Answer to Referee1: Dianming Wu: comment on EGUsphere-2024-2346

In this work, Daelman et al. offer a critical examination of greenhouse gas fluxes from a semideciduous tropical forest soil in the Congo Basin, an area underrepresented in the scientific literature. Utilizing a combination of automated and manual soil chamber measurements, the research provides a detailed analysis of the spatiotemporal variability of CO_2, CH_4, and N_2O emissions, revealing the forest soil as a significant source of CO_2 and N_2O and a minor sink for CH_4. The findings are pivotal in elucidating the nitrogen and carbon cycles within tropical forest soils, as well as in assessing the ecosystem's vulnerability to climate change.

We thank the reviewer very much for this positive feedback.

However, this study has the following issues:

1. *The Congo Basin is a vast and diverse region. How do you ensure that the data collected from the specific study site in Yangambi is representative of the broader Congo Basin's tropical forest soils?*

   Thank you for your question. The Congo Basin is indeed a vast and diverse region with different climate, soil types, different forest compositions, rich biodiversity, and different forest types in general. The results of this study are therefore not representative of the whole Congo Basin. However, the CongoFlux site is situated in a lowland mixed species forest, identified as semi-deciduous with patches of evergreen forest. According to (Shapiro et al., 2021), semi-deciduous rainforest covers around 104 330 000 ha of the Congo Basin and a combination of evergreen and semi-deciduous forest covers a total area of 18 000 000 ha. In terms of vegetation, the CongoFlux site therefore represents about 33% of the entire Congo Basin, assuming 3.6 million square kilometer total size. Moreover, lowland semi-deciduous forests as found at our site represent 91% of all tropical forest types in the Congo Basin. The main soil type at our research site is Ferralsols. According to (Baert et al., 2009) Ferralsols are the dominant soil type in the DRC, which contains most of the tropical forest of the Congo Basin. We are therefore confident that our site is well-suited to represent a significant part of the tropical forest realm in the Congo Basin.

   The Congo basin in general lacks in situ-data and comparisons with the data that is available for soil fluxes show that there is quite a diversity of measurement techniques and results. With the combination of automated and fast box chamber we tried to tackle the problems of previous studies and therefore provide a more robust estimate. Although our site is representative for a large area within the Congo Basin, this estimate will never cover the entire extend of the Congo Basin. However, it is a starting point for further investigation and a benchmark for model output.

2. *You mention the use of both automated and manual soil chambers. Could you elaborate on how the data from these two different methods were integrated, and whether any corrections or normalizations were applied to ensure consistency in the dataset?*

   No corrections or normalizations were applied to either dataset. We believe that the methods are comparable due to the fact that the processing steps of the two methods are the same. When comparing the datasets, we take into account that the manual chambers are only measured during a limited period of time. The same time periods are selected to avoid comparing measurements in different meteorological situations. In the article, we will mention more clearly that these overlapping periods are selected for comparison.

3. *The manuscript notes sporadic CH_4 emission events. What are the potential ecological or environmental triggers for these events, and how were they identified in your study?*

   Thank you for pointing out that this was not entirely clear. Line 328-342 says that several papers have suggested either heavy precipitation, termite activity or anoxic hotspots of microbial activity within the overall aerobic soil were put forward as possible triggers for these sporadic CH_4 emissions. In this study no clear evidence of termite activity was found at the chamber locations and the emissions did not occur only during wetter periods. Overall, this suggests that the emissions in our study are also associated with sporadically occurring anoxic microsites, dominated by methanogenesis.

4. *The study identifies water-filled pore space (WFPS) as a significant driver of N_2O emissions. Have you investigated other potential drivers, such as soil pH, nutrient availability, or microbial community composition, which could also influence N_2O emissions?*

   No, we did not investigate other potential drivers apart from WFPS in this study. We do not have information on soil pH, nutrient availability of microbial community composition for all chambers separately. However, we state in line 379-380 that the low marginal R^2 of the fit suggests that there are indeed also other main drivers behind our results found in the study. We were primarily interested in capturing the high spatiotemporal variability using automated chambers to obtain a robust estimate for N_2O flux magnitude and variability. Sampling for the mentioned other drivers even only at a weekly frequency was not feasible and not trivial. Problems such as sample preservation hinder sensitive analysis such as microbial composition. With continued developments in the field (e.g. DNA preservation solutions) and improved infrastructure we hope to implement these parameters in future studies.

