Reviewer 1 _N2O manuscript

Response to review of the manuscript "Nitrous oxide emission from pigeon pea – maize rotation in response to conservation agriculture and biochar amendments in a Ferralsol, northern Uganda" by Namatsheve et al.

This study investigates the effects of conservation agriculture (CA), both with and without biochar amendments, compared to conventional tillage in an unfertilised maize-pigeon pea rotation in Uganda. It also compares these treatments with a maize monoculture treatment.

The manuscript significantly contributes to the scientific knowledge base by presenting a novel dataset.

The introduction shows the relevance of the study and the basis of existing literature. The study design and hypotheses are well described. The data is highly valuable. It contains 17 observations of N_2O emissions and its driver variables per treatment over the course of one year (two seasons) in Uganda. The methods are sound and well described. The results are well described and the discussion a good start, but both need some revisions as suggested below.

I recommend to publish the manuscript after major revisions.

Response: We thank the reviewer for the constructive evaluation of our manuscript. We appreciate the recognition of the novelty and relevance of our dataset, the clarity of our study design and hypotheses, and the value of our methodological approach.

We have carefully addressed all specific comments and suggestions to improve the clarity and scientific rigor of the results and discussion sections, and we believe these revisions have strengthened the manuscript and hope it now meets the standards for publication in Biogeosciences.

L30: Overall, across all seasons, cumulative growing-season (279 days) N_2O emissions ranged from 0.44 – 1.11 kg N ha^{-1}

RC: Since this is a major finding, you should give the values specifically per treatment in the abstract.

Response: We thank the reviewer for the comment, we have now added the values per treatment: "Overall, across two growing seasons, weighted cumulative N_2O emissions in 279 days ranged from 0.46 kg N ha^{-1} in CA+BC treatment to 0.88 kg N ha^{-1} in Conventional treatment, respectively."

L127: Table S19

RC: You start with Table S19. You should instead name your Tables differently and make sure to have them ordered in the same way as they occur in your text. You start with table S1 here and so on.

Response: Thank you for the comment, we have now rearranged the tables, and numbered them in logical order (viz. table S1).

L130: RC: Please add average precipitation sums (for example 5 or 10 years) in order to show how usual the 2023 conditions were.

Response: Gulu received annual rainfall of 1460 mm yr^{-1} from 1980 – 2010 (Oriangi et al., 2024). The average annual temperature is 24 ℃, and the annual rainfall in 2023 was 1238 mm, of which 818 mm was received in the first and 419 mm in the second season. (Ln 132 – 135).

L135: Is it known how long the maize and cassava production have been practiced?

Response: We have included this information as follows: The experiment was established on a field that was fallowed for three years; before that it was used for maize and cassava production without fertilization, for at least five years (Ln 136 – 137).

L160: For CA, weeds were controlled by spraying glyphosate at a rate of 1.03 L ha-1, immediately after sowing and hand pulling throughout the season.

RC: Set in context how realistic glyphosate spraying would be under farmers practice conditions.

Response: Subsistence farmers normally control weeds with hand hoeing. Herbicide application is being promoted in the mainstream of conservation agriculture to reduce tillage and to control troublesome perennial weeds that are otherwise difficult to control with hand hoeing. Although the use of glyphosate among farmers is a relatively new technology, it is readily available at agro-dealers within the smallholder farming communities, and some farmers use it.

L 198: RC Write: Plot wise sampling in 0 – 20 cm was carried out at the onset (April 2023) and end (October 2023) of the first growing season from planting basins in CA and CA+Biochar treatments and in the planting rows in conventional treatments to assess the effect of different treatments on soil properties.

Leave out the next sentence.

Response: Thank you for rephrasing L198. We have now deleted the next sentence

L234: by (Žurovec et al., 2017).

RC: write by Žurovec et al. (2017).

Response: Thank you for the comment, the reference is now correctly cited.

