Leibniz Centre for
Agricultural Landscape Research
(ZALF)

Landscape Functioning

Data Analysis & Simulation

Prediction model for N_2O emissions related to fertilization and rain events over a 3-year period

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2Go HERMES

Introduction

Agriculture relies on nitrogen (N) based fertilizers for productivity, but excesses often lead to pollution, such as increases in N_2O emissions. Finding management options to minimize N_2O emissions faces the financial and physical limitations inherent in measuring N_2O at high spatial and temporal resolutions. Crop models, as tools for predicting productivity and simulating water and N processes in plants and soils, can be an appropriate tool for estimating N cycle-mediated emissions. Therefore, crop models can be used in combination with field measurements to monitor N_2O emissions.

Materials and methods

- High measurement frequency (N_2O, soil and biomass)
- Climate data (rain, air and soil temperature and humidity).
- Model HERMES: Process-based model simulating crop growth, water and N dynamics (Kersebaum et al., 2019).

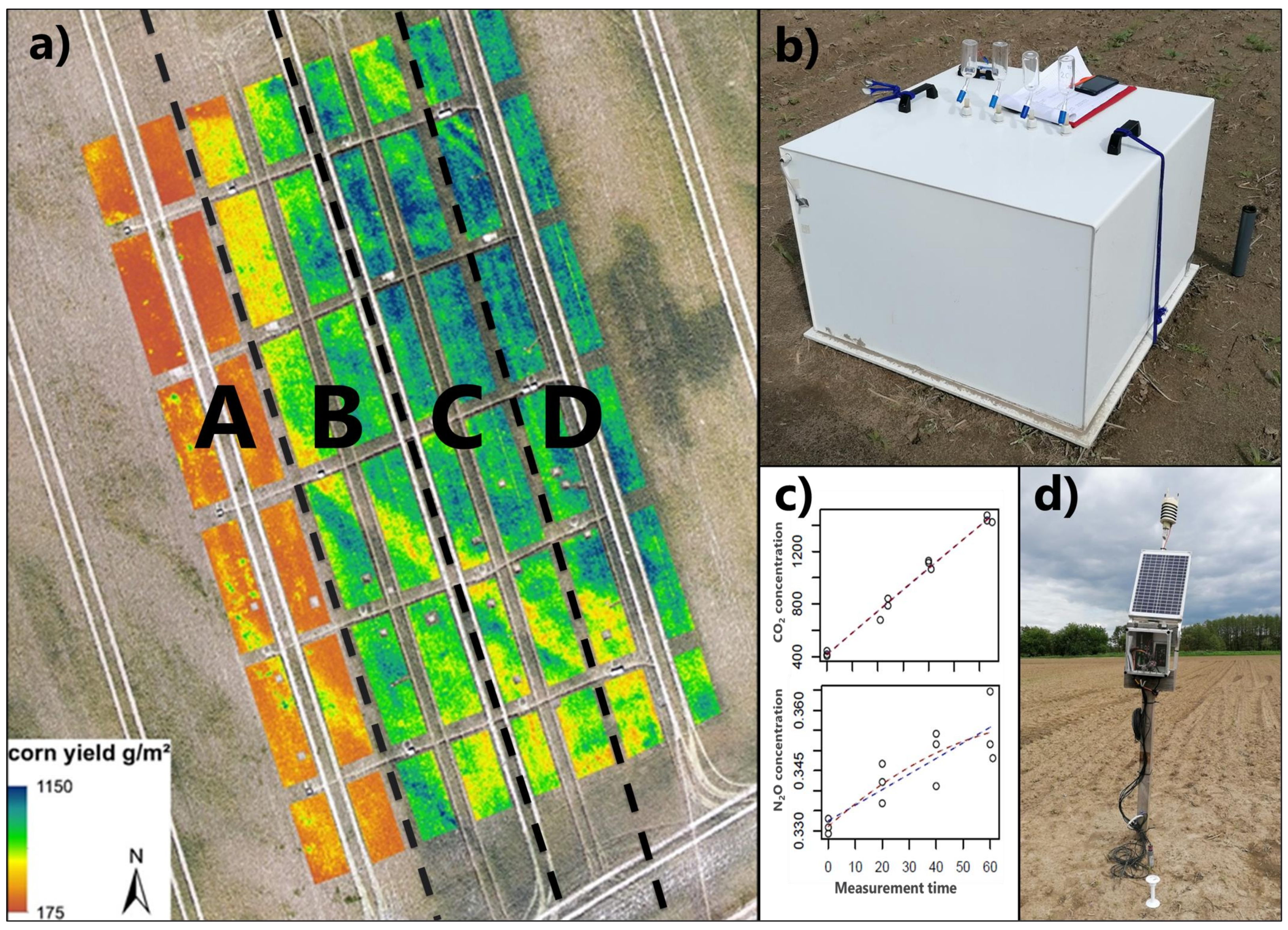

Fig. 1: Experimental site in Naugarten (53°18N, 13°40E), Uckermark, Germany. a) Aerial UAV imaging for small-scale spatial (yield) heterogeneity within the field trial. Treatments: A) AS-HS+UI+NI*, B) AS-HS+UI, C) AS-HS, and D) Control; b) opaque N_2O measurement chamber (V: 0.2925 m³), non-flow-through non-steady-state chamber system (Livingston and Hutchinson 1995); c) CO_2 and N_2O concentration increases, flux calculation, and quality control via CO_2 concentration increases; d) in-situ climate station.

