Project *brief*

2022/40a

Thünen Institute of Climate-Smart Agriculture

Measuring and modelling greenhouse gas emissions and nitrate leaching of raw material crop rotations (MASTER)

Konstantin Aiteew[1], Rene Dechow[1], Roland Fuß[1]

- **Mitigation measures to reduce nitrous oxide emissions in raw material crop rotations can affect soil carbon stocks. Under certain conditions nitrous oxide reduction can be compensated by decreasing soil carbon stocks. This relation is not yet investigated in detail.**
- **In this project, 2 field experiments were conducted to investigate the effect of raw material crop rotations and mitigation measures on nitrous oxide emission and soil carbon sequestration**
- **The biogeochemical model MONICA was calibrated and validated using the data from these and other experiments**
- **Scenarios with the calibrated model provide information on the effects of management measures, site conditions and climate scenarios on nitrous oxide emissions and soil carbon changes for the soil climate regions of Germany**

Background and Objectives

The sustainable production of energy and raw material crops is gaining in importance, globally and nationally. The use of biomass for energy purposes helps to save fossil energy sources and can thus contribute substantially to climate protection. Energy efficiency and GHG abatement performance of feedstock crops can vary greatly depending on the cropping system and site conditions. Meaningful climate assessments of these systems must capture all greenhouse gas (GHG) emissions involved. This includes direct and indirect nitrous oxide (N_2O) emissions during cultivation and carbon dioxide (CO_2) fluxes due to long-term changes in soil carbon stocks under different crop rotations.

The MASTER project investigated the GHG balance of different crop rotations of commodity crops and examined the efficiency of different GHG mitigation measures on direct and indirect nitrous oxide emissions and carbon dioxide emissions from soil carbon stock changes. The influence of site factors, crop rotation systems and climate warming was considered in the analysis.

Methods

The project used three long-term trials, two in Viehhausen (Bavaria) and one in Trossin (Saxony), in which commodity crops were grown in different crop rotations. On these trial plots, the TU Munich and the Landesamt für Umwelt, Landwirtschaft und Geologie of Saxony carried out measurements of greenhouse gas fluxes for different crop rotations typical for the location. The gas samples were analysed at the Thünen Institute. Since the trials existed for several years (duration 6 to 13 years), changes in soil carbon stocks caused by crop rotation effects and fertilization variants (digestate application versus mineral fertilization) could be quantified.

In combination with data from long term monitoring sites in Lower Saxony and an extensive collection of data from field experiments on land use-related direct nitrous oxide emissions from the FNR-funded project THG EMOBA, the experimental data from the project were used to calibrate the process-based model MONICA and thus enable it to represent the observed biomass development of the cultivated crop species, carbon dynamics and direct nitrous oxide emissions.

As part of the model calibration and evaluation, an attempt was made to identify a set of global parameters that would be valid for all sites and variants.

The calibrated model was used to investigate the effects of GHG mitigation options for soil-climate regions of Germany using different climate scenarios (RCP 2.6, RCP 4.5, RCP 8.5) for the period 2020 - 2050. The soil climate regions of Germany were represented by randomly selected sites of the German Agricultural Soil Inventory (GASI). The modelled crop rotation systems corresponded to the crop rotation systems of the Viehhausen system trial.

The simulated time horizon is chosen to ensure a final equilibrium setting of soil carbon sequestration and mineralization. As far as possible, the influence of different intensities of individual mitigation measures on CO_2 fluxes and direct and indirect N_2O emissions is evaluated.

Results

The MONICA model was able to simulate all investigated factors and locations. Depending on the variables studied and the site conditions, MONICA achieved inconsistent model performance. MONICA achieved good to very good performance in reproducing soil carbon changes, soil temperature and soil water. Furthermore, yields were mostly well reproduced after calibration. Weaknesses were seen in the reproduction of nitrogen dynamics. Optimization of the N_2O sub-modul significantly improved the simulation of annual fluxes. MONICA achieved overall better reproduction quality than conventional GHG accounting methods. Thus, the calibrated model, was suitable as a forecasting tool for simulating agricultural field-based GHG emissions under changing weather conditions.

