Responses of direct N2O emissions from agricultural mineral soils on natural conditions and management – a multi site analyses across Europe

Institut für Agrarrelevante Klimaforschung

Rene Dechow, Annettte Freibauer

Key results

- Nitrous oxide emissions of cropland soils and grassland soils exhibited distinct emission patterns
- On cropland soils significant amounts of N2O emit during autumn to spring and freeze thaw induced emission peaks highly impact the annual N2O budget. Increasing the N use efficiency over the year would be the most promising way to mitigate N2O emissions on cropland soils.
- In contrast, on grassland N2O emission peaks in response to precipitation events and fertilisation dominated annual N2O emissions. Magnitude of emission peaks on combined effects of fertilizer application and precipitation. Managing nitrification and denitrification in the growing period could be sufficient to minimize annual N2O emissions on grasslands.

Rationale

- Last decades efforts in measuring direct annual and seasonal N2O emissions on plot scale built up datasets covering wide ranges of environmental conditions and management options providing a
- Statistical and hybrid approaches (fuzzy inference scheme) were used to infer responses of direct annual and seasonal N2O emissions on natural and anthropogenic drivers from multi site measurements.

The data set

- Time series of measured N_2O emissions cover used to train the model originates from measurement campaigns across central and western Europe
- The cropland data set comprises 49 time series on 12 sites (4900 data points)
- The grassland data set consists of 47 time series on 20 measurement sites (5000 data points)
- Method to measure N_2O: closed chamber
- Additionally, meteorological data (precipitation, temperature, radiation), soil physical properties (texture, ph, soil organic carbon content [SOC], N_{tot}) and information on management were available (fertilisation, cropping)

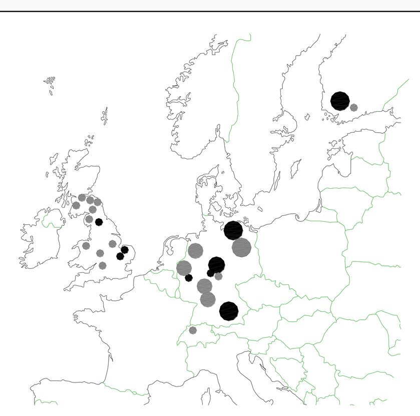


Fig.1:Position of observed nitrous oxide measurements; grey: grassland; black: cropland

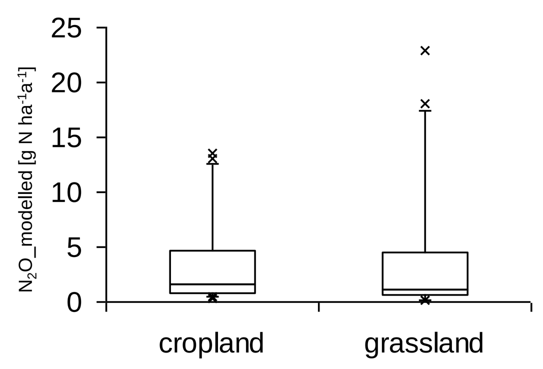
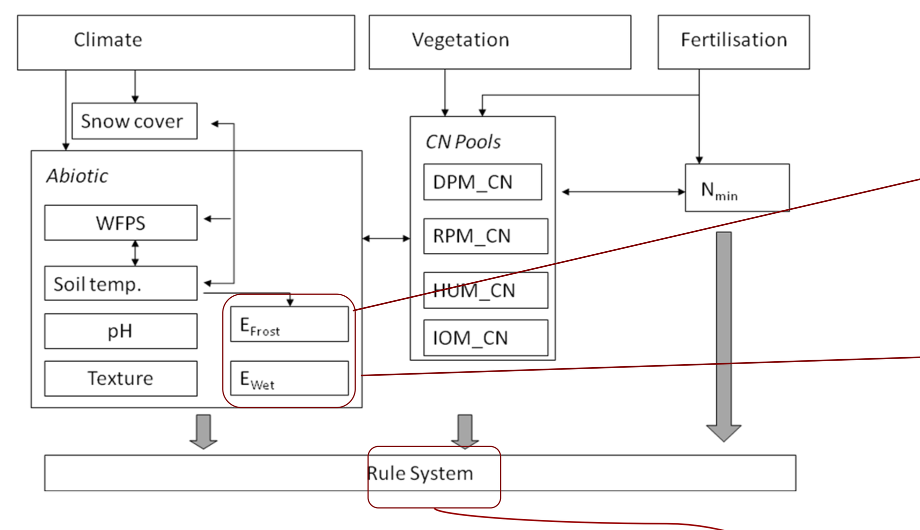


