BOKU UNIVERSITY


C. Foldal


E. Haas


M. Kittinger

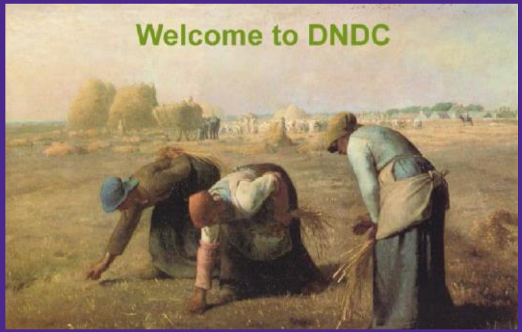
Policy measures effectively reduce soil nitrous oxide emissions with minor trade-offs in crop yield

Sophie Zechmeister-Boltenstern[1],
Cecilie Birgitte Foldal[1], Martina Kittinger[1] & Edwin Haas[2]

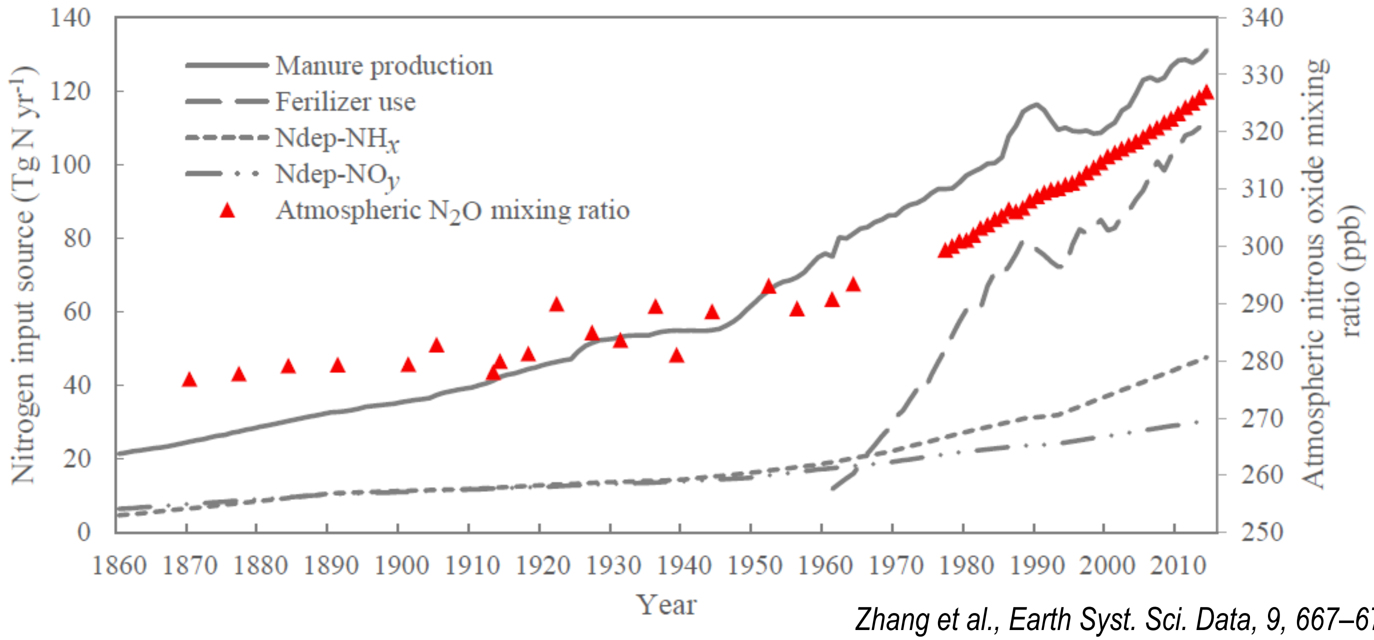
[1]University of Natural Resources and Life Sciences, Vienna, Austria

[2]Institute of Meteorology and Climate Research (IMK-IFU), Garmisch-Partenkirchen, Germany

Science for a [cooler future]



Why is N_2O so important?



Zhang et al., Earth Syst. Sci. Data, 9, 667–678, 2017

N_2O has the strongest radiative forcing of all greenhouse gases.

N_2O comes mainly from soils and its increase is related to N fertilizer use.