Model calibration and evaluation

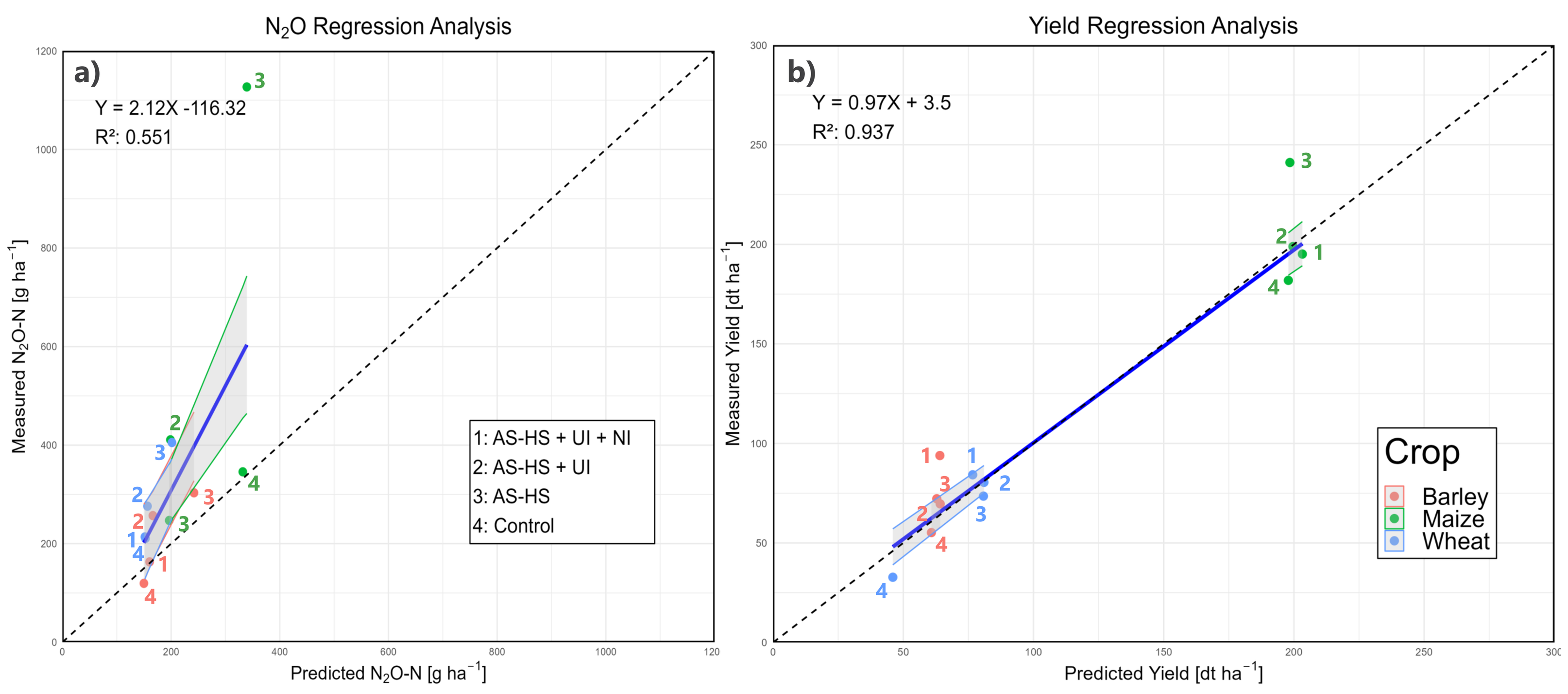

Fig. 2: 1:1 agreement between (a) N_2O-N total emissions [g ha^{-1}] and (b) measured and modelled yield [dt ha^{-1}]. The dashed line indicates the 1:1 agreement. The solid line (blue) indicates the regression through the data points. The confidence interval is given as shaded areas.

*AS-HS: Ammonium sulfate urea ; UI: Urease inhibitor; NI: Nitrification inhibitor

Results

- Measured and predicted N_2O values showed consistent dynamics, although peak heights and intensities differed.
- Predicted N_2O values were highly dependent on rain events, while measured N_2O was also influenced by N fertilization events (Fig. 3).
- HERMES tended to underestimate total N_2O-N losses compared to measured N_2O (Fig. 2a).
- HERMES accurately estimated yields when compared to measured yields (Fig. 2b).

