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Evaluation of Chamber-based soil greenhouse gas emissions in contrasting land use of the Sudanian savanna

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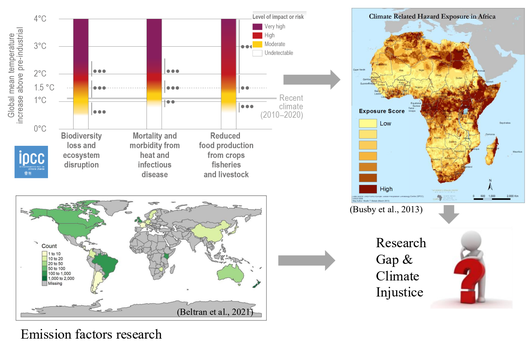
MOTIVATION



- The effects of major greenhouse gas (GHG) emissions in West Africa remain insufficiently documented.
- The aim of this study is to investigate the N_2O and CH_4 fluxes in contrasting land use of the Sudanian savanna

DATA & TOOLS

Experimental design

- Designed chamber is made of 37 x 26.7 cm size collar and intransparent cover implanted at 10 m from the EC tower
- Five sub-trial points (chambers) are deployed at each site to ascertain the spatial variability.

Gas sampling & Lab analysis

- GHG was sampled with syringes
- GHG measurement at KIT Lab (Germany)
- Isotope Ratio Mass Spectrometry test AIL-1.1c (2015-02) used for carbon (δ13C) and nitrogen (δ15N)

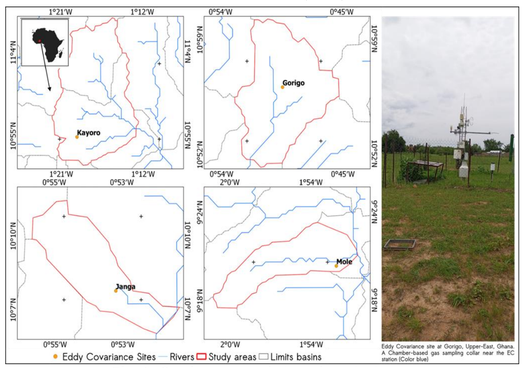


Fig. 1: Study area and sites description

METHODS

Flux calculation, statistical test and analysis

$$F_{CH} = \frac{dq}{dt} \times \frac{V \times P \times M_w}{R \times T} \times \frac{60}{A \times 1000} \text{ (Eq. 1)}; WFPS\,[\%] = \frac{W_{vol}}{\left(1 - \frac{BD}{2.65}\right)} \text{ (Eq. 2)}$$

F_{CH}: GHG flux (µg C m^{-2} h^{-1})
dq/dt: change in the mixing ratio over time (ppb min^{-1} or ppm min^{-1}) resulting from the linear fit,
V: chamber volume (m^3), **P**: air pressure (Pa), **Mw** = 12 for CO_2 and CH_4 and 28 for N_2O (g mol^{-1}),
T: average temperature during the closure time (°K),
A: surface area of the chamber (m^2) and R: universal gas constant (J mol^{-1} °K^{-1})
WFPS [%]: Water filled pore space
Wvol: Soil water content [%]; **BD:** Bulk density

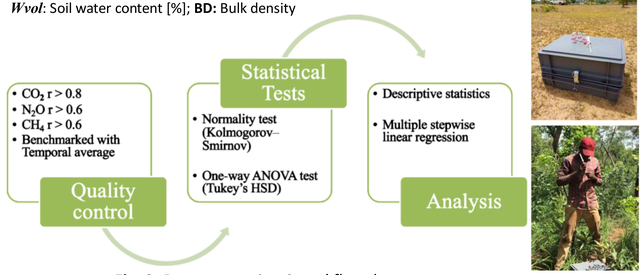


Fig. 2: Data processing Steps' flowchart

CONCLUSIONS

- Land use degradation has significant impact on CH_4 flux but marginal effects on N_2O flux.
- N_2O flux is less dependent on soil moisture and temperature changes unlike CH_4.
- Chamber-based approach reveals small scale site specific spatial variability compared to micrometeorological flux estimates

RESULTS & DISCUSSION

Weekly boxplot time series of in situ CH_4 flux

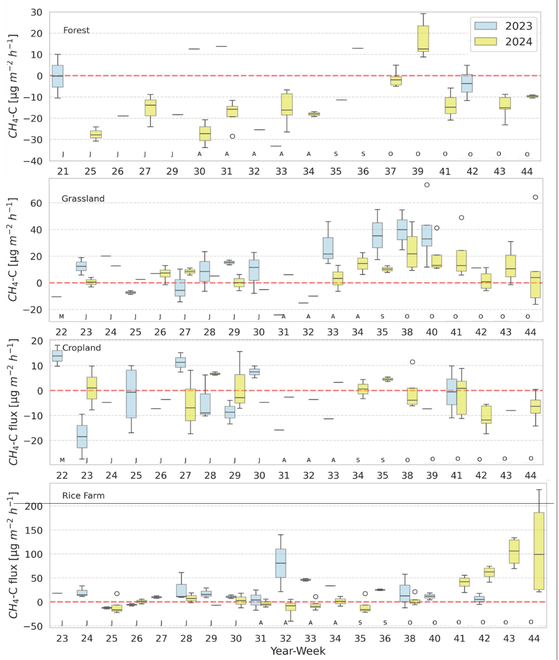


Fig. 3: Weekly boxplot time series of in situ CH_4 flux for 2023 (light blue) and 2024 (yellow). Each boxplot is made of fluxes from 5 sub-trial points (chambers). From top to bottom are the forest reserve, grassland, cropland, and rice farm. The number of the sampling week is in x-axis.

