Coupling a process-based soil-crop model and life cycle assessment to reduce GHG emissions of crop rotations

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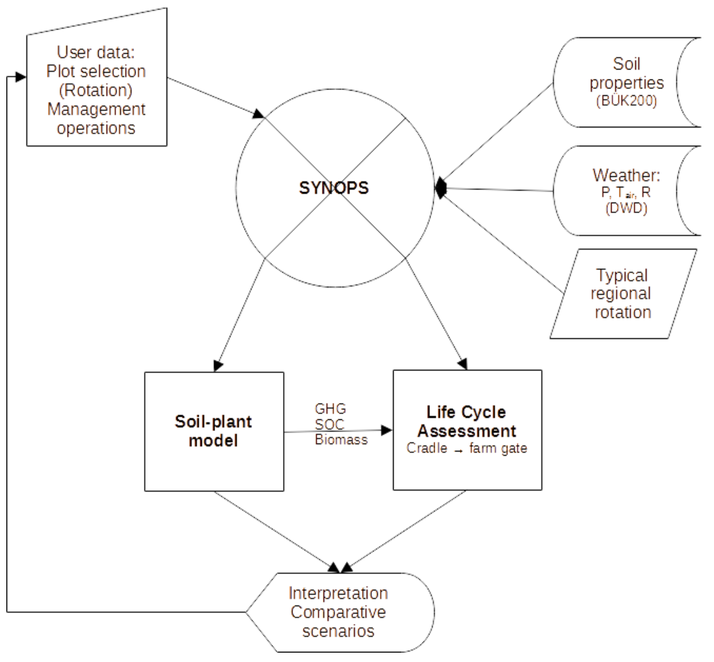
Rationale

- Agriculture is a significant source of greenhouse gases (GHG), e.g. 7.7% of total CO_2 and 74.5% of N_2O in Germany in 2023 (UBA).
- Improved rotations can improve the GHG balance of cropping systems a) sequestering CO_2 in soil organic matter (SOM); b) replacing mineral fertiliser (the main contributor to N_2O emissions in conventional agriculture) with N_2 fixed by legumes; c) capturing excess N after main crops, reducing the risk of leaching and indirect N_2O emissions.
- Farmers are hesitant to implement new crop rotations without evidence of beneficial effects on yields and climate.
- Process-based models can simulate nutrient cycles, plant growth and GHG emissions considering site-specific conditions.
- Life cycle assessment (LCA) with dynamic data from simulations can deliver more accurate GHG flux estimations than static emission factors.
- Scenario analysis using the coupled modelling-LCA approach helps identifying environmentally and economically promising crop rotations.

Objectives of the *KlimaFFolgen* project

Develop a coupled model-LCA interface combining

- a user friendly web application for practitioners to explore crop rotations on selected plots;
- a scientific tool for regional assessment of trends including projections under different climate scenarios (RCPs).

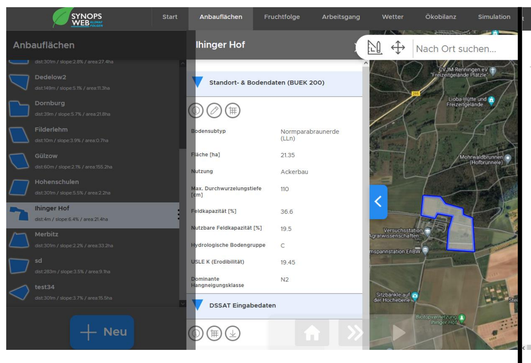


Materials and Methods

- Decision support tool: SYNOPS-KlimaFFolgen based on https://synops.julius-kuehn.de
- Soil data (horizon-specific, 1:200,000): BÜK 200 data base (BGR)
- Daily weather observations & projections (T_{air}, rain, solar radiation; 1970-2099; 1km^2 grid): German Weather Service (DWD)
- Models: DSSAT 4.8.2 for plant growth and soils, including DayCENT for SOM dynamics
- LCA: Cradle to farm gate, entire crop rotation.