L246: ∑(*fi* + (*fi*+1)/2 × (*ti*+1 − *ti*) × 24 × 10−5

RC: There is a bug in this formula, there are opening up three brackets but only two of them close again. Make sure to provide a correct and well formatted equation.

Response: Thank you for the comment, the formulae is now written as follows:

$$cumulative\ N_2O = \sum[(f_i + f_{i+1})/2 \times (t_{i+1} - t_i) \times 24 \times 10^{-5}] \qquad (2)$$

L255: (NO3-N and NH_4^+-N)

RC: Use NO_3^- here and elsewhere (Text & Fig. to ensure consistency.

Response: Thank you, we have now changed this in the whole manuscript.

L281-283: Adjust the text, since it is the same as before:

RC: My suggestion: For calculating yield scaled N2O emissions, the same scaling factor as for cumulative N2O fluxes of 0.12 for basin and 0.88 for interrows in CA treatments, and 0.50 for inrows and interrows in conventional treatments were applied.

Response: We have now rephrased the sentence as follows: Yield-scaled N_2O emissions (kg N_2O-N kg^{-1} grain yield) and N-yield scaled emissions (kg N_2O-N kg^{-1} grain N) were estimated for each season by dividing the area-weighted cumulative N_2O emissions with grain yield or N content of the grain (N concentration × grain yield).

L297: RC: The statistical approach makes sense. Nevertheless, I wonder how residuals data can be normal without any transformation, this is very unusual for N2O, could you show the residual plot?

Response: For cumulative N_2O emissions, we checked the normality of residuals. Visual inspection of the QQ plots showed that residuals were near normal without transformation as shown in fig 1.

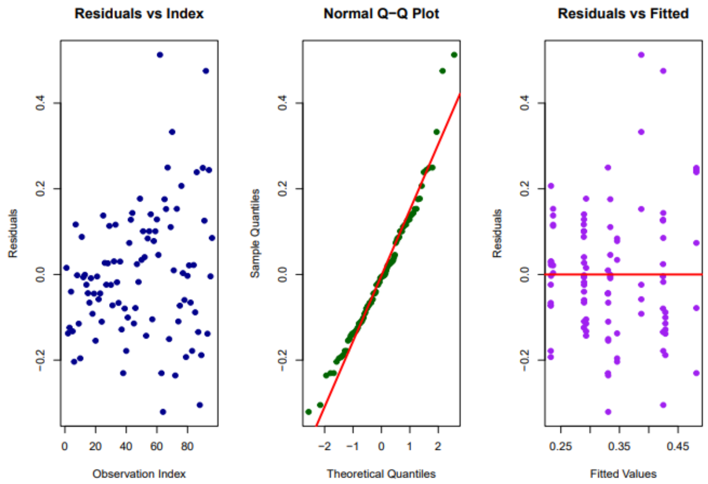

Fig 1: Cumulative N_2O

For N2O fluxes, The QQ plot shows a deviation from normality in the tails, which is common for N_2O flux data. However, mixed-effects models are robust to violations of normality in residuals (Zuur et al., 2009), especially with large sample sizes. We tested log transformation, but it did not improve model fit (AIC/BIC remained similar), so we retained the original scale for interpretability.

