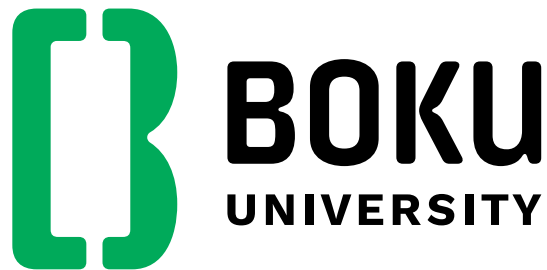


Long-term crop residue management effects on the greenhouse gas fluxes - an Austrian case study

Ulises Ramon Esparza-Robles et al.



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Background

As an effort to mitigate climate change, there is an increasing interest to implement agricultural practices aiming at increasing C storage in soil. In addition, the agricultural sector is also the largest contributor to anthropogenic non-CO₂ greenhouse gases. It is of concern that such impacts to N₂O and CH₄ fluxes can largely offset mitigation efforts in agriculture.

Objectives and main hypothesis

- Evaluate the consequences of long-term residue management on greenhouse gas (GHG) fluxes and the possible synergies or trade-offs with soil organic C storage.
- Understanding main soil drivers of GHG fluxes in this cropland.

We expect higher N₂O emissions when crop residues were incorporated to the long-term, i.e., in the incorporation treatment.

Methodology: Field measurements

(1) Field sampling for gas and soil. Long-term experiment in east Austria.

(2) Gas chromatography to estimate gas fluxes.

- Gas sampling on the field
- Static chambers (non-steady state)
- All relevant spring/irrigation
- Analysis: gas chromatography + ICD, FID, coulometer
- From measurements to fluxes

(3) Soil analyses

- Microbial C & N
- CO₂, Potassium Permanganate
- Available substrate for microbes: CPMPOC
- Available nitrogen species: NO₃⁻ and NO₂⁻ (μmol/l)

Figure 1. Field setup (marked each in a plot of the long-term incorporation treatments (off and on) and greenhouse gas sampling (left) in the long-term experiment in the field, Austria.

Soil data relationships

Figure 2. Principal component (PC) analysis of gas fluxes and soil variables. PC1: associated with soil moisture content, PC2: associated with basal N₂O and CO₂ fluxes.

PCA (Fig. 2) shows:

- For the year 2022: the ellipse of the incorporation treatment shifts downwards in the direction of CO₂ and N₂O.
- For the year 2023: the ellipse shifts to the direction of microbial C and N.
- The residue incorporation had a trend effect to increase the gas fluxes in the first year but, in the second year, the most influencing parameters are soil moisture and microbial biomass C and N.

In the correlation matrix (Fig. 4):

- N₂O emissions weakly related to CO₂, microbial C and microbial N
- This will require further exploration into individual events.

Figure 4. Correlation matrix of gas fluxes and soil variables.

Cumulative gas fluxes

Figure 3. Time series during three growing seasons in the field in the Markfeld for (top row in bottom): N₂O, CO₂, and CH₄ cumulative fluxes, daily mean air temperature and daily precipitation. Day hours represent the other parameters than in measurements were conducted and in the separation of the greenhouse gas fluxes and soil moisture content. The top row are mean values and error bars the middle row (red) indicates daily fluxes on top of the fluxes and the separate points in the different rows.

- Interannual variation in precipitation: from 365 mm (2022) to 613 mm (2023).
- Interannual variation in the treatment effect: likely combination of weather conditions, fertilization, and present and former crop.
- Modest increase in soil respiration in residue incorporation: Expected but not be considered as a climate mitigation trade-off as for other greenhouse gas fluxes.

Incorporation led to:

- Higher N₂O fluxes in 2021 and 2022
- Lower N₂O fluxes in 2023
- Similar to higher CH₄ uptake
- For both treatments, it was closer to zero in the drier year (2022), presumably due to the low microbial activity of methanotrophic bacteria.

Outlook

The long-term incorporation of crop residues led to modest increase in 2021 and 2022 but to a decrease in 2023. Overall, the study suggests that residue-driven changes in N₂O fluxes are of minor importance compared to the induced increases in soil organic carbon stocks.

CO₂ equivalents: N₂O vs soil organic C stocks

Crop	Year	N ₂ O change by residue incorporation (μmol/m ² /h)
Winter wheat (T. hybridum)	2021	+0.22 ± 0.3
Sorghum (Sorghum spp.)	2022	+0.33 ± 0.3
Wheat (x. Triticosecale Wittm. ex A. Camus)	2023	-0.68 ± 0.2

Table 1. Absolute changes in N₂O emissions in CO₂ equivalents by incorporating crop residues.

