#Reviewer 1

This manuscript presents a year-long dataset of GHG concentrations and fluxes from 5 headwater catchments in Germany from streams, agricultural ditches, and WWTP outflows. It identifies controls on GHG dynamics using mixed-effects models and structural equation models. In addition, it upscales flux rates to calculate annual emissions in terms of global warming potential. The main finding, that anthropogenically impacted streams have higher and more variable GHG concentrations and fluxes, was well supported. Overall, the manuscript presents results that will be an important contribution to our understanding of GHG emissions from inland waters and I find the analysis and results novel and worthy of publication.

I have a few suggestions, although they mostly minor and easy to address.

Abstract:

-I don't think that the analysis backs up the statements about separating in situ production of GHGs and direct inputs of GHGs (e.g., ln 27-28, 30-31). These statements should be removed or rephrased.

Response: Thank you for your critical comment and suggestion. We removed the initial sentences and rephrased them to clarify our meaning.

"Our findings also suggested that nutrient, labile-carbon, and dissolved GHG inputs from the agricultural and settlement areas may have supported these hotspots and hot-moments of fluvial GHG emissions."

-I think the authors should more clearly state that anthropogenically impacted streams have not only higher, but also *more variable* GHG emissions than natural streams in the abstract. (i.e., give some sort of variability stats)

Response: Thank you for the suggestion. We have added a sentence to the abstract to represent this finding better.

"Streams in agricultural-dominated catchments or with wastewater inflows had up to 10 times higher CO_2, CH_4, and N_2O emissions, which were also more temporally variable (CV > 55%) than forested streams."

-I would consider mentioning some of the other main findings in the abstract (if possible within word count limits): 1) the break down of the expected stream-order patterns in impacted sites and 2) the finding that CO2 is the dominant contributor in terms of global warming potential

Response: Thank you for the suggestion. We have added several sentences to reflect both findings in the abstract.

"Overall, the annual emission from anthropogenic-influenced streams in CO_2-equivalents was up to 20 times higher (~71 kg CO_2 m^{-2} yr^{-1}) than from natural streams (~3 kg CO_2 m^{-2} yr^{-1}), with CO_2 fluxes accounting for up to 81 % of the annual emissions, while N_2O and CH_4 accounted for up to 18 and 7 %, respectively. The positive influence of anthropogenic activities on fluvial GHG emissions also resulted in a breakdown of the expected declining trends of fluvial GHG emissions with stream size. Therefore, future studies should focus on anthropogenically perturbed streams, as their GHG emissions

are much more variable in space and time and can potentially introduce the largest uncertainties to fluvial GHG estimates"

Methods:

-I don't see temperature/seasonality or NH4 in the SEM results, even though these parameters are listed as input variables. Were they found insignificant and dropped? Please clarify.

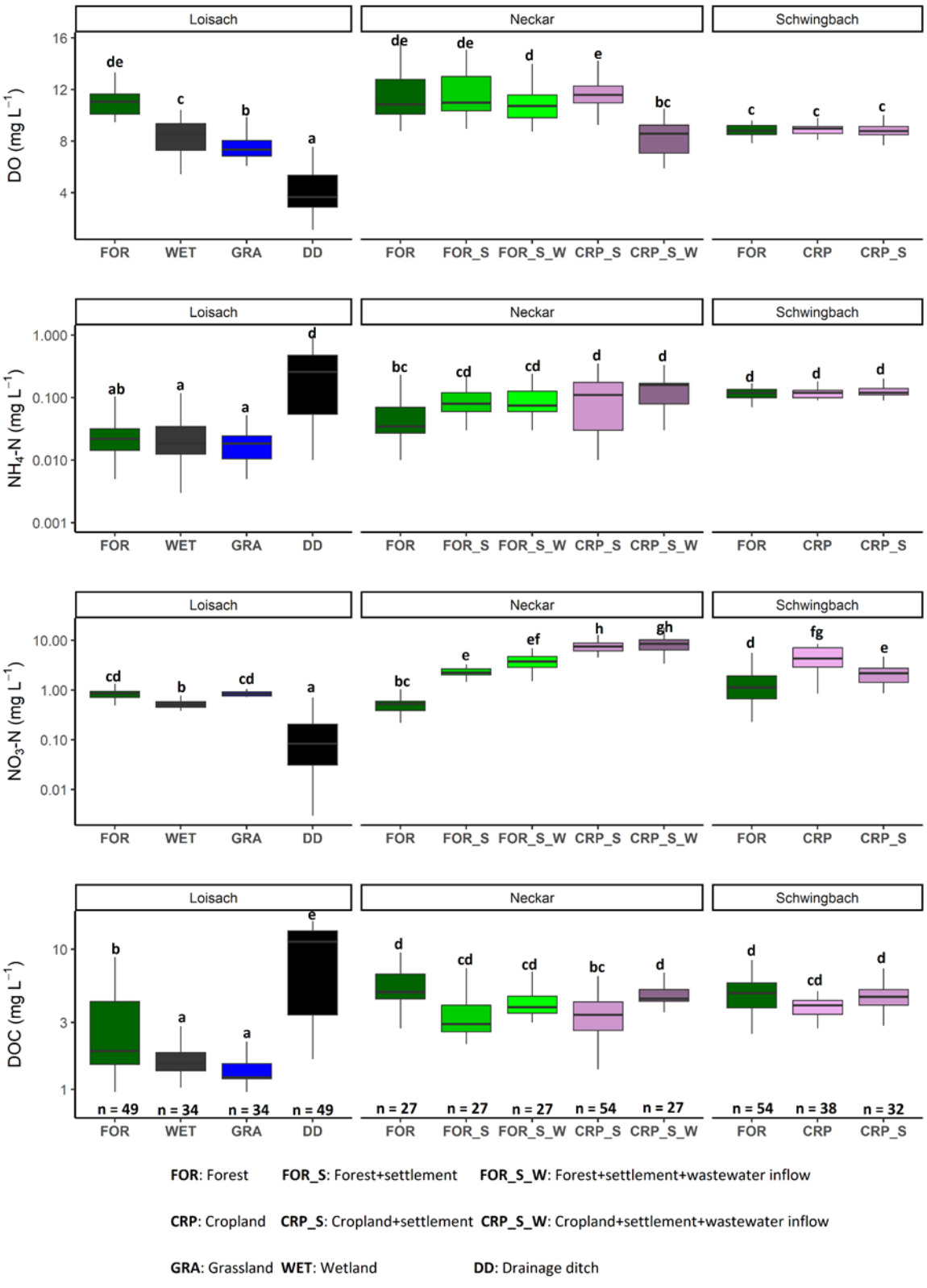
Response: Thank you for your question. Temperature and NH_4 were removed from the SEMs as they were insignificant. We have now clarified this in the results section.