Fig.2: Box plot of annual N_2O emissions

The model

1. Model structure

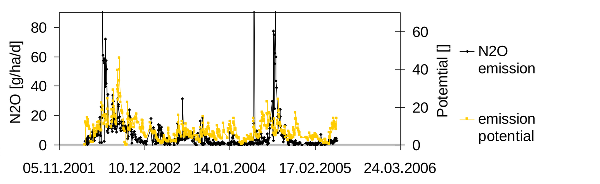


2. Emission forcing potentials

Precipitation

$$E_{wet} = \sum_{i=1}^{30} P_{30-i} / (30 - i)^{const}$$

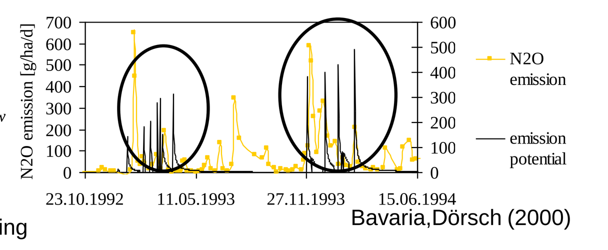
P_i precipitation on previous day i



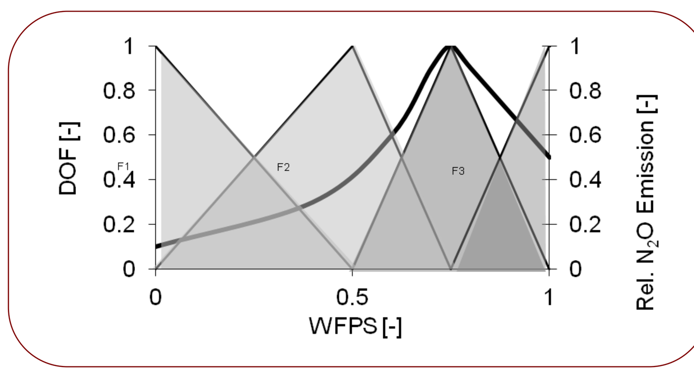
Frost-Thaw Cycles

$$E_{frost-thaw} = \overline{|T(d_{frost})|} / d_{thaw}$$

d_{frost} lenght of frost periode
d_{thaw} time after frostperiode
T soil temperature during freezing



3. The empirical approach MODE



- Daily N_2O emissions are simulated by an ensemble of restricted fuzzy decision trees (MODE).
- Potential drivers of MODE come from observations (texture, pH), assumptions (emission forcing potentials) and simple process based approaches (WFPS: water filled pore space, soil temperature, N_{min}).
- MODE is trained on N2O emission data (multi-site).
- Emission forcing potentials are based on observed N_2O time series and represent the influence of soil rewetting and freeze-thaw in dependence on the temporal distance to those system disturbances (system memory).