The Good News: Theoretically, according to the GHG inventories, anthropogenic soil N_2O emissions in the European Union have decreased by 17% since the 1990s (EEA, 2022). ☺

European Green Deal: Farm to Fork Strategy

The excess of nutrients in the environment is a major source of air, soil and water pollution, negatively impacting biodiversity and climate. The Commission will act to:

✓ **reduce nutrient losses by at least 50%**, while ensuring no deterioration on soil fertility.

✓ **reduce fertilizer use by at least 20%** by 2030.

Organic farming is an environmentally-friendly practice that needs to be further developed.

The European Commission will boost the development of EU organic farming area with the aim to achieve **25% of total farmland under organic farming by 2030**.

(Austria: already 27 %)

Research Questions

As part of the European Agricultural Funds for Rural Development (EAFRD), Austria introduced an agri-environmental program (ÖPUL) to enhance organic farming and, as part of the implementation of the Nitrate Directive (EC, 1991), incentives to reduce N fertilisation rates in 1992. These objectives remain central to the current Austrian EAFRD funds, effective from January 2023.

Organic farms have higher SOC, which could promote higher N_2O emissions

Therefore we wanted to know

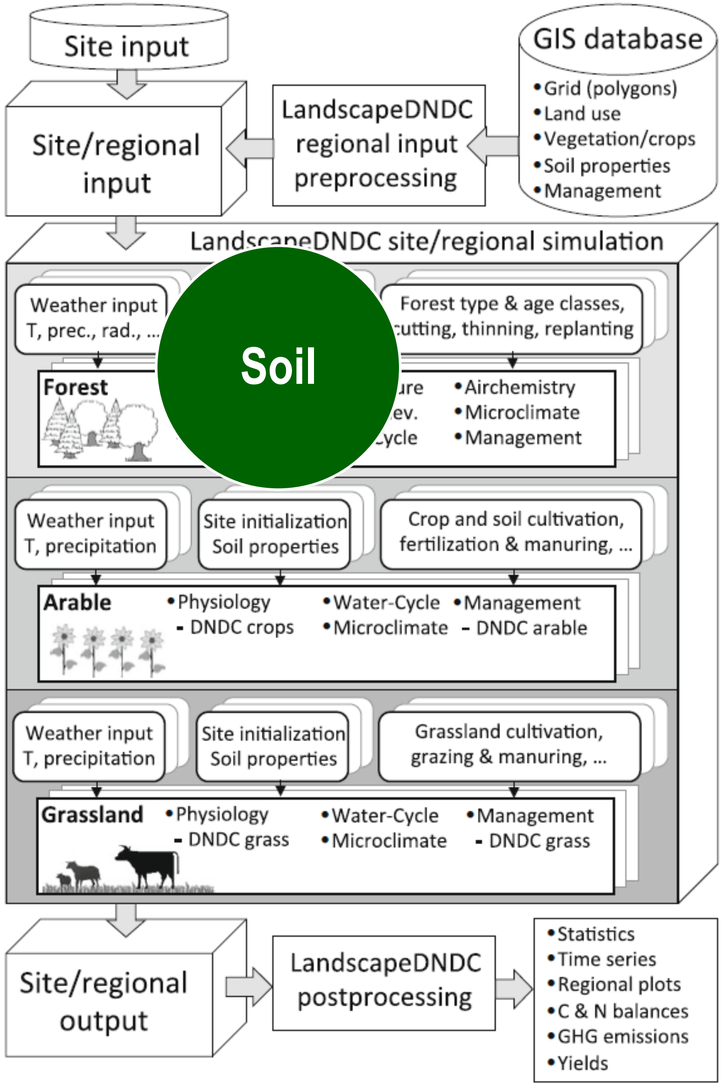
Do reduced N fertilisation and organic farming,

1) have a positive effect on soil N_2O mitigation?
2) have a negative effect on yields?
3) have a negative effect on soil N stocks and hence soil fertility?