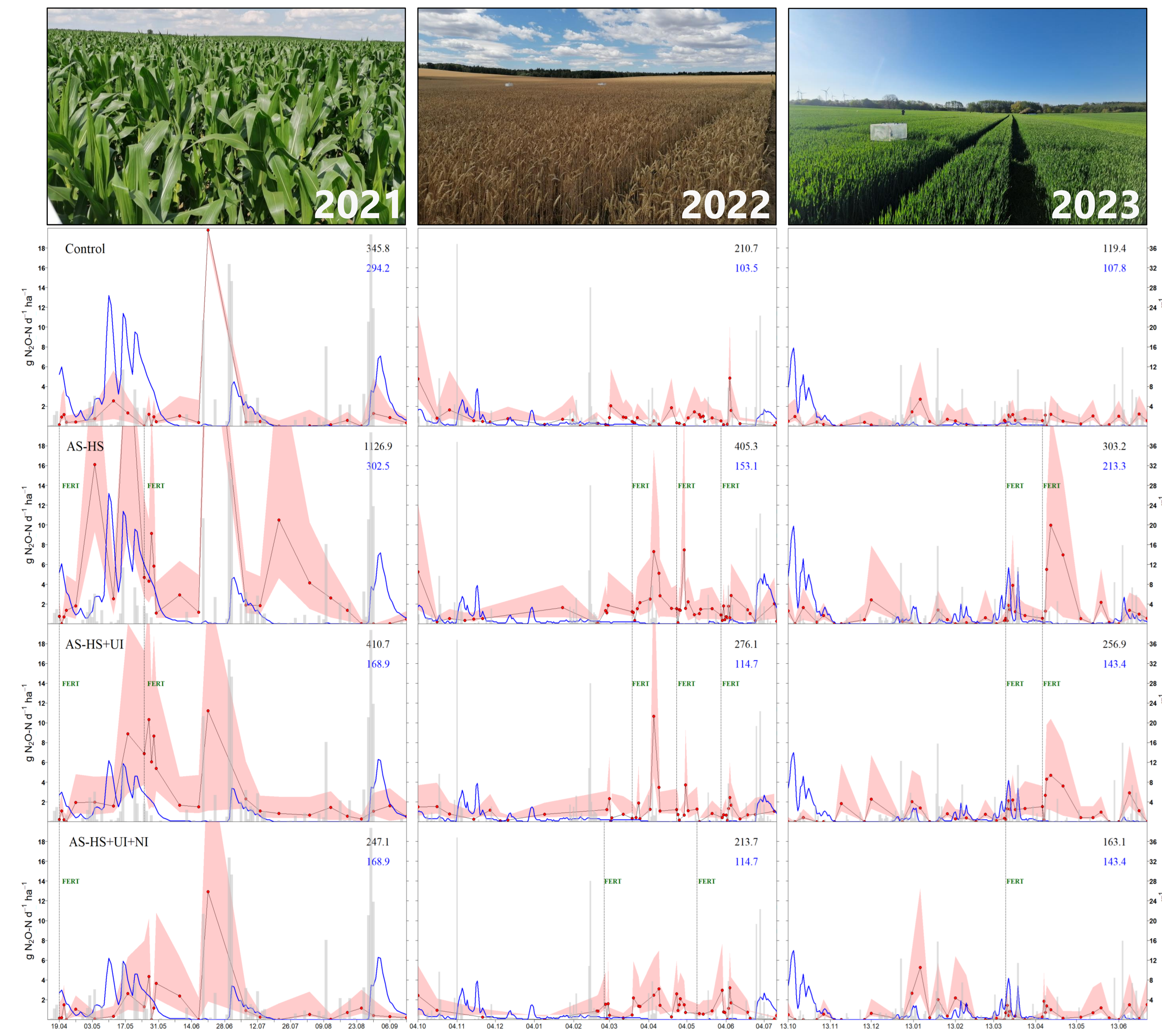

Fig. 3: Temporal N losses dynamics. Measured N_2O-N (dots) and interpolated N_2O fluxes with a confidence interval (red), predicted N_2O temporal dynamic (blue), and cumulative daily rain in mm (grey bars). Vertical dotted lines represent fertilization events in the treatments. Cumulative measured (black) and predicted (blue) N_2O-N values (g N_2O-N ha^{-1} crop^{-1}).

Model limitation and challenges

- Cumulative N_2O-N modelled losses tended to underestimate the emissions compared to field measurements.
- Despite inaccuracies in the simulations, models like HERMES seem to have the necessary structure to simulate all major components of the nitrogen cycle in cultivated fields. However, adjustments to the sensitivity of the model to climate and N inputs need to be made to improve its performance.

References

- Kersebaum et. al. (2019). Modeling Cropping Systems with HERMES–Model Capability, Deficits and Data Requirements. In Bridging Among Disciplines by Synthesizing Soil and Plant Processes. https://doi.org/10.2134/advagricsystmodel8.2017.0005
- Livingston, G.P; Hutchinson, G.L (1995): Enclosure-based measurement of trace gas exchange: applications and sources of error. With assistance of Blackwell Science Ltd. Matson, P.A. and Harris, R.C. Oxford, UK: Biogenic trace gases: measuring emissions from soil and water.

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