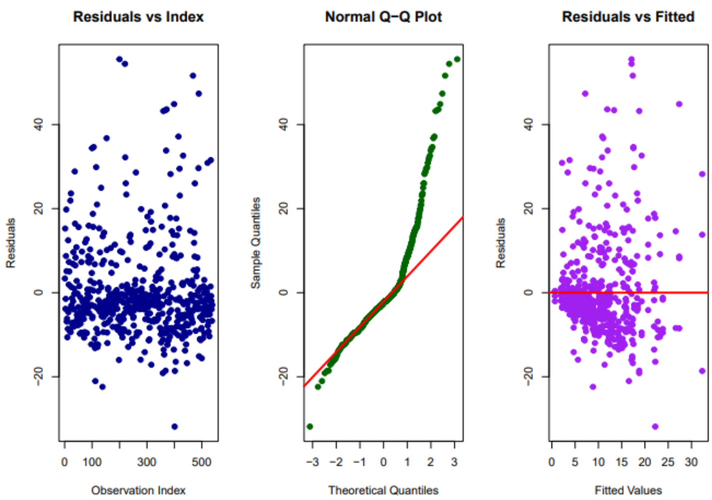

Fig 2: N_2O fluxes

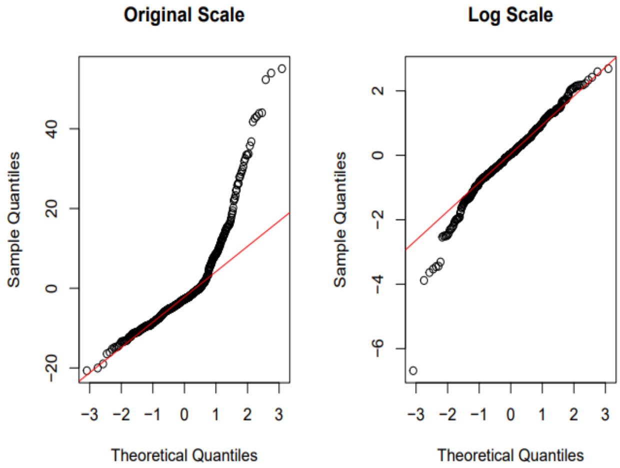

Fig 3: Original N_2O fluxes vs log transformed N_2O fluxes

L310

3.0 Result -> 3 Results

L316 : SOC ranged from 1.25 – 2.23% and biochar significantly increased C

RC: use SOC consistently since this is the abbreviation you introduced.

Response: Thank you for noting this; We now use SOC throughout the manuscript.

Figure 1: The insert in (a) shows mean ± se N2O fluxes during peak emission on 18 October 2023.

RC: This is the same as you see when looking at this peak day in the time series plot, so I do not see the additional value to much. Well if you want to pronounce it a lot you can keep it. I would rather show the cumulative values - but this might show up later in a separate Figure?

Response: we removed the insert in (a)

Table 3: Please round the yields meaningfully (Consider the accuracy of measurements!). Give no decimal number here if you have kg /ha. Same for N yields.

Response: Thank you for the comment, we have now rounded off the grain yield and N yield to whole numbers.

Figure 5+ 6 : Add the **weighted cumulative** values to the plots as a third colour besides basin/inrow and interrow, since this is the main result that should be also show here.

Indicate Tukey-HSD letters also in Fig 5

Response: Thank you for the comment. We have now included the weighted cumulative values for Fig 4 and 5. We also added letters to show significant differences in Fig 5 (Ln 397 – 413).

L388: Write two sentences, else it is confusing: Chamber position did not significantly explain variations in cumulative N2O emissions. There were no significant differences ($p > 0.05$) between conventionally tilled pigeon pea – maize rotation and conventionally tilled continuous maize monocropping (Table S17, S18, Fig. 5, Fig S3)

Response: Corrected

L477: corelated -> correlated: Please check spelling (and grammar) throughout the manuscript- I didn't.

Response: corrected

L481: probably immobilizing available N rather than releasing it for microbial N transformations; RC: I know what you mean but… The phrase "releasing it for microbial N transformations" is a bit unclear — microbes don't exactly "release" N for other microbes; it may be better to phrase it differently:

Better: This suggests that microbes in these soils compete effectively for mineral nitrogen, likely immobilizing it and thereby reducing its availability for microbial processes such as nitrification and denitrification

Response: Thank you for a helpful suggestion. The sentence is now rephrased as follows: This suggest that microbes in these soils compete effectively for mineral N, likely immobilizing it and thereby reducing its availability for microbial N transformations such as nitrification and denitrification.

