RESPONSE TO REVIEWER 2

➔ General comments:

❒ **This paper estimates organic carbon (OC) burial and describes patterns in sediment methane concentration based on extensive sediment coring (114 cores over two time periods) in an oligotrophic Amazonian reservoir. The authors describe their data set as unique given 1.) the lack of studies that look at both organic carbon burial and methane concentration/emission dynamics and 2.) the lack of Amazonian studies focused on reservoir organic carbon burial. While there is a lack of organic carbon burial estimates from reservoirs (relative to the number of greenhouse gas emission estimates), I think the authors have somewhat overstated the novelty of their findings (at least in terms of the magnitude of OC burial they report). For example, I am confused as to why the authors classify their reported burial rates as "high" (e.g. in the title of the paper and elsewhere). The mean rate of 91 g C m-2 yr-1 they report appears to be more towards the lower end of the reservoir OC burial rates reported by Mendonca et al 2017 (looking at Figure 1 of that paper). Also, while studies that have looked at both OC burial and greenhouse gas emission are rare, the ones that exist should be discussed.**

Response: Thank you for the positive and constructive comments. The OC burial rate we found in Curuá-Una reservoir is high if compared with other tropical hydroelectric reservoirs. In fact, as we stated in the abstract, this is the highest OC burial rate in a tropical hydroelectric reservoir reported so far. The global study by Mendonça et al. 2017 included, as "reservoirs", agricultural ponds and fish farms, which usually have extremely high organic carbon burial rate, and which we do not compare with, because they are completely different systems in terms of hydrology and size. In order to make the context of the word "high" clearer, we added the word “hydroelectric” to the title, restricting the type of system we are focusing on. The title now reads: “*High organic carbon burial but high potential for methane ebullition in the sediments of an Amazonian hydroelectric reservoir*”. We also checked the entire text to make sure that the connotation of high burial applies in comparison to other hydroelectric reservoirs at low latitudes.

❒ **I recommend that the authors reference Jacinthe et al. 2012 and Teodoru et al. 2012 as part of this discussion.**

Response: Jacinthe et al., 2012 worked in a different climatic and geographic context, a reservoir in a temperate agricultural landscape, and we decided to keep the discussion limited to the context of low-latitude reservoirs (see also our reply to reviewer #1). We are now citing Teodoru et al., 2012 in the new discussion, even though it is a study of a reservoir in Canada, since it presents data on the balance between emission and burial, which has rarely been done. Adding to our study the emission estimate of Duchemin et al., 2000, we found that sediment C burial represented around 15% of C emission, while Teodoru et al., 2012 found that C accumulation represented around 10% of the reservoir emissions. Moreover, we are now using Stratton et al., 2019 to argue about OC burial variability in space and time and, consequently, the importance to represent different regions in the aquatic systems to estimate C burial.

<u>New References:</u>

Duchemin É, et al. (2000) Comparison of greenhouse gas emissions from an old tropical reservoir with those from other reservoirs worldwide. Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, 27(3), 1391-1395.

Stratton LE, et al. (2019) The importance of coarse organic matter and depositional environment to carbon burial behind dams in mountainous environments. Journal of Geophysical Research: Earth Surface.

❒ **Overall, I think this dataset is quite novel and worthy of publication, but the presentation and data analysis deserve more time and thought than has currently been invested. For example, the positive relationship between sediment methane concentrations and sediment OC burial (currently reported as a figure in the supplement) seems worthy of its own figure and of more interpretation.**

Response: Thank you for the suggestion. We have now made a separate figure for that in order to explore the relationship. Although the correlation is not very strong, we observed that a high burial rate was positively related to a high number of samples (as percentage of total samples in each core) above the CH_4 saturation concentration. Moreover, we are now splitting the Results and Discussion section, which allows a more comprehensive discussion of our findings (see also our reply to reviewer #1).