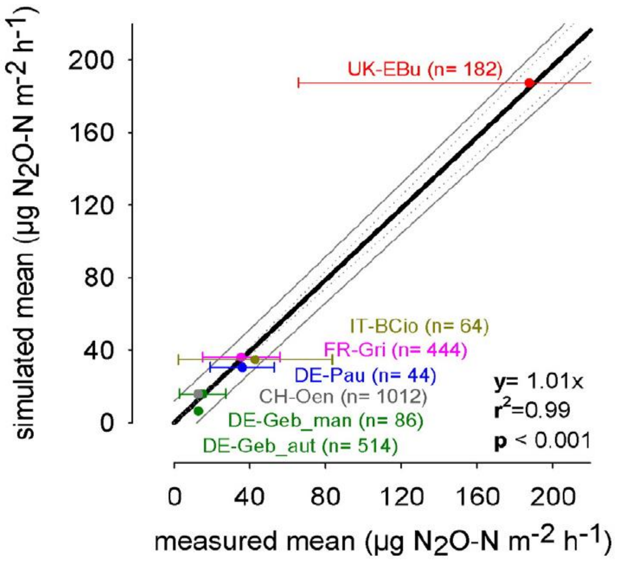
Landscape scale DeNitrification-DeComposition model

Modeling can refine national greenhouse gas inventories and detect hotspots of N losses.

Climate



Crops



Molina-Herrera et al., STOTEN 2016

Dataflux of LandscapeDNDC for site/regional input: 80 Parameters modelled

Haas, Klatt, Fröhlich, Kraft, Werner, Kiese, Grote, Breuer, Butterbach-Bahl, Landscape Ecol (2013) 28: 615-636.