Responses

Cropland

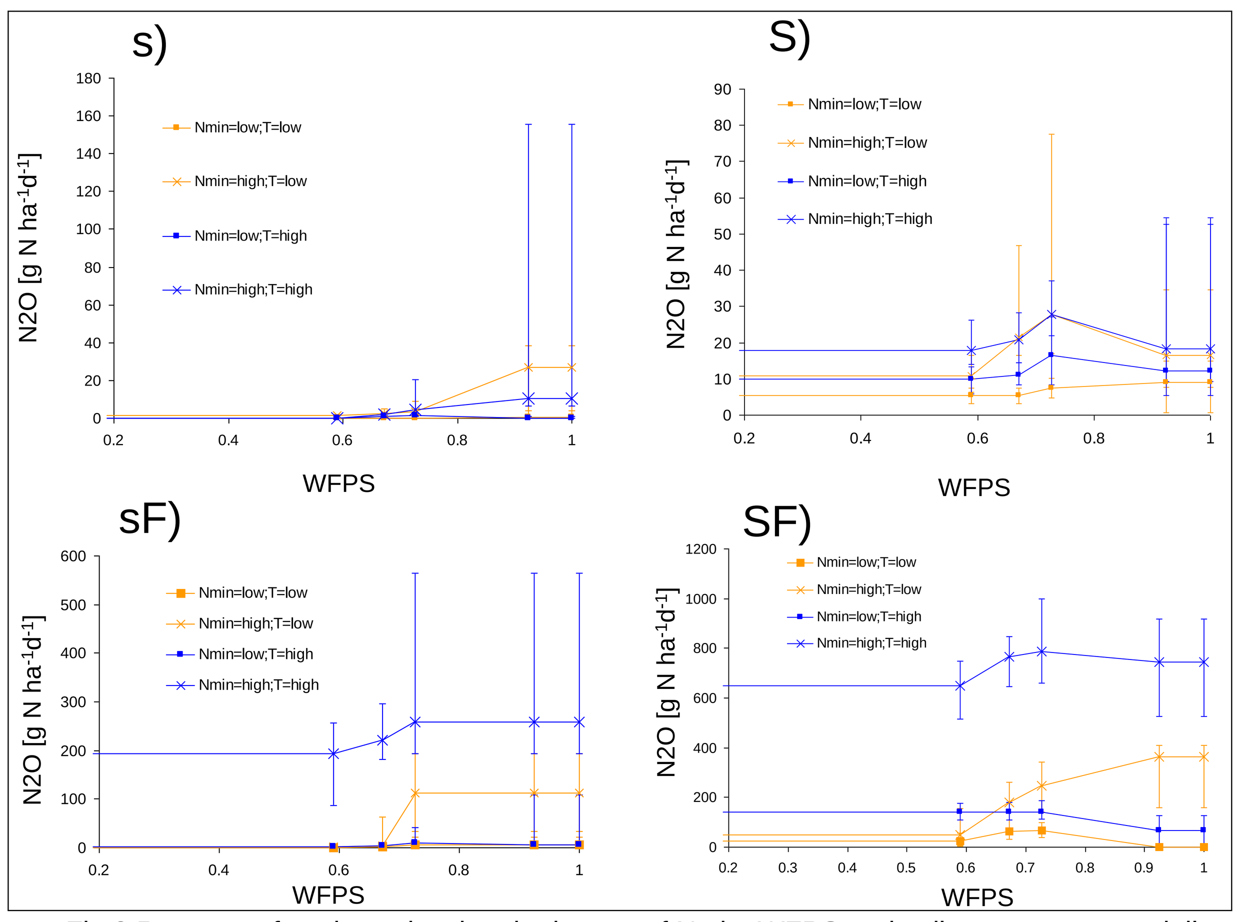


Fig.3:Response functions showing the impact of Nmin, WFPS and soil temperature on daily N_2O emissions; s) low SOC (0.8%); S) high SOC (2.1%); sF) and SF) predicted occurrence of freeze thaw (E_{Frost}); error bars: 25% and 75% quantile of all ensemble members

- Out of the pool of potential drivers WFPS, soil temperature, SOC, N_{min} and E_{Frost} (emission forcing potential to account for freeze-thaw cycles) were selected by a forward search.
- The derived N_2O response functions for cropland soils give raise to the assumptions that:

1) Soils with low SOC are more sensitive to Oxygen availability controlled by soil water content
2) Freeze-thaw induced N2O emission peaks react sensitive on available N sources. Managing the N ressources that are available during freeze-thaw will reduce annual N_2O emissions significantly