Contrasting land use effects on CH_4 and N_2O fluxes

- Methane release is significantly different between the four land use conditions with the highest rate recorded in the rainfed rice farm (1.67±0.41 and 1.97±0.51 kg C ha^{-1} yr^{-1}).
- A unit increase in soil water content increases CH_4 flux by 0.96 µg C m^{-2} h^{-1} at the rice farm in contrast there is a decrease of -0.85 µg C m^{-2} h^{-1} in response to temperature increase.
- The forest reserve behaves as a methane sink (-0.05±0.48 and -1.01±0.31 kg C ha^{-1} yr^{-1}) while the grassland is a net source (1.26±0.84 and 0.89±0.3 kg C ha^{-1} yr^{-1}) for the two years.
- Significant methane release occurred in response to soil water content change during rainfall onset.
- Around 60% WFPS and moderate soil temperature (30 to 40°C), the highest methane release occurs at the grassland site.

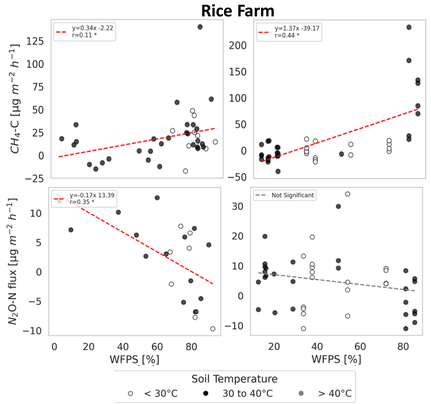


Fig. 4: CH_4 and N_2O response to soil moisture (% WFPS) and soil temperature (°C) change

CH_4 flux

Ecosystem	Annual mean [kg C ha^{-1} yr^{-1}]	
	2023	2024
Forest	-0.05±0.4	-1.01±0.3
Grassland	1.26±0.84	0.89±0.3
Cropland	0.16±0.48	0.18±0.33
Rice Farm	1.67±0.41	1.97±0.51

N_2O flux

Ecosystem	Annual mean [kg N ha^{-1} yr^{-1}]	
	2023	2024
Forest	-0.05±0.4	-1.01±0.3
Grassland	1.26±0.84	0.89±0.3
Cropland	0.16±0.48	0.18±0.33
Rice Farm	1.67±0.41	1.97±0.51

Weekly boxplot time series of in situ N_2O flux

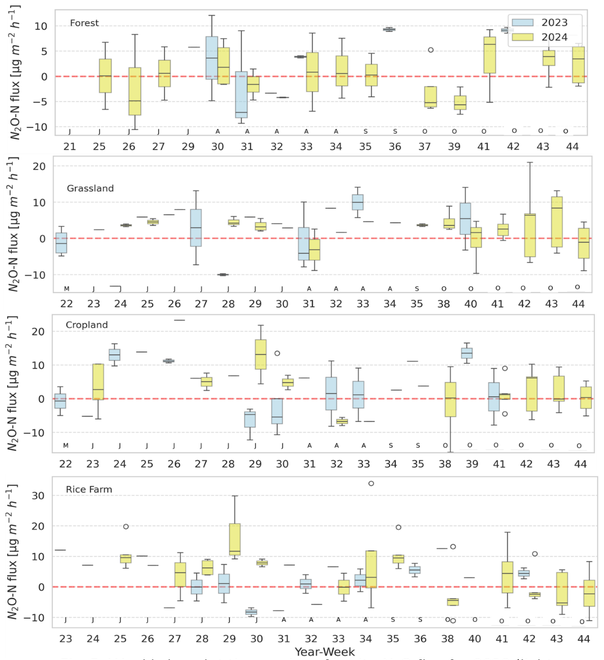


Fig. 5: Weekly boxplot time series of in situ N_2O flux for 2023 (light blue) and 2024 (yellow).

- No significant difference is observed between the land use conditions likewise between the two years for N_2O emissions.

Soil moisture & Temperature impact on the fluxes

- Soil water content and temperature have opposite effects on CH_4 flux with the highest impact recorded at the rice farm.
- Cultivated soil of the Sudanian savanna limits CH_4 flux for a net sink (-0.16±0.48 -0.18±0.33 kg C ha^{-1} yr^{-1}) unlike the grassland unperturbed soil.
- The methane flux variability is most explained by soil water content (0.21 to 0.42)
- A major limitation to N_2O flux is low soil nitrogen content.
- Soil water content and temperature have marginal to low effects on N_2O flux.
- Monthly variability of methane flux is made of uptake and source depending on soil moisture and temperature.

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