Material and Methods

Grieskirchen

Oststeirisches
Huegelland

Marchfeld

Fertilization:
Cmax
-15%
-25%

organic

5 soil types

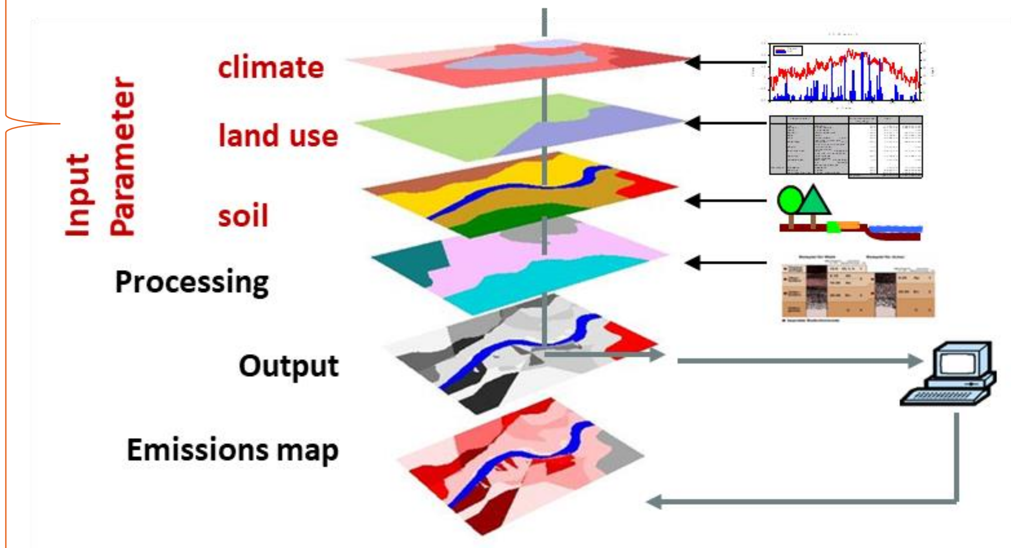
4 soil types

3 soil types

climate and management modelled in daily steps for 10 years

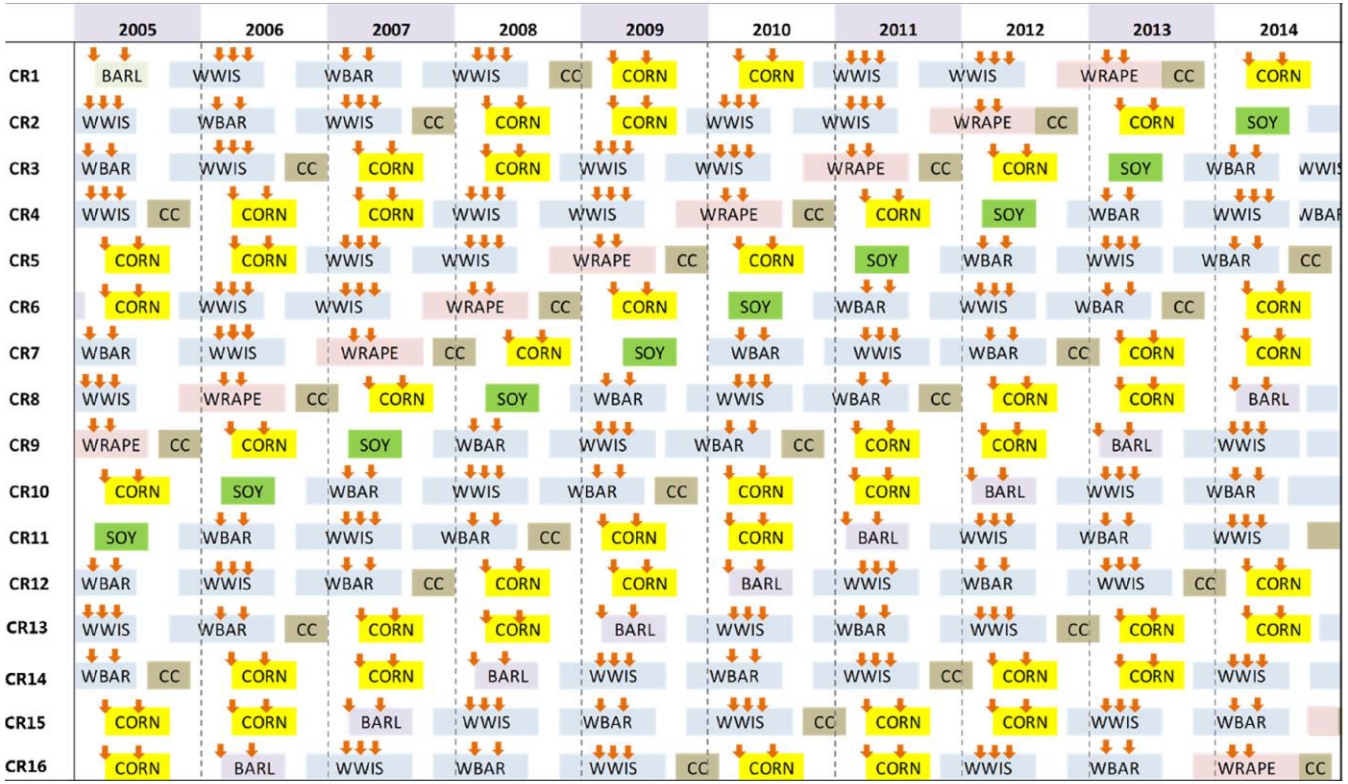
We modelled
15611 simulation years;
More than 5.7 mio days

