12 March 2025

Dear Editor,

Journal of Biogeosciences

We are pleased to resubmit our revised manuscript titled "Estimation of Particulate Organic Carbon Export to the Ocean from Lateral Degradations of Tropical Peatland Coasts" for further consideration in the Journal of Biogeosciences.

We sincerely appreciate your thoughtful review and the valuable feedback provided by the reviewers. We are grateful for the opportunity to revise our manuscript and for the constructive suggestions that have helped us improve the clarity and quality of our work.

We have carefully addressed the comments, and our detailed responses are provided in the submission file. The major revisions primarily involved the abstract and introduction, as well as the addition of new results in Sections 4.2, "Identification of the Timing of Peat Mass Movement Events," and 4.3, "Estimation of Coastal Retreat." Additionally, the methods and conclusions have been revised accordingly to reflect these changes.

We sincerely appreciate your time and effort, as well as those of the reviewers, in evaluating our work. We hope that the revised manuscript meets the expectations of the journal, and we look forward to your decision.

Best regards,

Hiroki Kagawa
Graduate School of Sciences and Technology for Innovation, Yamaguchi University
2-16-1, Tokiwadai, Ube, Yamaguchi 755-8611, Japan
Email: hkagawa@yucivil.onmicrosoft.com

My point-by-point responses are as follows:

RC1 Comments addressed:

Q1. First, to my understanding, this study is more like a study of remote sensing or GIS, rather than a biogeochemical study. The major works involved in this study is about feature (e.g. vegetation, and topography) recognition based on UAV and satellite images. Few biogeochemical analysis has been involved or revealed in this study. Maybe a journal of remote sensing is more suitable to this manuscript.

Response1.

We sincerely appreciated the time and effort you dedicated to reviewing our manuscript. We were grateful for your insightful comments and suggestions. Since the associate editor has expressed his support in his comments, I would like to respectfully submit the revised manuscript to Biogeosciences. However, as reviewer 1 pointed out, we acknowledge that there is a risk that readers may misinterpret this paper as focusing on land classification and edge detection techniques rather than POC flux estimation. Therefore, to address this issue, we have moved Chapter 3.6, Error Evaluation Method for Traced Coastal Erosion Areas and Landslide-Affected Areas in GIS Software (L304-316 in the preprint manuscript), to Appendix B.

Q2. Second, I am a bit worrying about the novelty of this study. The findings in this study depends strongly on the specific conditions of topography, vegetation, climate, tide and coastal wave. I don't think the POC loss rates due to coastal erosion at the current study site can be used as a reference for estimating the coastal POC loss rates in other places. So I am wondering whether this study has provided a vital or reliable implication for understanding global land-ocean POC fluxes. By the way, the authors should give a better discussion on the implications of this study.

Response2.

We greatly appreciated your valuable insights, which were extremely helpful in refining our manuscript. In response to your comments, we have made the necessary revisions to improve the clarity and comprehensiveness of our research. Our findings suggested that the occurrence of coastal erosion and PMMs in the study area was influenced by specific factors, including topography, vegetation, climate, tides, and coastal waves. Regarding PMMs, we added results from cross-sectional land surveys using RTK-GNSS, aerial photogrammetry, and NDVI, as well as a time series of SAR images, to better identify the timing of PMMs (see Sections 4.2 in revised manuscript). Furthermore, we incorporated results that determined the collapse timing in greater detail by analysing variations in precipitation and water level fluctuations associated with the breaching of the drainage channel. Based on these results, we included an explanation demonstrating that PMMs occur due to increased water levels following heavy rainfall. For coastal erosion, we included results on the cumulative long-term coastline retreat for different land-use types using SAR images (see Sections 4.3 in revised manuscript). Additionally, we presented results analysing the relationship between significant wave heights and maximum wind speeds during periods of accelerated coastline retreat. Based on these findings, we included results demonstrating that erosion intensifies during periods when monsoonal winds are predominant. Furthermore, we summarized and incorporated wind direction and speed observations from the study area in the form of wind rose diagrams. Given that progressive erosion and wave-induced coastal retreat have been studied in

this region, we added relevant references to strengthen our manuscript. Finally, in response to the comment that our findings might not be applicable for estimating POC loss rates in other locations, we emphasized that similar coastal erosion processes have been documented in peatlands worldwide (see Fig. 1and Introduction in revised manuscript). Boreal peatlands also contain extensive coastal peatland areas, suggesting that phenomena like those observed in our study may be occurring in other regions. To better contextualize our study, we incorporated a global peatland distribution map and examples of coastal erosion and PMMs from different parts of the world into the introduction section. Specifically, we added Sections 4.2 Identification of the Timing of Peat Mass Movement Events and 4.3 Estimation of Coastal Retreat to the Results and Discussion section. Additionally, we incorporated a map of the global distribution of peatlands into Fig. 1 in the Introduction to illustrate the widespread occurrence of peatlands adjacent to the coast. Furthermore, we reviewed studies on coastal erosion and PMMs in peatlands worldwide to provide a broader research context.