L485: Our results imply that the process of symbiotic N fixation per se, and residue

retention do not affect soil mineral N and N2O emissions in unfertilized soils with inherently low N. Rochette et al. (2004) also reported that there is considerable uncertainty related to the emissions of N2O from soils under legumes, and the soil mineral N alone was a poor indicator of N2O emissions for two seasons in acidic soils in Canada.

RC: 1) It is well-known that N2 fixation itself does not affect N2O emissions, please rephrase so this gets clear.

2) In many studies soil mineral N is a bad indicator for N2O emissions. This is nothing particular to legumes. Please adjust.

Response: Thank you for the insightful comments. We agree that there is no direct link between N_2-fixation and N_2O emissions. We also acknowledge that soil mineral N is a poor indicator of N_2O emissions. We have now rephrased as follows:

Our results imply that N_2-fixation and residue retention do not directly affect soil mineral N or N_2O emissions in unfertilized soils with inherently low N. Rochette et al. (2004) also reported considerable uncertainty in N_2O emission from soils under legumes, and they noted that soil mineral N alone was a poor predictor of N_2O emissions for two seasons in acidic soils in Canada.

L536: Lentz et al. (2014) also found that biochar reduced N2O emissions by 50%, indicating that biochar inhibited nitrification and N immobilisation.

RC: Did they measure nitrification and immobilisation? It is a bit contrary to the study by Munera-Echeverri et al. (2022), so the effect of biochar on nitrification and the difference between these studies should be explained.

Response: Lentz et al., 2014 measured N2O emissions and net mineralization, which is affected by nitrification and N immobilisation. We agree that Lentz et al., 2014 contradicts Munera-Echeverri et al., 2022 results. We have rephrased the whole paragraph, and we have now discussed the weighted N2O emissions results.

Biochar applied at a rate of 5 Mg ha^{-1} to CA systems reduced weighted N_2O emissions by 33% and 66% compared to Conventional treatment in the first and second season, respectively. Biochar with a high C:N ratio of >60, as applied in this study, was shown to reduce the bioavailability of inorganic N through microbial immobilisation (Namoi et al., 2019) or sorption of NO_3^- due to unconventional H-bonding between NO_3^- ions and biochar surface functional groups (Kammann et al., 2017; Nguyen et al., 2017). In a fertilized Ultisol in western Kenya, Fungo et al. (2019) reported a 22% reduction in emissions. Case et al. (2015) also reported that biochar suppressed N_2O emissions in a sandy loam soil fertilized with 140 kg N ha^{-1} yr^{-1}. Biochar applied in a calcareous soil also reduced N_2O emissions by 50%, and increased soil NH_4^+/NO_3^- ratio, indicating that biochar impaired nitrification and N immobilisation processes (Lentz et al., 2014). Our results support the growing evidence that biochar can mitigate N_2O emissions via various N cycling modifications (Liu et al 2018, Zhang 2021, Borchard et al., 2018; Kammann et al., 2017). However, in a short-term study, Munera-Echeverri et al. (2022) reported that biochar amendments did not affect N_2O emissions in Zambia despite increased gross nitrification rates in the biochar treatments. In a global meta-analysis, Shakoor et al. (2021) showed that biochar increased N_2O emissions by 20%. Discrepancies on response of N_2O emissions to biochar might be explained by biochar type, soil parameters, climatic conditions and experimental duration. Yield and yield scaled N_2O emissions. (Ln 537 – 555).

L554 – 561:

End the paragraph with your study, not with the numbers of another study. Put the following sentence to line 554: Our results are in line with other studies in SSA, although they applied mineral N fertilizer; for example, Shumba et al. (2023) reported yield scaled emissions of 0.09 – 0.19 in maize after applying 58 kg N ha-1 in a Ferralsol and Lixisol in Zimbabwe.

Rephrase to make it consistent again

Then end the discussion with this: These practices were effective in minimising emissions without penalising pigeon pea productivity, supporting CA as a sustainable agricultural practice.

Response: Thank you for the useful comment we have taken the comment into consideration (Ln 573 – 575).

L569: Typo: Yield-scaled

Response: corrected