Model LandscapeDNDC



E. Haas et al., 2013

Conventional crop rotation setup in Grieskirchen

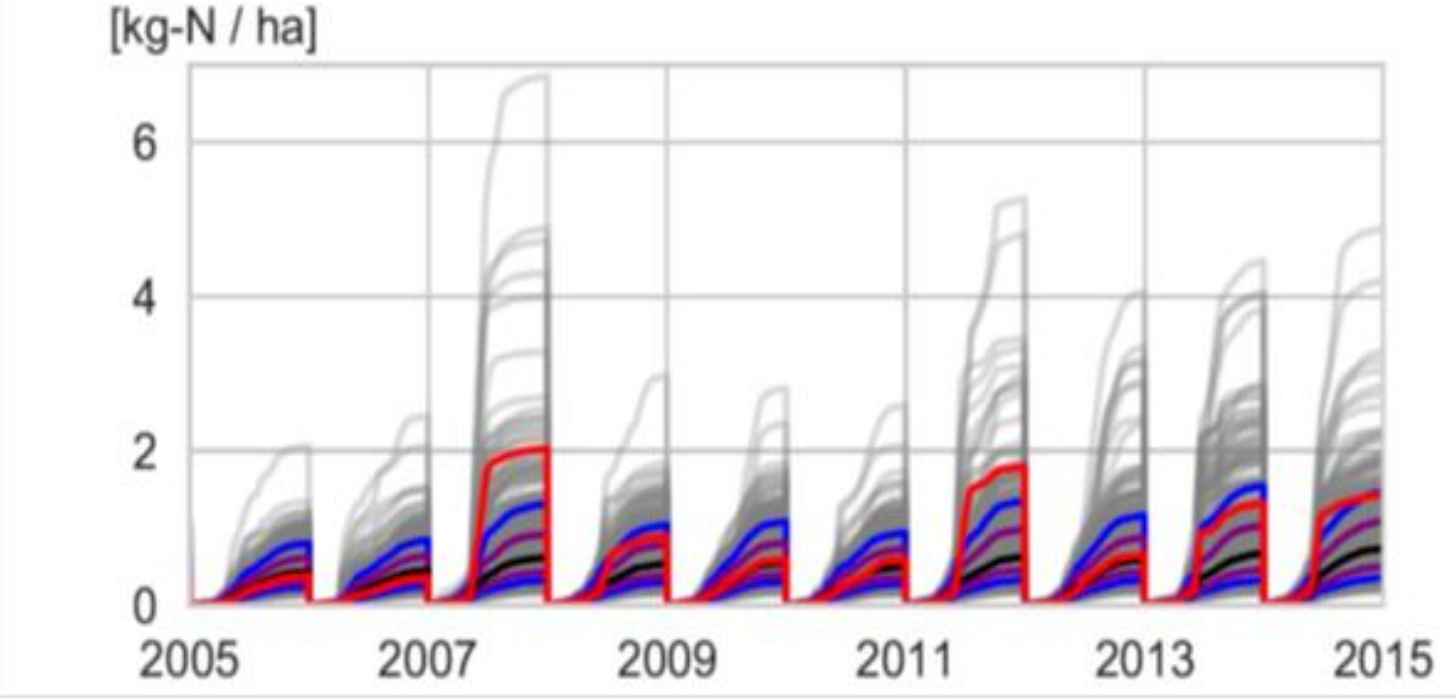


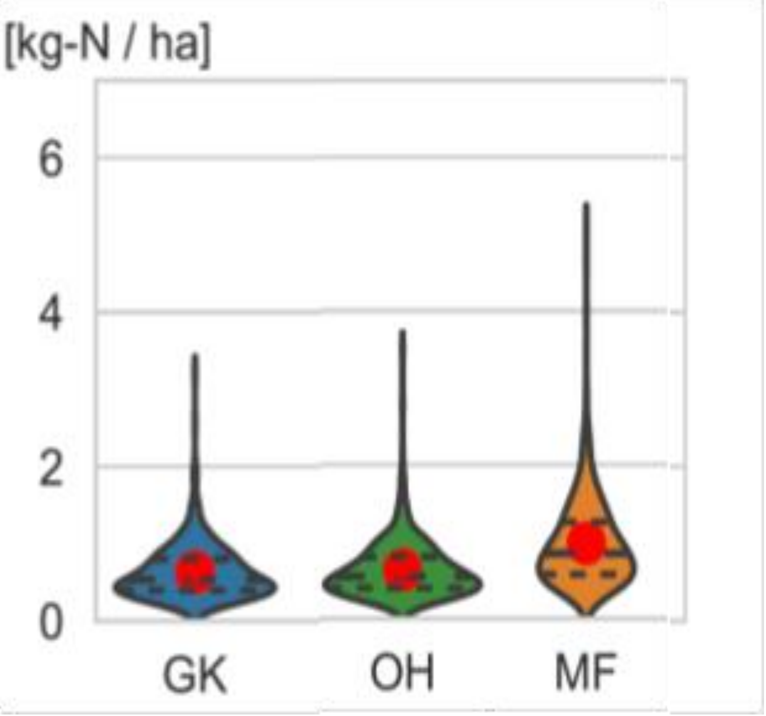
BARL = summer barley; CORN = corn; WWIS =winter wheat; WBAR= winter barley; WRAPE= winter rape; SOY = soy beans; CC = catch crops (mustard);

16 – 35 crop rotations were modelled per region for each year and each soil type. Individual management steps (e.g. tillage, seeding, fertilizer application, etc. of all crops) were compared with daily weather data and adjusted within a timespan (+/-1-14 days) given by regional farm advisors.