5. *The high temporal variability of N_2O emissions is noted. Could the authors provide insights into the seasonal patterns and inter-annual variability observed in the study, and how this variability might be linked to climate drivers?*

In terms of seasonal variability and the drivers, we mention in the paragraph starting on Line 368 that we see higher emissions in the wet compared to the dry season. We also see higher emissions after rain events, but these seem to disappear with the onset of the dryer season. Regarding the intra-annual variability, we mention that there is a large variability between consecutive years in the automated chamber measurements as we see lower fluxes during the onset of the second wet season around June and July than in the first wet season. However, during the second wet season, higher fluxes are measured by the manual chambers, which could indicate that the soil conditions have changed, triggering the lower fluxes in the manual chambers

> LINE 368 -372: "WFPS is the strongest driver (Table S9) and has the largest relative effect size within its range of variability compared to other predictors (Fig. 2). The positive relationships fitted by the linear mixed model are found in several studies, confirming higher emissions during wet season, compared to dry seasons (Iddris et al., 2020; Werner et al., 2007). Shortly after rain events, N_2O emissions increase rapidly and then slowly decrease again with decreasing WFPS (Fig. S9 c). From January 2023, with the onset of the drier months, the high fluxes and peaked responses to increasing WFPS seem to disappear."
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> LINE 357: "Emissions change significantly from year to year. The same months separated by only one year can differ in N_2O emissions by a factor of four."
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> LINE 374 – 378: "With the onset of the early wet season around June and July, the emissions do not increase again. However, the fast box flux in August is almost the same as the high average flux measured by the automated chambers around the same period in the previous year (June and July 2022). The large difference could therefore also be the result of altered conditions at the chamber locations due to the long deployment of the automated chambers on the same location."

6. *What is the detection limit of the flux /GC? Are these real negative fluxes? please state detection limits - important when claiming negative fluxes.*

Thank you for noticing that the detection limits of the measurement instruments are not mentioned in the article. The negative CH_4 fluxes mentioned in the study are real in the sense that negative fluxes are generally expected for methane and CH_4 uptake has been measured before in other studies in similar areas, for example Barthel et al., 2022. The analyzers used in this study measure at a frequency of 1 Hertz. The linear fits are therefore performed on many datapoints which is in contrast to the static chamber method, analyzed with a GC, where linear fits are performed on 4 data points only. Therefore, we assume that the detection limits in our case are less important than when using the static chamber method linked to GC. The detection limit against background ambient concentrations of the set-up is not measured by ourself. We do know the precision of the analysers given by the company and this information is added in the supplementary material:

Precision (1σ) of the analysers used in the set-up

CO_2 Measurements
3.5 ppm at 400 ppm with 1 second averaging
CH_4 Measurements
0.60 ppb at 2 ppm with 1 second averaging
N_2O Measurements
0.40 ppb at 330 ppb with 1 second averaging

From this information we could calculate the detection limit of the flux by using 2 times this standard deviation divided by the closure time of 15 minutes as dq/dt in equation 1 from the manuscript. This results in a detection limit for CO_2 equal to 2.0 mg C m^{-2} h^{-1}, for CH_4 equal to 0.3 µg C m^{-2} h^{-1} and for N_2O equal to 0.5 µg N m^{-2} h^{-1}. We also added these values to the Supplementary Material.

7. *L120, give a reference for the equation used*.

Thanks for noticing that the use of this formula was not clear. The formula is a combination between the ideal gas law and additional scaling variables to arrive at the units we work with in this article. We reformulated the equation so that it is more clear how the equation is used.

The equation is now written as:

$$Flux = \frac{dq}{dt} \times \frac{V \times P \times M_w}{R \times T} \times \frac{60}{A \times 1000} \quad (2)$$

8. *2.3.2: should provide detailed information about the experimental design for manual chamber measurements, which is crucial for understanding the methodology and interpreting the results. For example, clarify the time of day when measurements are taken and whether these times are consistent across all measurements or vary according to a specific schedule*.

The section about the fast box measurement indeed missed some crucial information for the reader to understand the method we applied correctly.

The measurements were only taken during daytime, between 08:00 and 18:00 and the route through all plots was changed every day such that the measurement timing of each chamber was different for every measurement.

We changed various line in the article to make this more clear:

> LINE 133: " During a period of three weeks from August 4 to August 28, 2023, flux measurements of CO_2, CH_4 and N_2O were made during daytime (between 08:00 – 18:00) in these plots using two portable analysers …."

LINE 136: ". Two plots were measured per day with on average 5 minutes between consecutive chamber measurements."

LINE 137: "To avoid consistently measuring the same chamber on the same time of day, the order in which the plots were measured was alternated and the route from chamber to chamber within one plot was changed every session."

References

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