Project *brief*

Thünen Institute of Climate-Smart Agriculture

2021/28a

Mitigating Agricultural Greenhouse Gas Emissions by improved pH management of soils; MAGGE-pH

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- **Direct nitrous oxide emissions might be mitigated by an optimized pH management in agricultural soils. The project MAGGE pH investigated potentials and trade-offs of a greenhouse gas optimized pH regulation at agricultural soils by lab experiments and modelling.**
- **Liming effects and pH effects on fluxes of CO_2, N_2O and N_2 from agricultural soils were investigated by lab incubations and lysimeter experiments. Results indicate that soil-pH controls the $N_2O/(N_2O+N_2)$ product ratio. Thus, soils with elevated pH emitted less nitrous oxide emissions.**
- **The analyses of a meta data set showed also less nitrous oxide emissions for field sites with higher soil pH supporting the findings of the lab experiments.**
- **In Germany, about 41% of arable land and 52% of grasslands are characterized by soil pH below recommended intervals. Thus, there is potential to reduce nitrous oxide emissions by just implementing recommended liming practise.**
- **On the other side, CO_2 emissions due to liming with carbonates which are estimated with emission factor approaches counteract reduced nitrous oxide emissions partly.**

Background and aims

The project MAGGE-pH examined the effect of soil pH on the relationship between nitrous oxide production and consumption assuming that an increase of pH would support the transformation of the potent greenhouse gas nitrous oxide to climate-neutral atmospheric nitrogen in soil. Thus, nitrous oxide emissions could be mitigated by pH regulation.
In MAGGE-pH, combined laboratory studies, field experiments and model simulations were applied to approximate the mitigation potential in North and Central Europe and New Zealand.

Approaches

The Thünen Institute participated with two work packages. One package analysed the effects of soil pH on N_2O production and consumption pathways and the sensitivity of these enzyme mediated reactions on soil environmental conditions by mesocosm and lysimeter experiments. In particular we were interested in pH effects on

- nitrous oxide emissions,
- the ratio between nitrous oxide production and consumption,
- mineralisation,
- carbon dioxide losses due to mineralisation and liming.

The other package developed and evaluated process models and empirical approaches to consider pH effects that have been observed in lab and field experiments. We were interested in long-term effects of soil pH on greenhouse gas emissions and related sensitivities on natural conditions.
After preparing the necessary data we quantified mitigation potentials that would be achievable by a climate smart pH regulation on national scale.

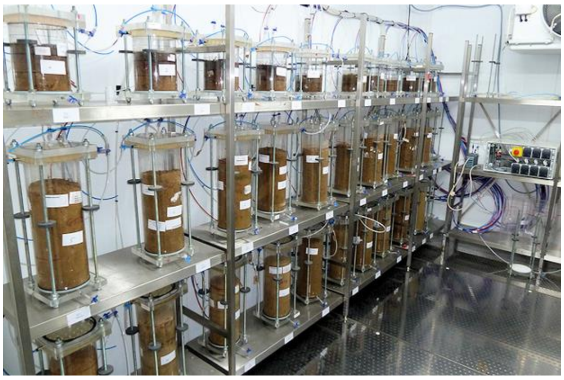

Fig.1: Automated soil mesocosm incubation system for continuous monitoring of gaseous fluxes at Thuenen Institute, Braunschweig (© Thünen-Institut/Patrick Wordell-Dietrich)

Key findings

The mesocosm experiments showed that soil pH affects the N_2O/N_2 product ratio considerably. Thus, nitrous oxide emissions produced by denitrification processes are lower at high pH levels.

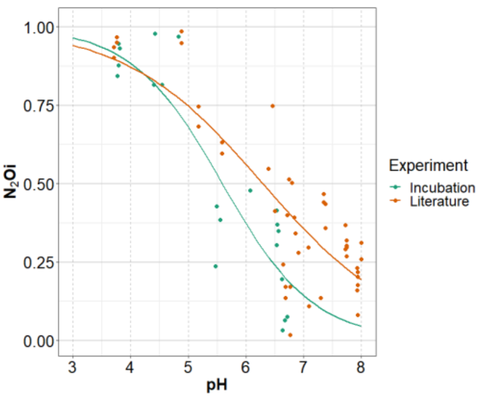

Fig. 2: $N_2O/(N_2+N_2O)$ product ratio (N_2Oi) in relation to soil pH. Results for experiments at our test soils and other published data for anoxic incubation experiments in the soil.

Instantaneous limed soils show elevated CO_2 emissions but it is yet unclear to which extent CO_2 originates from liming products or elevated decomposition processes, respectively.

The analyses of published meta data sets about N_2O emissions for field experiments showed that nitrous oxide emissions are generally lower for soils with elevated pH values. This supports the observations of the mesocosm experiments. The effect depends on soil properties like the clay content and the soil organic carbon content and on natural conditions like the mean annual precipitation.

In Germany, about 41 % of arable land and 52% of grassland have soil-pH values below recommended levels corresponding to good agricultural practise. Thus, there is a potential of mitigating direct nitrous oxide emissions by increasing the pH level of those sites up to recommended levels

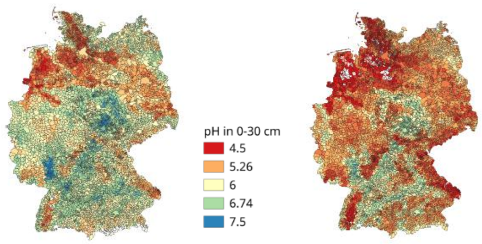

Fig.3: Distribution of soil pH in the top soil (0-30cm) of agricultural areas in Germany spatially aggregated to community levels with (A) cropland and (B) grassland

The efficiency of greenhouse gas mitigation by pH increase depends strongly on CO_2 emissions caused by additional liming. A wide range of emission factors to quantify CO_2 emissions from applying carbonates have been published.

We quantified the greenhouse gas mitigation potential for two scenarios. Scenario 1 assumes a pH increase until the lower boundary of the optimal pH range. Scenario 2 assumes a pH increase up to the higher boundary of recommended pH levels. Calculations were done for the sites of the German agricultural soil inventory.

Scenarios 1 and 2 caused pH increases and therefore N_2O mitigation for about 45% and 77% of agricultural sites, respectively. On average, nitrous oxide emissions were reduced by about 6% in scenario 1 and 14% for scenario 2. Assuming emission factors for CO_2 emissions from lime applications by IPCC and West and McBride, we find a greenhouse gas decrease by pH regulation for 10.7 – 12.2 % of sites for scenario 1. For scenario 2 the share of sites with greenhouse gas mitigation by pH increase adds up to 13 till 17.3%.

The application of the biogeochemical model DNDC-CAN using data of the mesocosm experiments has shown that former implemented effects do not describe observed N_2 and N_2O fluxes and the product ratio in dependence on pH satisfactory. Modifications of implemented functions and calibration helped to improve the description of observed N_2O $(N_2O+N_2)^{-1}$ product ratios by the model.

Conclusions

The project results indicate that an adequate pH management can reduce direct N_2O oxide emissions from agricultural soils. Whether this reduction is compensated or overcompensated by CO_2 fluxes from liming needs to be investigated.

Further Information

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Duration

11/2017 – 3/2021

Project-ID

1916

Publication

None so far

Funding

Bundesanstalt für Landwirtschaft und Ernährung

DOI:10.3220/PB1635773027000