Current SOC stock difference* in the 30 cm by residue incorporation*	Relative (%)
+57,25	+14 %

Table 2. Current soil organic C stock difference after 42 years of residue incorporation (g/kg soil).

*N₂O emission rate at 20°C and 100% RH at 10 cm depth.

References/Literature

(1) Ravin et al. (2022) Earth Syst Sci Data 12, 1961–1973. (2) Ugghe et al. (2018) Int. J. Clim. Change 3, 216–223. (3) Zhou et al. (2017) Glob. Change Biol. 23, 4268–4281. (4) Oen et al. (2014) Biogeochemistry 119, 208–227. (5) Mead-Hewitt et al. (2010) ESRJL 14, 35–46. (6) Jang (2021) 199–19. (7) SOMMIT. (8) SOMMIT project: Sustainable Management of soil Organic Matter to Mitigate Trade-offs between C sequestration and nitrous oxide, methane and nitrate losses. European Union Programme for Research and Innovation Horizon 2020.

Acknowledgements

EJP SOIL

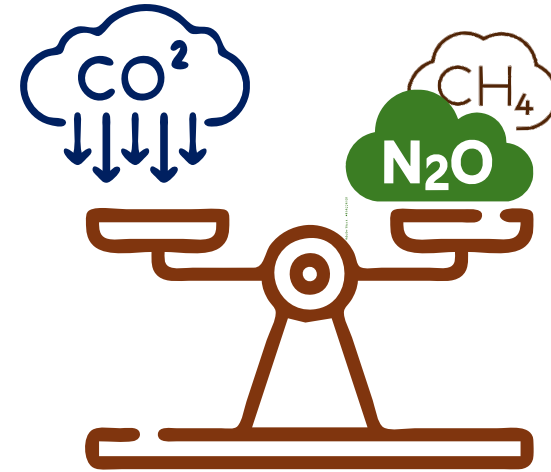
Objectives

- To **quantify** the impact of **residue management** on current GHG* fluxes after long-term management
- To **compare** the GHG fluxes with **SOC stocks**

Hypothesis

- We expect **higher GHG emissions** from the long-term **crop residue incorporation**