Q3. Third, an analysis on the environmental controls (land use change, climate change, see level rise?) of the interannual variation of peat mass movement and the POC export from land to the ocean is important to improve the novelty of this study, and will make this study better fit the scope of Biogeosciences. Unfortunately, I have not seen any analysis on the drivers of the peat mass movement and the POC loss.

Response3.

We greatly appreciated your valuable insights, which were extremely helpful in improving our manuscript. In response to your comments, we made the necessary revisions accordingly. As stated in Q2, we added results that clarified the characteristics of meteorological and water level fluctuations associated with PMMs in tropical peatlands. These findings were obtained through a combination of field surveys and remote sensing techniques, allowing us to identify the timing of PMMs and analyse the conditions under which they occurred. We also conducted a literature review and found studies reporting peat loss into rivers due to gully erosion in boreal peatlands. However, we were unable to identify any studies documenting the direct discharge of peat into the ocean due to PMMs, as observed in our study. However, the effects of climate change and sea level rise are still unknown on coastal erosion as well as PMMs because of the short observation period compared to the phenomenon of long-term change.

RC1 Specific comments addressed:

Q1. The Introduction section has not been organized well. The authors using a lot words to describe the importance and formation of peatland, however, the introduction on coastal erosion, in particular the coastal erosion of peat, is very weak. Moreover, the specific aims of this study should be provided in the last paragraph of the Introduction section.

Response 1.

Thank you for your valuable feedback. As you correctly pointed out, while our preprint manuscript explained the importance and formation of peatlands, it lacked a sufficient introduction to coastal erosion and PMMs. Your comments helped us recognize this weakness, and we revised the introduction accordingly. To address this, we first presented the global distribution of peatlands as of 2024. Following this, we introduced cases of coastal erosion affecting peatlands in Siberia, Canada, Alaska, and the Baltic Sea coast of northern Germany. In addition, we reviewed peatland degradation processes, peat landslides commonly studied in boreal peatlands, and a collapse example from Florida. Furthermore, we highlighted the potential for similar phenomena to occur beyond our study area. Reports on PMMs in tropical peatlands are limited, except for a documented case in 1966 along the Tutoh River in Malaysia. However, studies on wave-induced coastal erosion and collapse mechanisms have been conducted on Bengkalis Island, our study area, and we included a discussion of these findings. Finally, we revised the introduction to clearly articulate the objectives of our study. Specifically, we have added L66‑183 in the Introduction section.

Q2. Fig. 5: The current figure caption is lengthy. A figure caption should be like "Flowchart used in this study to ***"**

Response 2.

Thank you for your valuable feedback. As you have pointed out, we have revised the figure captions to make them more concise and clearer. Additionally, incorporating comments from other referees, we have adjusted the glossary and abbreviations to ensure they correspond accurately to the relevant captions for better clarity. However, this has resulted in slightly longer captions

Q3. L140-144: Why not include more satellite in different times? Is there any Google Earth image or satellite images for recent years after 2018?

Response 3.

In estimating the particulate organic carbon (POC) flux resulting from coastal erosion and PMMs in this study, it was necessary to use not only optical satellite imagery but also a Digital Terrain Model (DTM). However, the most reliable DTM data available was limited to 2018. Therefore, our analysis was constrained to data up to that year.

Q4. Fig. 12: What are the P01-P04 represent? Are they soil cores from different locations of the study area? Please provide a map of the soil collection sites.

Response 4.

The sampling locations in our study area are indicated in Fig. 4 of the manuscript. Additionally, a detailed explanation can be found in Section 3.1.8, Sampling and analysis of peat soils. We kindly ask you to refer to this section for further details. Additionally, we have revised the chart to incorporate color-coded axis labels, ensuring clearer differentiation of the data points.

Q5. Fig. 16: Why the unit of POC export rate per unit length is tC m^{-1}, rather than tC m^{-1} yr^{-1}?

Response 5.