Uncertainty Analysis

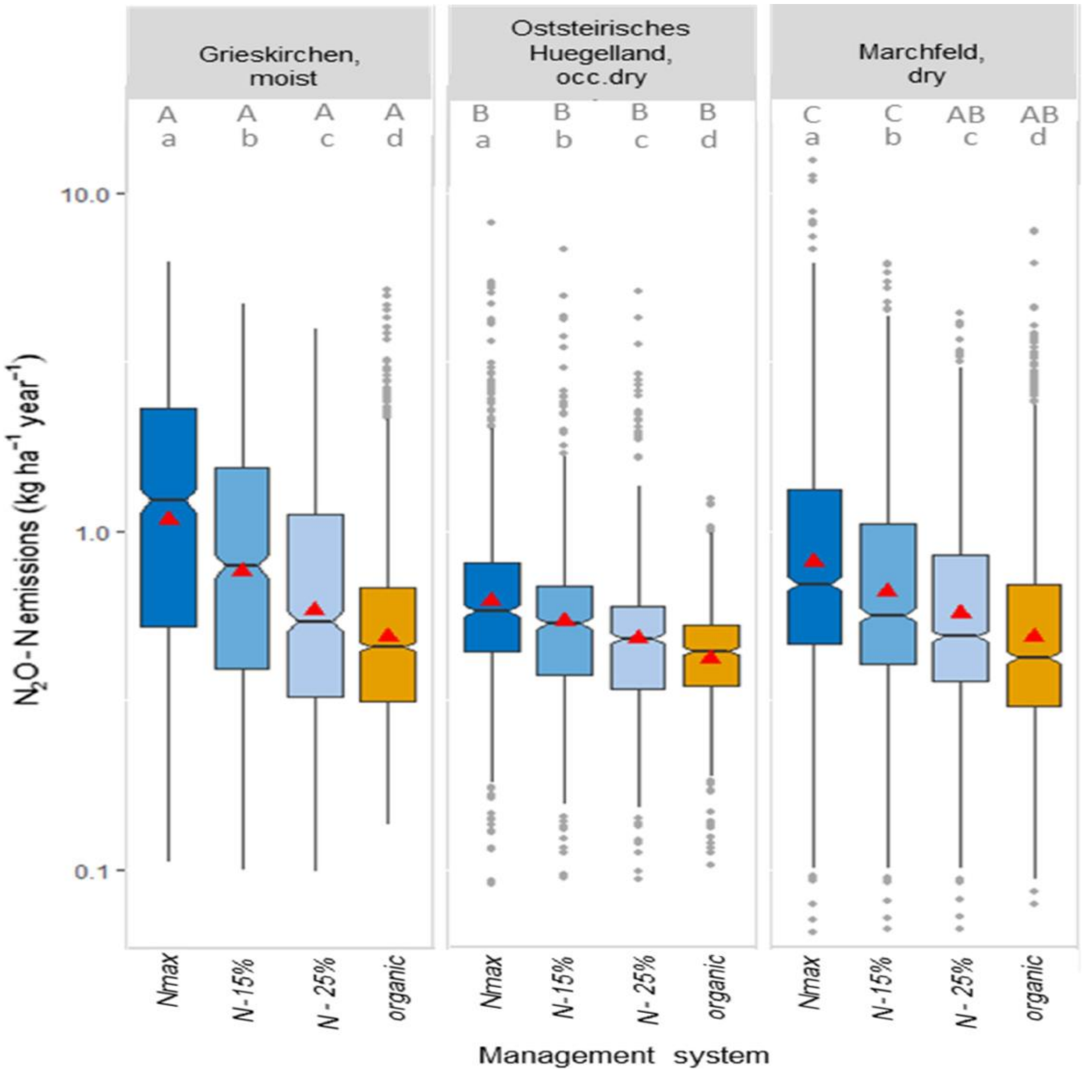
Illustration of the temporal dynamics of cumulative sums of soil N_2O emissions for the site in Grieskirchen; red line: mean of N_{max} baseline simulation, grey lines: realization of the 500 parameter samples, **black line: median**, blue lines: quantile ranges Q25 – Q75, purple lines: quantiles Q10 – Q90 of the 500 simulation results.





Overall result distribution of annual N_2O emissions for Grieskirchen (GK), Oststeirisches Huegelland (OH) and Marchfeld (MF)

Uncertainty range -30.8% to +50.8% shows that our modelled data are robust (more than IPCC EF: uncertainty -66% to +200%)