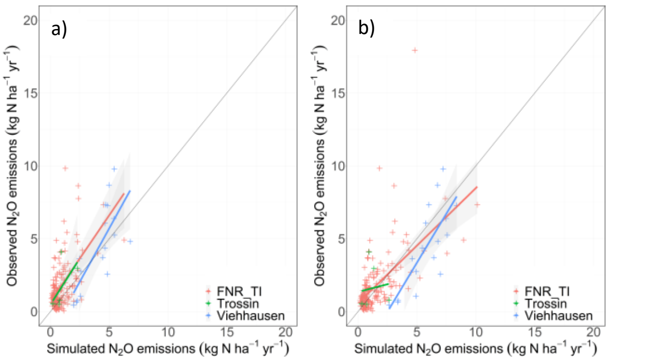

Fig.1: Comparison between measured and modelled annual N2O-fluxes for (a) the default and (b) the calibrated model version.

The examination of the model scenarios showed clear differences between the cultivation methods considered and minor differences between the climate scenarios. The reduction of mineral N fertilization and the cultivation and incorporation of alfalfa-clover grass mixtures proved to be particularly productive methods for improving the GHG balance on arable land. Here, reducing fertilization reduced direct and nitrate leaching induced N_2O emissions while increasing CO_2 losses from humus decomposition. Green manuring increased carbon sequestration.

Evaluation of the model calculations shows, that averaged across GASI sites, a reduction in organic or mineral fertilizer applications reduced N_2O emissions, but at the same time increased CO_2 emissions due to humus depletion (or reduced sequestration). This was approximately 0.1 t CO_2eq ha^{-1} a^{-1} per ton of nitrous oxide emissions saved (in CO_2eq) for mineral and 0.4 t CO_2eq ha^{-1} a^{-1} for digestate applications.

The spatial distribution of GHG potentials showed that the highest mitigation potentials can be achieved in central and southern Germany. This is due to the fact that higher nitrous oxide emissions were simulated in these parts of the country than in the northern German lowlands. In comparison with humus changes, a stronger influence of N_2O emissions on the GHG balance was found. The potential of direct GHG emissions is strongly influenced by weather conditions and soil properties. Decisive site factors for the emission potential were water capacity, temperature, pH, and initial soil carbon content.

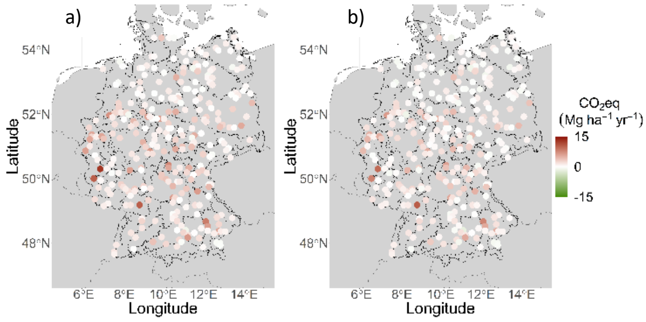

Fig. 2: Spatial distribution of annual agricultural GHG emissions from CO_2 fluxes and direct and N leaching-related N_2O emissions for Germany, for the years 2020 to 2050 under RCP8.5. (a) cash crop/ conventional and b) cash crop/ organic

The effect of the climate scenarios on the GHG balance was not always clear. There was a tendency for humus depletion to increase with climate warming (RCP2.6, RCP4.5, RCP8.5) while direct nitrous oxide emissions decreased.

Conclusion

In order to assess the suitability of mitigation measures for land-use related GHG emissions, all emission pathways need to be considered in the accounting depending on site conditions. Although further development is needed, biogeochemical models are promising tools to ensure an integrative assessment of GHG mitigation measures.

Further Information

Contact

[1] Thünen-Institut für Agrarklimaschutz
rene.dechow@thuenen.de
www.thuenen.de/ak

Duration

03/2019 – 6/2022

Project-ID

2076

Publication

None so far

DOI:10.3220/PB1668506133000