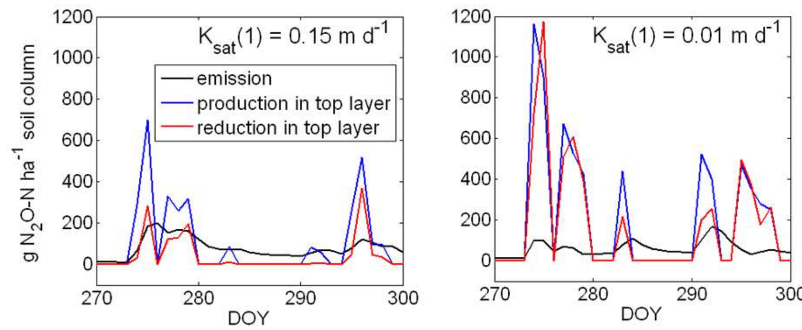


Figure 3 Effect of hydraulic conductivity of the top soil, $K_{sat}(1)$ on N_2O production, reduction and emission .

Conclusion

Aggregated soils have lower emisssions than non-aggregated soils. This is mainly caused by extra reduction inside the aggregates. This effect is stronger for larger aggregates.

With an aggregate model we are able to simulate the dynamics of daily N2O fluxes from drained and fertilized peatland very well.

The effect of the changing aeration status on the N_2:N_2O ratio is dependent on the NO_3 content. It is expected that in NO_3 poor soils the effect of aggregates on the NO_3 concentration affects N_2O emissions and should be taken into account.

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Stolk et al., Biogeosc. Disc., 8:3253-3287, 2011.