N_2O reduction potential

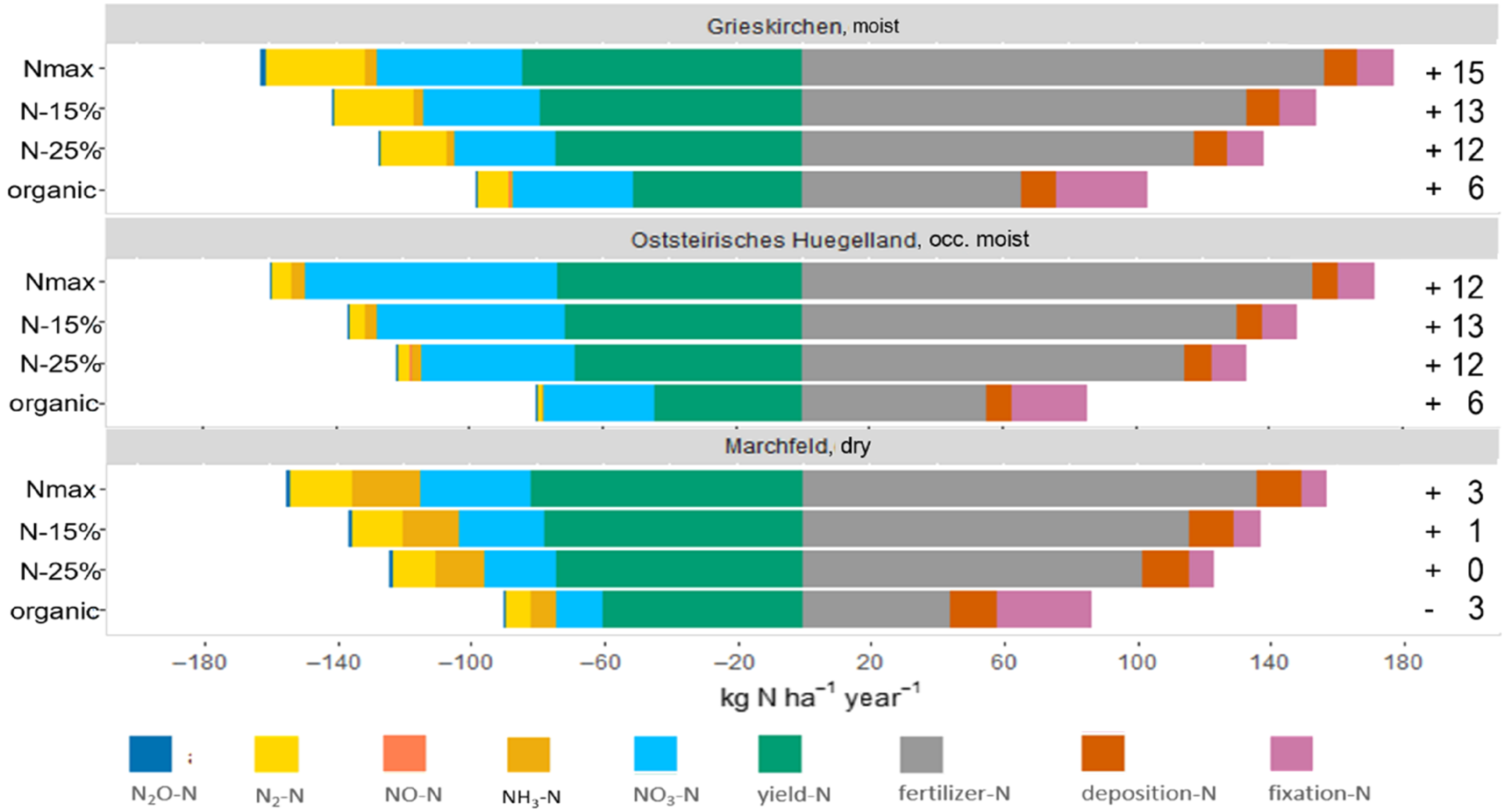
Reducing nitrogen fertilisation by 15% reduced N_2O emissions by, on average **22%.**

Reducing nitrogen fertilisation by 25% reduced N_2O emissions by **39%.**

Organic farming reduced emissions by **60%**.

N_2O emission reduction potential was the greatest in regions and crops (corn, vegetables) with the highest emissions.

N-budgets with different agri-environmental measures



Yields are only slightly reduced by fertilizer reduction.
Reducing nitrogen fertilisation by 15% and 25% the yield was reduced by 5% and 9%, respectively.

In the organic cropping system yield was declined on average by 23%.

The overall N-budgets are positive: Soil fertility is retained.

In organic systems, the nitrogen use efficiency was best: >67% of N output was found in crop yields and little N was lost.