As stated in Section 3.2.7, Estimation of POC Mass by PMM Event and Estimation of POC Flux Due to Coastal Erosions, from L345 onward in the preprint manuscript, "The POC mass from the displacement of peat mass caused by PMMs was not evaluated by flux because PMMs are sudden events. Therefore, discharged POC mass by PMMs was calculated based on the areas that had already collapsed by each observation date." For this reason, the unit is expressed as tC m^{-1}. In addition, since there are no studies on boreal peatlands that express collapse volume along a time axis, we have added the following sentence from L521 to 523 in the revised manuscript: " In general, peat mass movements in boreal peatlands only uses the unit without time such as m^3 or tons to evaluate the magnitudes of these events."

RC2 Specific comments addressed:

Q1. Abstract: I recommend rephrasing the abstract to follow a logical flow: background, objective, methods, results, and conclusions. Currently, the abstract jumps directly into specific findings without providing sufficient context or framing the significance of the study.

Response 1.

We sincerely appreciated the time you dedicated to reviewing our manuscript and your insightful comments and constructive suggestions, which were invaluable in improving our work. As you rightly pointed out, the abstract in the preprint manuscript primarily focused on the specific findings of our study. In response to your suggestion, we revised the abstract in the revised manuscript to follow a logical structure that includes background, objectives, methodology, results, and conclusions. This restructuring has enhanced clarity and better highlighted the significance and context of our research. Thank you once again for your valuable feedback and for guiding our manuscript in a better direction.

Q2. Abstract: The unit abbreviations in the abstract are inconsistent and confusing. Please define all units clearly and maintain consistent terminology throughout.

Response 2.

Thank you for your valuable feedback. We identified the inconsistency in the use of "m" or "metre" and "ha" or "hectare" in the manuscript. We have revised these terms to ensure consistency throughout the text. We appreciate your attention to detail and your helpful suggestions.

Q3. Introduction: Major concern: While the introduction focuses on the important role of peatland erosion in carbon cycling, the paper seems to be centered on using spatial data and machine learning to get barren land area estimation and land displacement due to erosion. I suppose it would be better you emphasized more on coastal erosion in the introduction section.

Response 3.

Thank you for your insightful comments. As you have correctly pointed out, our introduction primarily focused on the importance of peatlands and their role in the carbon cycle. However, it lacked a comprehensive review of previous studies on coastal erosion and PMMs, and did not provide sufficient detail on coastal geomorphological changes. To address this, we revised the introduction to include a more thorough review of relevant studies on coastal erosion and PMMs. By incorporating similar research on these phenomena, we provided a broader global context for understanding the processes driving POC flux due to coastal erosion and PMMs. We revised the manuscript to present the global distribution of peatlands as of 2024. Following this, we introduced cases of coastal erosion affecting peatlands in Siberia, Canada, Alaska, and the Baltic Sea coast of northern Germany. In addition, we reviewed peatland degradation processes, peat landslides commonly studied in boreal peatlands, and a collapse example from Florida. We sincerely appreciated your valuable feedback, which helped improve the clarity and comprehensiveness of our manuscript.

Q4. Introduction: The introduction generally talks about land erosion in carbon cycles; however, the object of this study is the lateral exported OC from peatland through coastal erosion. I suppose it would be better to emphasize more on the role of coastal erosion in carbon cycling, and the possible fate of these carbon in the marine environment. I would also recommend authors emphasize the importance of peatland as it has been done in the introduction.

Response 4.

Thank you for your valuable feedback. As your comment was like the point raised in Q3, we recognized the need to elaborate further on how coastal erosion and PMMs contribute to carbon export toward the marine environment while emphasizing the importance of peatland degradation in the carbon cycle. Additionally, regarding the question of how carbon behaves in the marine environment, we addressed this topic in both the introduction and the section 4.6 to provide a more comprehensive explanation.

Q5. Introduction: The Introduction is not well-structured; I recommend authors improve the logical connections between each paragraph, and each paragraph should have a topic sentence or idea to follow.

Response 5.

Thank you for your valuable feedback. In response to your comments, we restructured the introduction to improve its logical flow and coherence between paragraphs. We appreciated your insightful suggestions, which helped us strengthen the overall structure and presentation of our manuscript. Specifically, we restructured the introduction by first presenting peatlands and their significance, followed by an overview of tropical peatlands, the challenges identified in these regions, a literature review on the global prevalence of these challenges, a review of global research on POC discharge, and a clearer articulation of the study's objectives.