"In contrast to all other variables, water temperature and NH_4-N mg L^{-1} did not contribute significantly (p-value>0.05) to the variance explained by the best-fit SEMs and were removed from the final path analyses (Table B4)."

Results:

F2. Consider using colors to represent major land-use classifications and shades to differentiate the sub-classifications. For example, crop, crop + settlement, and crop + settlement + WW inflow could be given different shades of the same color. Also, yellow is somewhat difficult to see on all these plots.

Response: Thank you for the suggestion. We have edited all the colors in our plots to reflect this suggestion.



I don't have the background to fully assess how the SEM analysis was applied but it seems to make sense and F5 is great.

Response: Thank you for the compliment. We also found it practical in explaining how multivariate drivers interact to drive the intra-annual trends in GHG concentrations.

I find the conclusion that typical stream order patterns break down in anthropogenically impacted streams interesting (L573-584). However, I don't see the data presented in the results section. Please include it here (and perhaps add to the abstract as well).

Response: Thank you for the observation. We have added this information in the results section and also in the abstract.

Abstract

"The positive influence of anthropogenic activities on fluvial GHG emissions also resulted in a breakdown of the expected declining trends of fluvial GHG emissions with stream size."

Results

" In addition to land use effects, we also examined spatial variability in the GHG concentrations and fluxes linked to stream order differences. We found tendencies of higher CO_2, CH_4, and N_2O concentrations and fluxes with increasing stream orders in the Schwingbach and Neckar catchments dominated by croplands and settlement areas. In contrast to the Neckar and Schwingbach catchments, GHG concentrations and fluxes in the more natural Loisach catchment decreased with stream order (Fig. A4). Comparing across catchments, higher stream orders (5&6) in the human-influenced Neckar catchment had higher or comparable GHG concentrations and fluxes than lower stream orders (1–3) in the Schwingbach and Loisach catchments(Fig. A4). "

Discussion:

Consider discussing the result that CO2 was the main contributor when emissions of all three gases are converted to CO2 equivalences (F6). I found this result to be interesting and perhaps it deserves more attention in the manuscript.

Response: Thank you for the observation. We have added a sentence at the beginning of the discussion to indicate this finding and further expanded on the fact that an increase in upstream human activities increased the contributions of the CH_4 and N_2O relative to CO_2.

"In agreement with previous studies, CO_2 accounted for most (>81 %) of the annual fluvial fluxes in CO_2 equivalents (e.g., Marescaux et al., 2018; Mwanake et al., 2022; Li et al., 2021). However, the presence of upstream agricultural and settlement areas seemed to alter these trends by reducing the contribution of CO_2 and increasing N_2O and CH_4 contributions. The effects of the above anthropogenic activities on aquatic GHG dynamics were twofold. Drainage ditches were landscape hotspots for CH_4 emissions, while increasing upstream agricultural and settlement areas resulted in fluvial N_2O hotspots."