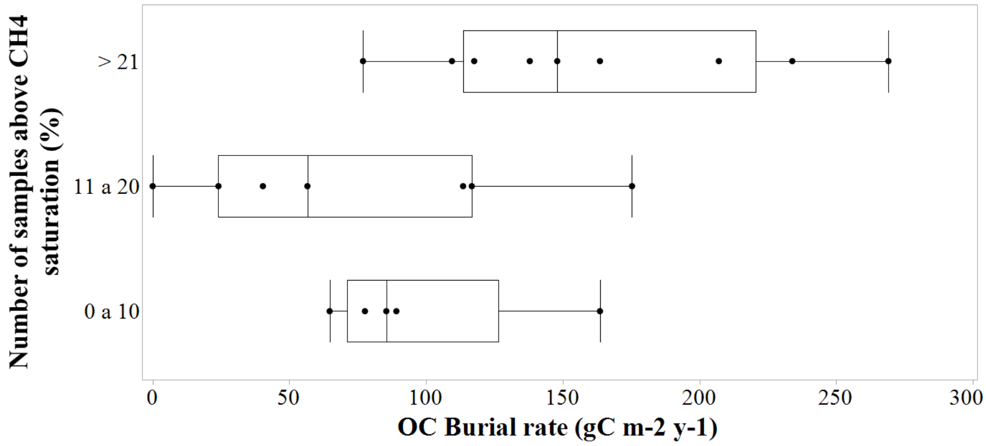

Figure. Boxplots of percentage of sediment layers with CH_4 concentration above saturation (%) and OC burial rate (gC m^{-2} y^{-1}).

❐ **It is also interesting that the sediment methane concentrations did not differ significantly between the rising and falling limb of the reservoir hydrograph. This finding could be highlighted more in the context of other work that has been done to look at water level as a driver of methane emission.**

Response: We agree and are now citing some papers (Mattson & Likens 1990; Eugster et al. 2011; Maeck et al. 2014) on the influence of water level or pressure changes on CH_4 ebullition in relation to this observation.

New References:

Mattson MD, et al. (1990) Air pressure and methane fluxes. Nature, 347(6295), 718.

Eugster W, et al. (2011) Eddy covariance flux measurements confirm extreme CH (4) emissions from a Swiss hydropower reservoir and resolve their short-term variability. Biogeosciences, 8(9), 2815-2831.

Maeck A, et al. (2014) Pumping methane out of aquatic sediments: Ebullition forcing mechanisms in an impounded river. Biogeosciences, 11(11), 2925-2938.

❐ **I am also surprised that the authors haven't placed their findings in the context of other work that has been done on Curua Una to estimate GHG emissions (Duchemin et al. 2000). Duchemin and colleagues estimated 42.5 mg CH4-C m-2 d-1 ebullitive + diffusive emissions, which could be compared to the C burial estimated in this study via CO2-equivalents.**

Response: In response to this suggestion, we have added a comparison of our findings to the emission estimate published by Duchemin et al. 2000. We added this information in the manuscript: "*The OC burial rate found in CUN is high comparing to other tropical hydroelectric reservoirs (Sikar et al., 2009; Kunz et al., 2011; Mendonça et al., 2014). However, our OC burial estimate represents only 15% of the total carbon emission previously reported for the CUN reservoir (509 g C m^{-2} yr^{-1}, Duchemin et al. 2000). Similarly, a study conducted in a boreal Canadian reservoir found that OC burial corresponded to 10% of reservoir C emission (Teodoru et al. 2012). It seems that in both reservoirs, emission is much higher than burial, even though burial was about 10 times higher in CUN than in the Canadian reservoir (9.8 g C m^{-2} yr^{-1}).*

❒ **Line 22: add "and emitted" after "produced"... it is important to be clear that production is different than emission**

Response: We changed this sentence accordingly: "*Reservoir sediments sequester significant amounts of organic carbon (OC), but at the same time, high amounts of methane (CH_4) can be produced and emitted during degradation of sediment OC.*"

❒ **Lines 23-25: this sentence is rather vague and doesn't add very much to the abstract as currently written. I suggest highlighting the lack of studies that look at both OC burial and GHG emission in reservoirs with no studies focused in the Amazon**

Response: We changed the statement for: "*There is a lack of studies focusing on OC burial and GHG emission, with no studies in the Amazon. Hydropower is expanding in the Amazon basin and understanding its biogeochemical processes and impacts are crucial for decision makers*".