Results: Prototype of the *KlimaFFolgen* decision support tool

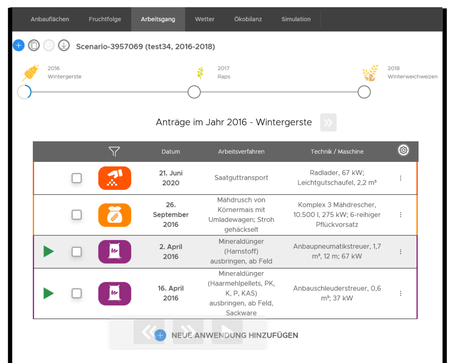
Input data (coverage: Germany)



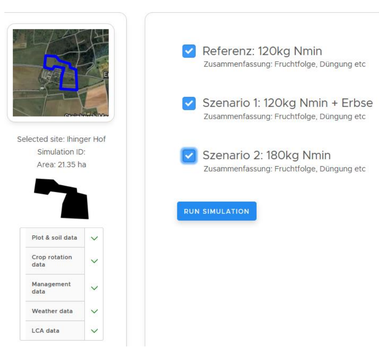
Plot selection
Soil properties loaded from BUEK 200

Weather data (1km^2 grid):
Daily T_{air}, rain, solar radiation

User-defined crop rotation
incl. cover crops

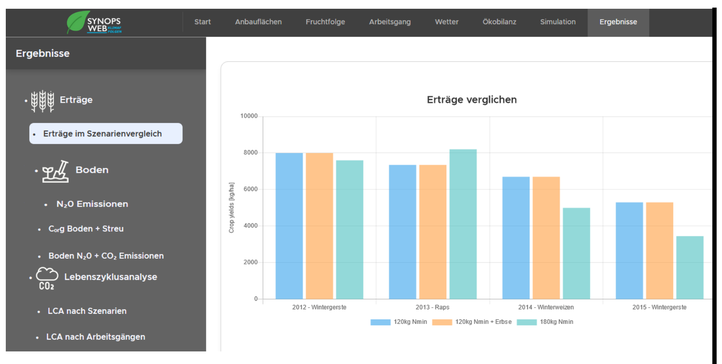


User-defined management:
Soil preparation, fertiliser …

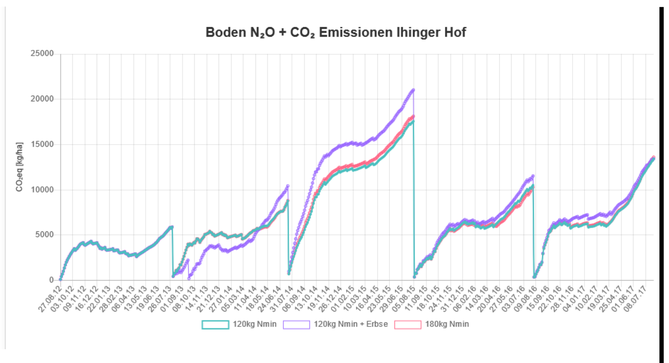


Definition of alternative scenarios

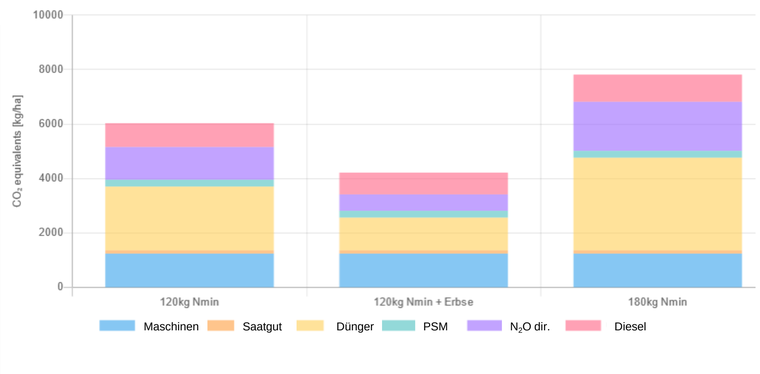
Simulated outputs



Crop yields [kg ha^{-1}] DSSAT HWAH



N_2O [kg N ha^{-1}] DSSAT N2OGED



Illustrative LCA outputs [kg CO_2eq ha^{-1}]

Discussion

- Counterintuitive effect of legume cover crop on N_2O emissions (more SOC built up, but also higher respiration)
- Plant parameters of typical rotations calibrated & validated for SW Germany (Attia et al. 2024); plant and soil parameters (ongoing) for SOC and N_2O emissions across Germany (Mallast et al. 2021)

Outlook

- Default rotations per site; automatised planting & harvest dates;
- Feedback workshops with potential users (farmers, consultants, researchers);
- Deployment of the tool to the public (until Nov ´26)

References
- Attia et al. 2024. doi.org/10.1016/j.agee.2024.109167
- Mallast et al. 2022. doi.org/10.3220/DATA20220119144442
- UBA:Beitrag der Landwirtschaft zu den Treibhausgas-Emissionen. https://www.umweltbundesamt.de/daten/land-forstwirtschaft/beitrag-der-landwirtschaft-zu-den-treibhausgas

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