*GHG: Greenhouse gas



Control:
removal



Treatment:
incorporation

Cumulative emissions

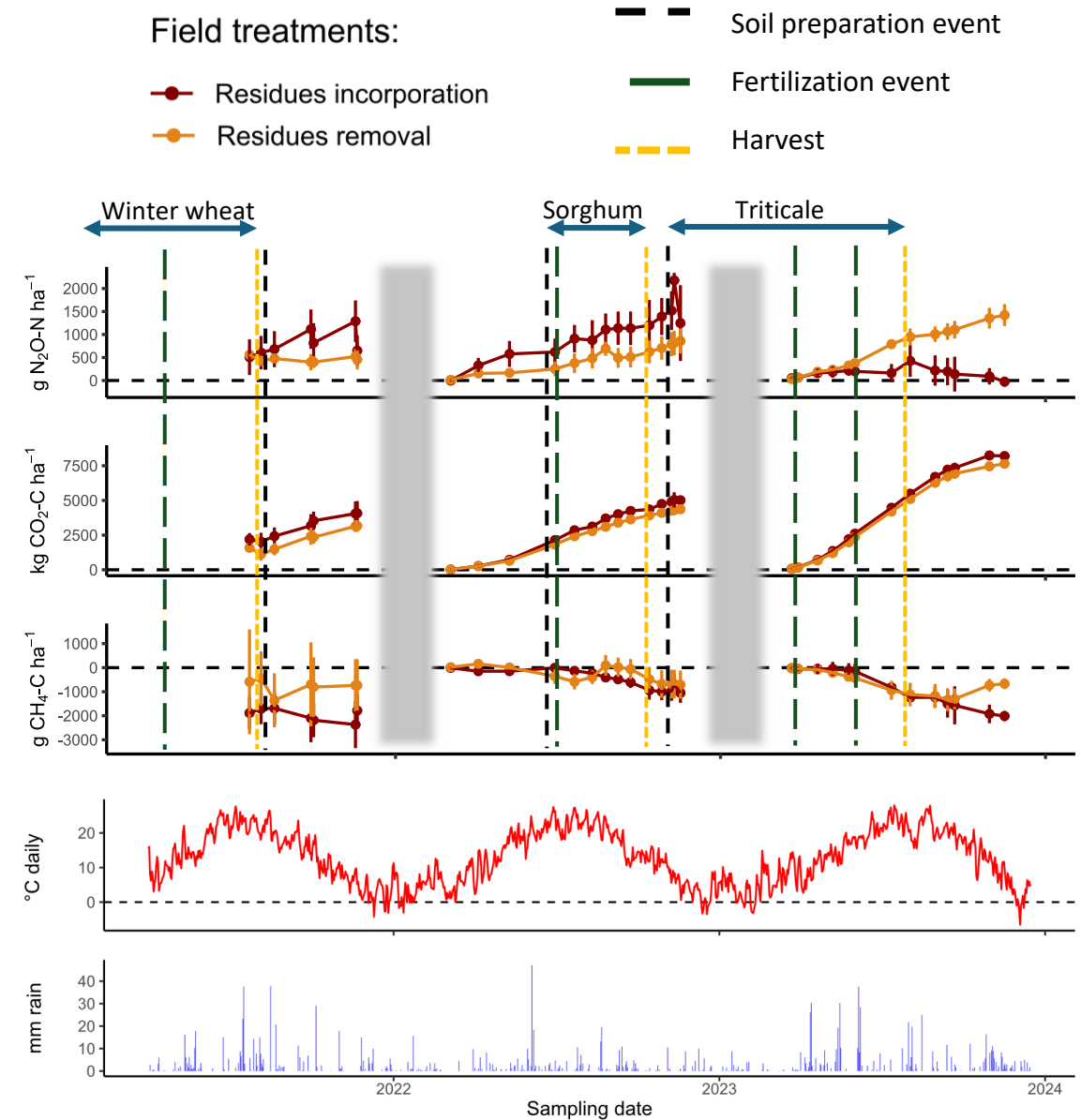
Gas sampling in 39 events

- Gas chromatography
- Static chambers



Soil sampling

- soil moisture, temperature,
- extractable C (NPOC) and N (DTN)
- microbial C and N



N₂O vs SOC stocks

Table 1. Absolute differences in N₂O emissions in CO₂ equivalents **by incorporating crop residues.**

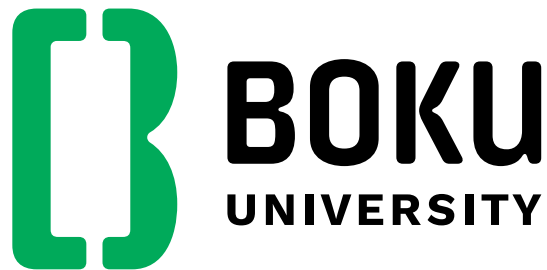
Crop	Year	N ₂ O change by residue incorporation
		Mg CO ₂ eq ha ⁻¹
Winter wheat (<i>T. hybernum</i>)	2021	?
Sorghum (<i>Sorghum spp.</i>)	2022	?
Triticale (× <i>Triticosecale</i> Wittm. ex A.Camus)	2023	?

Table 2. Current soil organic C stock differences **after 40 years of residue incorporation** against removal.

Current SOC stock difference in first 50 cm by residue incorporation	
Mg CO ₂ eq ha ⁻¹	Relative (%)
?	?

Thanks for your attention and...

See you at the poster session!



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Objectives and main hypothesis

- Evaluate the consequences of long-term residue management on greenhouse gas (GHG) fluxes and the possible synergies or trade-offs with soil organic C storage.
- Understanding main soil drivers of GHG fluxes in this cropland.

We expect higher N₂O emissions when crop residues were incorporated to the long-term, i.e., in the incorporation treatment.

Methodology: Field measurements

(1) Field sampling for gas and soil. Long-term experiment in east Austria.

(2) Gas chromatography to estimate gas fluxes.

- Gas sampling on the field
- Static chambers (non-steady state)
- All aliquot (per day) incubate
- Analysis: gas chromatography + GC, N₂O, methane
- From incubations to fluxes

(3) Soil analyses

- Mineral C & N
- CH₄ Potential Production²
- Available substrate for microbes: C/N:P:OC
- Available nitrogen species: NO₃⁻ and NO₂⁻ (year?)

Figure 1. Field setup showing control (no residue) and treated (residue) plots with gas sampling equipment in the long-term experiment in the cropland, Austria.

Soil data relationships

Figure 2. Principal component (PC) analysis of gas fluxes and soil variables. PC1 associated with soil moisture content, PC2 associated with basal N₂O and CO₂ fluxes.

PCA (Fig. 2), shows:

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CO₂ equivalents: N₂O vs soil organic C stocks

Crop	Year	N ₂ O change by residue incorporation ^a
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^a N₂O change in kg CO₂ eq/ha/yr

Current SOC stock difference ^b in the 30 cm soil by residue incorporation ^c
Mg CO ₂ eq/ha/yr
Relative (%)
+57,25 +14 %

^b N₂O change in kg CO₂ eq/ha/yr

- Interannual variation in precipitation: from 365 mm (2022) to 613 mm (2023).
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