❒ **Line 34: change "indicate" to "suggest"**

Response: Changed accordingly.

❒ **Line 51: change to "estimates of"**

Response: Changed accordingly.

❒ **Lines 63-64: Maybe describe regions where there is a particular lack of OC burial data? Also, you might describe briefly the difference between total C burial and organic C burial somewhere here (since you are focused on organic C rather than carbonates).**

Response: Thank you for the comment. We will modify the sentence for: "*In particular, large regions of the Earth are at present completely unsampled concerning inland water carbon burial. Approximately 90% of the sites sampled for carbon burial are in North America and Europe, while there are only few measurements in South American and Asian countries (Mendonça et al. 2017).*"

Our study focused on organic carbon burial because of its importance to carbon sequestration and CH_4 production in inland waters. We make sure that this is clear in our text and we prefer not to mention the carbon fractions that were not studied or discussed in the paper.

❒ **Line 86: The fraction of methane that is emitted via ebullition vs. diffusion varies from system to system (where ebullition is not always the dominant pathway).**

Response: We have changed the wording of this sentence (see also our reply to reviewer #1), to become more balanced as to the relative magnitude of emission pathways. The sentence now reads: "*However, in many reservoirs, CH_4 ebullition (i.e., gas bubbles) is an important or dominant emission pathway, but it is very difficult to measure due to its strong variability in space and time (McGinnis et al., 2006; Deemer et al., 2016).*"

❒ **Line 95: First whole-reservoir OC burial estimate in what context? In an Amazonian**

reservoir? Clarify.

Response: This sentence was clarified to: "[…] *to present the first whole-reservoir OC burial estimate and the first mapping of concentrations of* CH_4 *in sediment pore water in an Amazonian reservoir"*.

❒ **Lines 129-130: How did you spatially distribute the cores? Randomly? Stratton et al. 2019 is a good reference for the importance of sampling across multiple regions of the reservoir (which is not done often — more often burial estimates are collected from a single site/region).**

Response: We distributed the sampling sites in a way to have them approximately evenly distributed, covering the reservoir as much as possible, and taking samples from multiple regions, both longitudinally and laterally, as suggested by Stratton et al. 2019. We have clarified the text and added the reference.

❒ **Figure 1: I think the inset map would be more helpful for an international readership if the whole shape of South America was shown (rather than just Brazil).**

Response: We changed the figure accordingly.

❒ **152: change "exactly" to "exact" 154: omit word "approximately"**

Response: Changed accordingly.

❒ **Lines 166-168: What did you do after adding acid? Was this a qualitative test (looking for evidence of fizzing?) or did you re-analyze for C after adding acid?**

Response: This was a qualitative test and we added this information in the manuscript: "*The* *presence of carbonates was checked in the samples qualitatively by adding drops of acid, and no evidence of solid carbonates was found".*

❒ **Lines 179-188: Did you measure atmospheric CH4 concentrations here? More detail on the equations/calculations would be helpful.**

Response: Yes, we measured the atmospheric CH_4 concentration from air samples taken at the same location as the cores were sliced, and used as background in the calculations. More specifically, we subtracted the atmospheric CH_4 mass from the total CH_4 mass in the equilibration vials. We now added more details on the calculations to the methods section, as well as references of other studies that used the same approach (Sobek et al., 2012; Mendonça et al., 2016).

❒ **Line 181: I don't think it is necessary to mention "an R script" unless you are citing a specific existing R package.**

Response: Changed accordingly.

❒ **Lines 190-194: Again, equations would be helpful for describing how OC burial rates were calculated.**

Response: We now give the equations of these calculations in order to clarify (see also our reply to reviewer #1).

❒ **Line 205: The spatial analysis for pore water CH4 saturation and C:N was done with fewer data points right?**

Response: Yes, we had 25 sites for pore water CH_4 concentration and 19 for C:N ratio. However, the interpolation of pore water CH_4 or sediment C:N is only used for visualization, and not used for any quantitative analysis. In order to clarify, we added the sampling sites in the figures, as dots, and we mention in the “Data analysis” section that these interpolations are used for visualization only.

