Reply on RC1
Alexandra Klemme et al.

Author comment on "CO2 emissions from peat-draining rivers regulated by water pH" by Alexandra Klemme et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-13-AC1, 2021

Referee:
The manuscript by Klemme et al. presents a study explaining why tropical peat draining rivers are only a moderate source of CO2 to the atmosphere, which stands in contrast to what was assumed for global estimates. Klemme et al. test the hypothesis that decomposition and thus CO2 production in these organic C rich waters is limited by pH and O2 availability. For this, they use a comprehensive dataset of observations of DOC and CO2 concentrations, pH and other relevant physical and chemical parameters from SE Asian, peat draining rivers in combination with a conceptual model representing limitations of DOC decomposition by low pH and O2 concentrations. They find that DOC decomposition in those peat draining rivers is likely more limited by pH than by O2, and suggest that increased loads of carbonates due to agricultural liming or enhanced weathering could increase decomposition of DOC and thus CO2 emissions from those peat draining rivers.

The study is original and of great interest for the readership of Biogeosciences. The manuscript is well written, the methodology is clearly described, and results are clearly presented and support the main findings of this study. I suggest publication after minor revisions. Please, find my comments below.

Response:
We thank the reviewer for the work with our manuscript and are pleased about their positive response to the concept and findings of our study. The suggestions by the reviewer were very helpful and improved the manuscript.

Referee:
L15-17 : Other studies have shown that large amounts of CO2 evading rivers are actually put in as dissolved CO2 from soil respiration (both heterotrophic and root respiration) (Abril and Borges, 2019; Lauerwald et al., 2020). Maybe you should mention that source as well.

Response:
We included this suggestion in our manuscript. In the revised manuscript we state: » ... riverine CO2 is fed by decomposition of organic matter that is leached from soils (Wit et al., 2015) and by the leaching of dissolved CO2 from soil respiration (Abril and Borges, 2019; Lauerwald et al., 2020). «
Referee:
L17-18: These are actually not model based studies that would represent peat soils. Those are more upscaling studies that lacked observations from these important systems.

Response:
We realise that the use of the term "model-based studies" is imprecise. As the reviewer points out these studies do not include soil models but are based on upscaling. We corrected this and in the updated manuscript we state: » Despite scarcity in river CO2 measurements from Southeast Asia, studies suggest it as a hotspot for river CO2 emissions (Lauerwald et al., 2015; Raymond et al., 2013) due to the presence and degradation of carbon-rich peat soils. «

Referee:
L42: In peat draining rivers, is there also less instream production by algae that would otherwise be a source of O2 to the water column?

Response:
Indeed, low nutrient concentrations (Baum and Rixen, 2014) as well as the dark water colour of peat-draining rivers that limit the light availability to algae (Wit et al., 2015) cause low rates of instream production. This further decreases O2 concentrations within those rivers that due to the high DOC and the concomitant high O2 consumption by decomposition exhibit low O2 concentrations. In the corrected manuscript we state: » Due to high rates of decomposition caused by the carbon rich environment and low rates of photosynthesis due to low nutrient concentrations and dark water colours that limits light availability to algae, peat-draining rivers are usually undersaturated with regard to atmospheric O2 (Wit et al., 2015, Baum and Rixen, 2014). «

Referee:
L48-51: You should link these quite specific objectives here again to the more general research objective (or hypothesis to be tested): explain the moderate CO2 emissions from peat draining rivers by the effect of low pH and O2 limitation.

Response:
We included this as suggested. In the revised manuscript we state: » This study aims at quantifying the impact of pH and O2 on the DOC decomposition in peat-draining rivers in order to explain the measured moderate CO2 emissions from those rivers by the limiting effect of these parameters. «

Referee:
L95-97: I don't understand why you have used such a projection for determining areas. For that purpose, I would rather use an equal area projection, like an equal area projection after Lambert or the EckertIV projection.

Response:
Our phrasing at this point was misleading. We did not use the projection to determine catchment sizes but instead the Hydro-SHEDS data that our calculation of catchment sizes was based upon were provided in that geographical projection (Lehner et al., 2006). In the revised manuscript we rephrased this section to: » Catchment sizes were derived from Hydro-SHEDS (Lehner et al., 2006) at 15s resolution in WGS 1984 Web Mercator Projection. Subbasins belonging to the catchments were identified using the HydroSHEDS 15s flow directions data set and added to the main basins. «

Referee:
L110-112: The exponential limitation factor related to pH, which is defined as negative decadic logarithm of H+ activity - would that be comparable to a linear factor relating to
the H+ activity? That might be worth discussing here in one or two sentences.