Do reduced N fertilisation and organic farming

1. have a positive effect on soil N_2O mitigation?
2. negatively affect yields?
3. negatively affect soil N stocks /soil fertility?

1. **Yes:** A 25% reduction in N-fertilization resulted in a 39% reduction of N_2O emissions.
2. **Slightly:** A 39% reduction of N_2O emissions, was accompanied with a **9% reduction in yield.**
3. **No: N-balances were still positive**: only for organic farming in pure cropland regions it can become critical in the long-term.

BOKU UNIVERSITY

KIT Karlsruher Institut für Technologie

KIT-Campus Alpin
IMK-IFU: Atmosphärische Umweltforschung

EJP SOIL

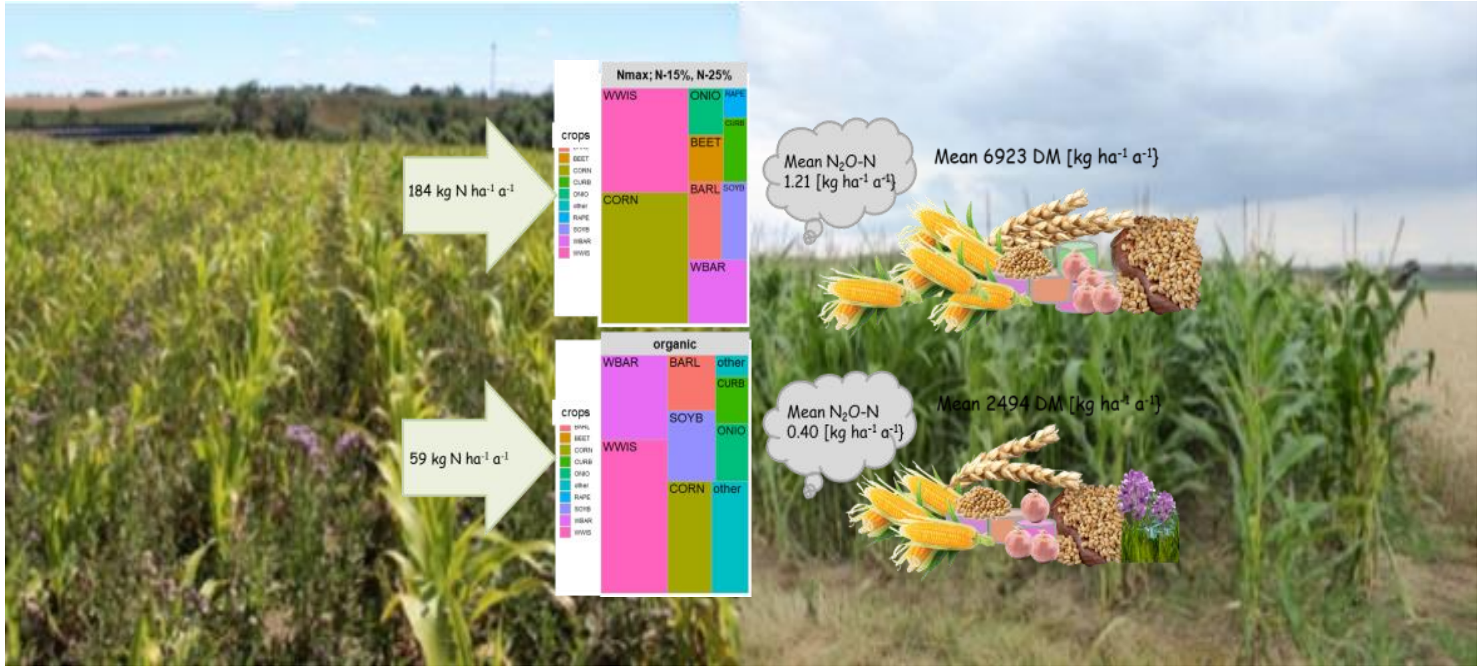
Received: 30 October 2023 | Revised: 31 January 2024 | Accepted: 1 March 2024
DOI: 10.1111/ejss.13475

European Journal of Soil Science WILEY

RESEARCH ARTICLE

Policy measures effectively reduce soil nitrous oxide emissions with minor trade-offs in crop yield

Cecilie Birgitte Foldal[1,2] | Martina Kittinger[1] | Edwin Haas[3] | Sophie Zechmeister-Boltenstern[1]



Thank you for your attention!