❒ **Lines 206-212: I’m unclear how the land cover data was used in this paper.**

Response: The land cover analysis was indeed underexplored in our manuscript. We now added more information on how we used land cover and on the results we found. We checked if land cover (which is different for the different sub-catchments of the reservoir) has an effect on the spatial distribution of OC burial, CH_4 saturation and C:N ratio. For that, we compared the land cover in the different sub-catchments of the reservoir with the sediment variables along the respective reservoir arm. We found that the arms with higher SAR and OC burial rate, as well as higher C:N ratio were in sub-catchments with higher percentage of managed areas.

❒ **Line 244-246: Why are they likely to receive larger sediment inputs? Higher catchment area: surface area ratios?**

Response: Curuá-Una is likely to receive large sediment inputs not only because of the large catchment area : surface area ratio (as of most hydroelectric reservoirs), but also because of the high percentage of forest that contributes with a large input of terrestrial carbon. Moreover, the managed areas in the watershed contribute directly with sediment due to the high vulnerability to erosion.

❒ **Line 288: Get rid of second “in”**

Response: Changed accordingly.

❒ **Line 301-302: See my general comments. This is not convincing as currently written. I think the authors need to show a breakdown of estimated OC burial by latitude or by climate zone to make this point more convincing.**

Response: It was not clear enough in the text that we are comparing in the context of tropical hydroelectric reservoirs. We will clarified this throughout the manuscript.

❒ **Line 331: Change "dominating" to "dominant"**

Response: Changed accordingly.

❒ **Line 334: The lack of a relationship between OC burial rate and C:N ratio is interesting.**

Response: It is indeed. Even though C:N ratio certainly affects OC burial efficiency (and, thus, OC burial rates), the relationship between them is masked by the strong effect of SAR on OC burial. We now discuss this issue more clearly in the revised Discussion.

❒ **Lines 337-339: This seems like a pretty ancillary comment and isn't very convincing the way currently written/visualized.**

Response: This statement is important to justify the lower C:N ratio in some regions of the reservoirs. We have clarified this in the revised manuscript.

❒ **Line 346: add "for" in btween "accounting" and "the"; Line 347: add "us" in between "allow" and "to".**

Response: Changed accordingly.

❒ **Lines 375-377: Seems like this information about linkages belongs in the**

introduction.

Response: We use this statement here to give background about our findings, for example, we observed that high burial rates were correlated with a high proportion of samples above the CH_4 saturation, which in turn increases the probability for ebullitive CH_4 emission. We therefore prefer to keep this information.

❒ **Line 383-392 and throughout: It would be helpful to more thoroughly describe to the reader why, in this case, you think the pool of CH4 in the sediment is indicative of the flux out.**

Response: We now more clearly state that a high share of gas bubbles is indicative for an elevated probability of CH_4 ebullition. We do not insinuate that the degree of pore water CH_4 saturation relates quantitative to ebullition flux, because ebullition flux to the atmosphere is also dependent on water depth, grain size, and pressure fluctuations.

❒ **Lines 388-389: Why not just use 100% saturation then? It makes it more comparable to other studies and less confusing.**

Response: We now use 100% as a saturation threshold, and state that because of the high likelihood of gas bubble loss during coring and sampling, the CH_4 concentrations reported are conservative (see also our response to reviewer #1).

❒ **Line 264: I haven't heard to term 'muddy lake area' before. Also, run-of-river reservoirs are probably ones where fine sediment is transported all the way to the dam.**

Response: In CUN, water retention time is low in the main river channel, which is narrow and well separated from the dead tree area, presumably permitting transport of fine sediment to the dam area. We moved the references concerning the term “muddy lake area” to right after the term is mentioned.

❒ **Lines 275-276: I thought you used spatial interpolation (not an average)?**

Response: The average OC burial from the interpolation (90.9 gC m^{-2} y^{-1}) was practically the same to the average from the coring sites (91 gC m^{-2} y^{-1}). We now use the average from the interpolation and we changed the text accordingly.