**Response:**
The logarithmic pH relation in the exponential limitation factor is indeed striking. Yet, it would not result in a linear correlation with the H+ activity but with this activity by the power of the exponential constant \( \lambda \) divided by \( \ln(10) \), which for the rivers we studied results to approximately 0.2. We included this information in the revised manuscript. In the methods we state: » *Considering the definition of pH as negative decadic logarithm of H+ activity (\( \{H^+\} \))*, the exponential limitation factor can be written as \( \{H^+\}^{(\lambda/\ln(10))} \). « and in the discussion we write: » *The exponential pH coefficient is \( \lambda = 0.5 \pm 0.1 \). Thus, in terms of H+ activity the correlation is given by \( \{H^+\}^{(0.5/\ln(10))} \), which roughly equals the fifth root of \( \{H^+\} \). «

**Referee:**
L122-123: That would require that dissolved CO2 inputs via groundwater inputs and CO2 consumption by autotrophic production is negligible. These are strong assumptions that would be worth mentioning here explicitly and some discussion later on.

**Response:**
We included this suggestion. In the methods we state: » *This approximation assumes photosynthetic CO2 consumption and direct CO2 input from leaching to be negligible.* « and later on we include discussions in form of: » *For this study, we neglect the leaching of CO2 from soils as well as the consumption of CO2 by autotrophic production. Since CO2 leaching rates are high for peat soils and autotrophic production is limited in peat-draining rivers, both of these processes would work against the observed recession in CO2 growth. This indicates that exclusion of those processes could cause underestimation of the limitation factors rather than overestimation.* «

**Referee:**
L140: *“spatially as well as temporally”*

**Response:**
We changed this as suggested.

**Referee:**
Figure 3: The grey lines, are those regression fits or the 1:1 line, or both?

**Response:**
Those lines represent the 1:1 line. We included this information in the revised manuscript.

**Referee:**
For figures 3 and 4, it would be great if you could report in addition the RMSEs.

**Response:**
We included those as suggested.

**Referee:**
L184: There’s a “c” missing in “concentration”.

**Response:**
We changed this.

**Referee:**
L189-191: Do Borges et al. also report CO2 emission rates or CO2 concentrations which are comparable to those in your study?
Response:
Yes, the CO2 and DOC concentrations by Borges et al are comparable to the concentrations measured in our study. In the revised manuscript we included this information and state: » A similar pattern of stagnating CO2 concentrations has been observed in river sections of high DOC at the Congo river (Borges et al., 2015). The CO2 and DOC concentrations measured in these rivers are comparable to those measured in our study, indicating that the underlying process is valid not only for Southeast Asian rivers but for tropical peat-draining rivers in general. «

References:

Abril and Borges, 2019: Abril, G. and Borges, A. V.: Ideas and perspectives: Carbon leaks from flooded land: do we need to replumb the inland water active pipe?. Biogeosciences 16, 769–754 (2019).

Baum and Rixen, 2014: Baum, A. and Rixen, T.: Dissolved inorganic nitrogen and phosphate in the human affected blackwater river Siak, central Sumatra, Indonesia. Environment and Pollution 11, 13-24 (2014).

Borges et al., 2015: Borges, A., Darchambeau, F., Teodoru, C. et al.: Globally significant greenhouse-gas emissions from African inland waters. Nature Geoscience 8, 637–642 (2015).

Lauerwald et al., 2015: Lauerwald, R., Laruelle, G. G., Hartmann, J., Ciais, P., and Regnier, P. A.: Spatial patterns in CO2 evasion from the global river network. Global Biogeochem. Cycles 29, 534– 554 (2015).

Lauerwald et al., 2020: Lauerwald, R., Regnier, P., Guenet, B., Friedlingstein, P. and Ciais, P.: How Simulations of the Land Carbon Sink Are Biased by Ignoring Fluvial Carbon Transfers: A Case Study for the Amazon Basin. One Earth 3, 226-236 (2020).

Lehner et al., 2006: Lehner, B., Verdin, K., and Jarvis, A.: HydroSHEDS, Technical Documentation. Tech. rep., HydroSHEDS, version 1.0, 1-27, (2006).

Raymond et al., 2013: Raymond, P. A., Hartmann, J., Sobek, S., Hoover, M., McDonald, C., Butman, D., Striegel, R., Mayorga, E., Humborg, C., Kortelainen, P., Dürr, H., Meybeck, M., Ciais, P., and Guth, P.: Global carbon dioxide emissions from inland waters. Nature 503, 355–359 (2013).

Wit et al., 2015: Wit, F., Müller, D., Baum, A., Warneke, T., Pranowo, W. S., and Müller, M.: The impact of disturbed peatlands on river outgassing in Southeast Asia. Nature Communications 6, (2015).