Grassland

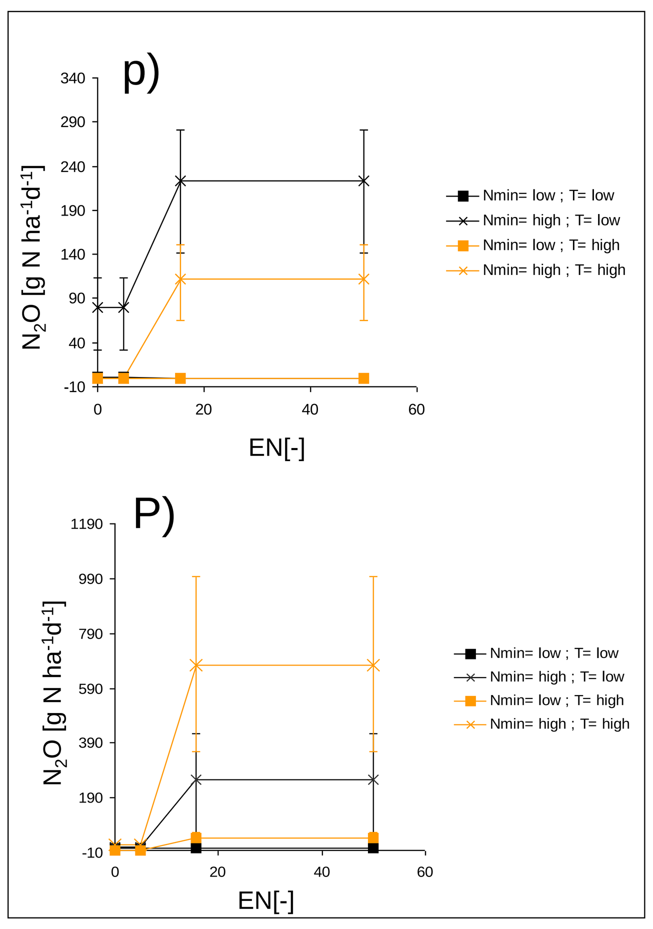


Fig.4: Response of N_2O emissions to Nmin, E_{wet} and soil temperature; p) low precipitation sum in summer P) high precipitation amout in summer; error bars: 25% and 75% quantile of all ensemble members

- Precipitation intensity (E_{wet}), available N, soil temperature and the climatic zone (represented by longterm precipitation sum in summer) were the factors found to best describe N_2O emission dynamics on grasslands
- The impact of freeze thaw induced emissions on annual N2O budgets is low compared to cropland soils
- Contrary to croplands, the coincidence of fertilisation and precipitation causess N_2O emission peaks with significant influence on annual budgets.
- The Consideration of the climatic zone in the model approach significantly improves the model fit.

Model results

- The model approach was validated via crossvalidation (leaving one site out while calibrating the model on the remaining data).
- It is possible to approximate the general emission pattern on daily scale. The formulated emission forcing potentials help to identify sensitive time windows. With successive temporal aggregation the model fit increases.
- The model approach could serve as a method that goes beyond recent annual N_2O models and also considers seasonality in management and N_2O fluxes in large scale estimations.