❒ **Figures 1, 2, and 4: I find the picture of the houses are awkward and I don’t think they really add much to the figure.**

Response: The houses are used for interpretation of spatial patterns, thus we prefer to keep them in the graph. However, we changed the picture of the houses and we hope you like it better.

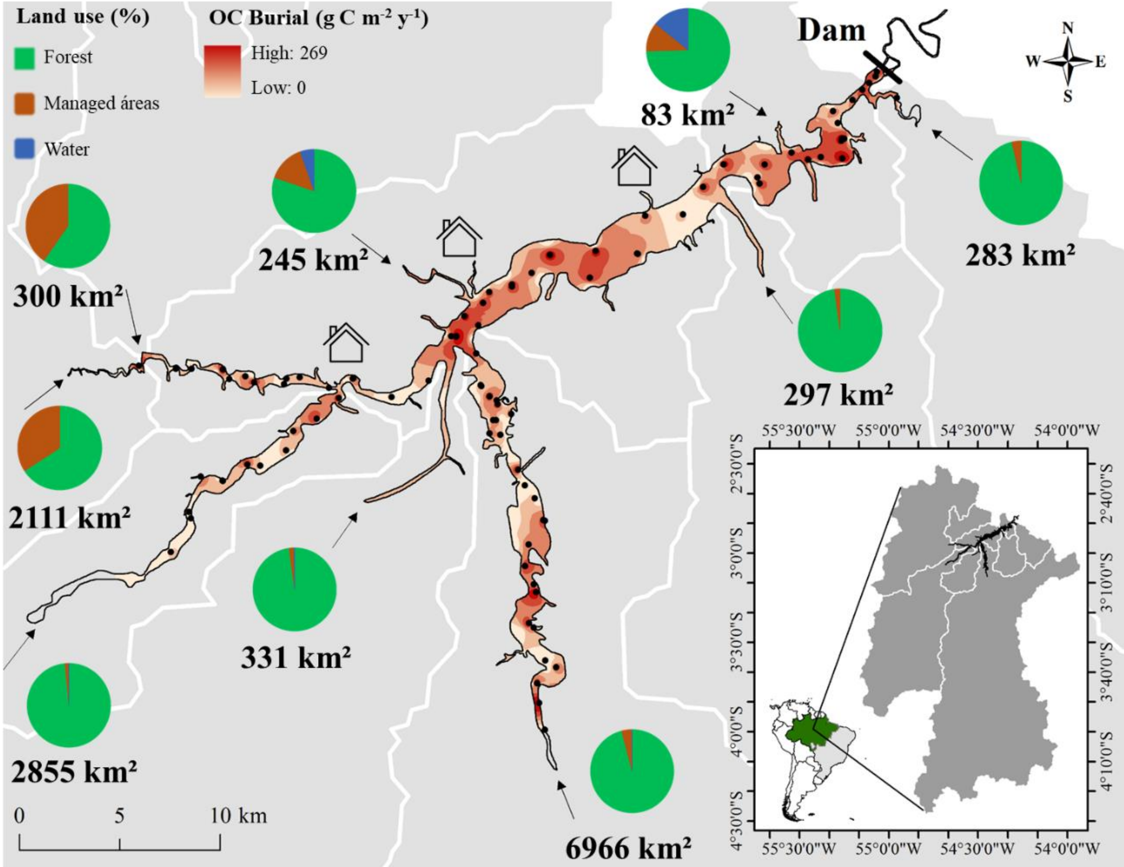

Figure 1. Organic Carbon Burial rate (OC burial; g C m^{-2} yr^{-1}) and land cover of Curuá-Una reservoir. The circles show the land cover of each sub-catchment. The numbers near the circles show the area in km² for each sub-catchment. The black dots represent the sediment sampling sites to estimate SAR and OC burial rates. The arrows represent the main rivers inflow. The house represents settlements at the reservoir. The bottom-right map shows the location of the reservoir in Brazil (the green area is the Brazilian Amazon region) and the total extension of each sub-catchment.