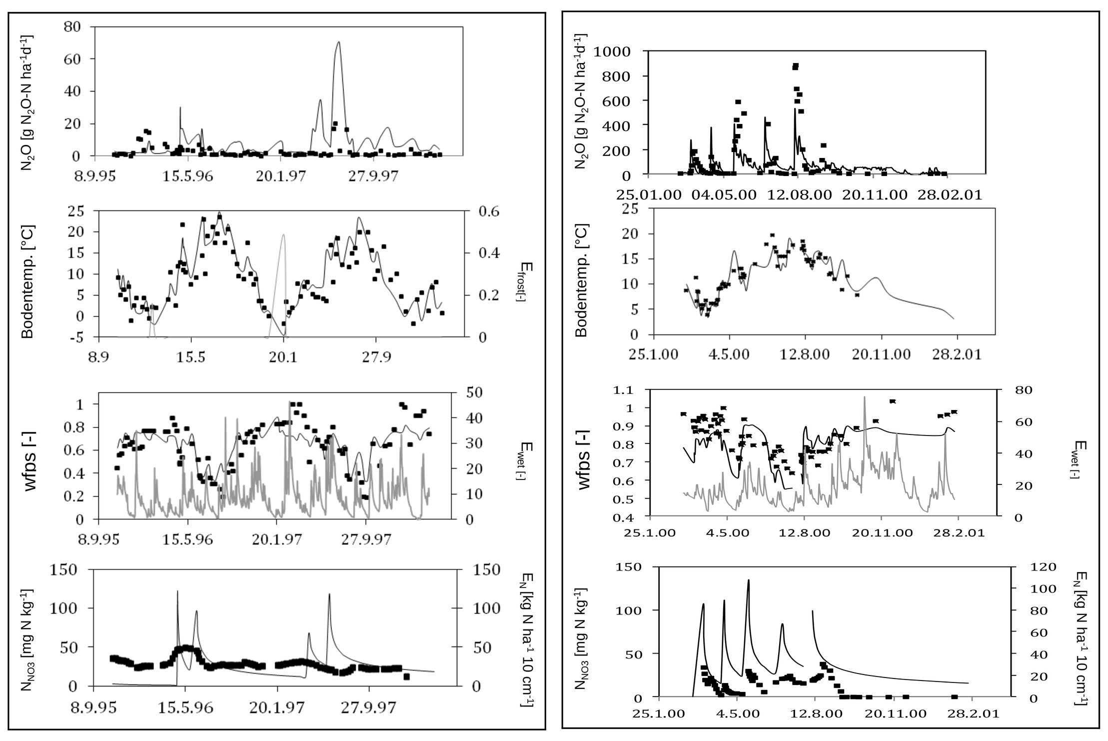


Fig.5:Time series of calculated and measured nitrous oxide emissions, wfps, soil temperature and emission forcing potentials (grey lines and right ordinate); a) Bavaria, cropland (Dörsch, 1999) b) Aberystwyth, grassland (Dobbie et al., 2003)

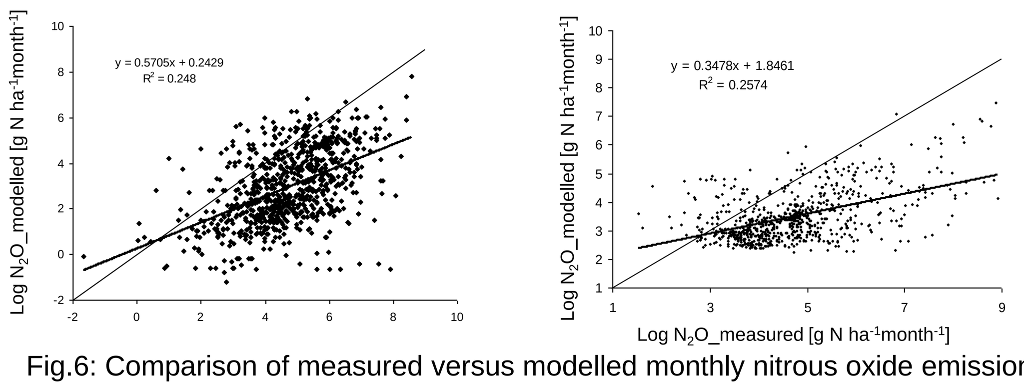


Fig.6: Comparison of measured versus modelled monthly nitrous oxide emissions

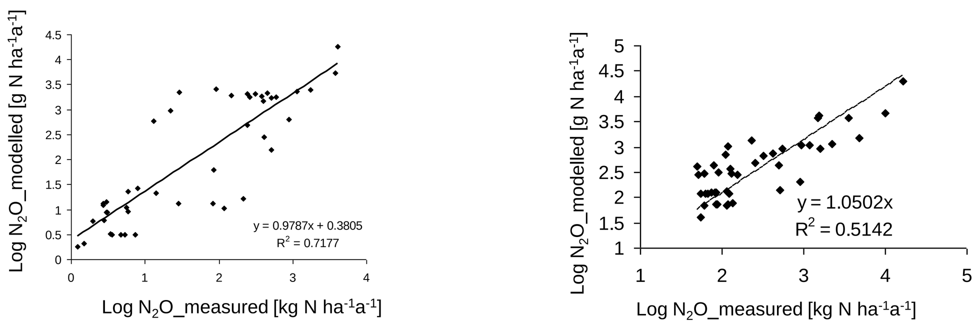


Fig.7: Comparison of measured versus modelled annual nitrous oxide emissions

Rene Dechow, vTI Institute of agricultural climate research,Tel.:+49.3641.576148, rene.dechow@vti.bund.de

Annette Freibauer, vTI Institute of agricultural climate research,Tel, Tel.: +49.3641.576164, annette.freibauer@vti.bund.de