Q6. Line 29-42: The authors provide some numbers of OC stock of peatland; I would recommend making a comparison to global soil stock to emphasize OC stock in peatland is important. Besides, the net radiative force seems not to be useful information in this context.

Response 6.

Thank you for your valuable feedback. While providing a precise estimate of the global peatland stock may be challenging, it is possible to present the current distribution of peatlands as of 2024. Therefore, we have revised the manuscript to include a representation of the global peatland distribution in the introduction, as shown in Fig. 1. Additionally, we have included the proportion of peatlands relative to the Earth's land area in the introduction. We have removed the sentence corresponding to: "Besides, the net radiative force seems not to be useful information in this context."

Q7. Line 47: Does peat fire a major concern of your study? I would delete irrelevant information.

Response7.

Thank you for your valuable feedback. We recognized that the introduction should provide a more detailed discussion of coastal erosion and PMMs on a global scale. In response, we removed the explanation of peatland fires from the introduction and instead incorporated a more comprehensive review of global coastal erosion and PMMs. This revision has clarified the context of our study and better positioned it within the broader research landscape. Specifically, as you pointed out, we deleted the sentence at L47 in the preprint manuscript, added Fig. 1 as included in the revised manuscript, incorporated L66‑183, and revised the introduction to focus on coastal erosion and PMMs.

Q8. Line 49: Is the number reported by Ludwig et al., 1996 consistent with the number reported by Galy et al., 2015? The units are switching between the global and local studies; no meaningful comparison was made to emphasize the importance of local export of POC from land.

Response8.

As you have correctly pointed out, the units are different. Therefore, the area of the target watershed reported by Galy et al., 2015 has been added at L167 - 168 in the revised manuscript.

Q9. Fig. 2: Does the ocean's water level always remain lower than the peaty debris fan? Based on Figure 1, seawater appears to reach the peat layer. Please clarify this.

Response9.

Thank you for your valuable feedback. Based on the tidal observations conducted using ADCP at the boundary between the Strait of Malacca and the Strait of Bengkalis in our study area, we have revised the conceptual diagram to better reflect the actual conditions. Specifically, we have added the HWL, MSL, LWL, and clay layer thickness to Fig. 3 at L194-201 in the revised manuscript.

Q10. Methods: Major concern: While the methods section provides detailed information, its length can mislead readers into thinking the paper focuses on land classification and edge detection techniques rather than POC flux estimation. I suggest moving detailed methodological descriptions to the supplementary materials to improve focus.

Response10.

Thank you for your valuable advice. As you rightly pointed out, we recognized the risk that readers might misunderstand aspects that should not be misinterpreted in this study. Therefore, we moved Chapter 3.2.6, Error Evaluation Method for Traced Coastal Erosion Areas and Landslide-affected Areas in GIS Software (L304-316 in the preprint manuscript), to Appendix B.

Q11. Methods: The image data used in this study come from sources with varying resolutions. Since accurate volume estimation is critical, assessing the uncertainty associated with the methods is essential. Although the authors conducted an uncertainty analysis for data with differing resolutions, have they cross-compared data from the same time window but with different resolutions? This could help validate the accuracy of the method.

Response11.

Thank you for your insightful comments. We greatly appreciated your suggestions, which we believe have helped improve the accuracy and representation of our research. We evaluated the errors caused by differences in resolution using satellite images from Landsat 8 and Sentinel-2 acquired simultaneously (n = 7). For this evaluation, we conducted 20 tracings per time for

comparison. Landslide-affected areas captured at the same time were manually traced using Landsat 8 with a 30 m resolution and Sentinel-2 with a 10 m resolution, and the error was assessed. Specific details are provided in Appendix C.

Q12. Detailed comments: Please combine Fig. 3 and Fig. 4.

Response12.

Thank you for your valuable advice. As you rightly pointed out, we have integrated them as shown in Fig. 4 of the revised manuscript at L220. Additionally, we have separated the areas surveyed and analysed through field surveys and remote sensing, revising them as Fig. 4b and Fig. 4c. Furthermore, we have included the areas that were additionally analysed to incorporate the referee's comments.

Q13. Please associate Table 1 with Fig. 5, such as writing in the captions.

Response13.

Thank you for your valuable feedback. As you rightly pointed out, we have revised the glossary and abbreviations to ensure they correspond accurately to the relevant captions, enhancing clarity.

Q14. Results and Discussion: Major concerns: This section primarily presents results rather than engaging in insightful discussion; it puts a lot of effort into presenting the results on land evolution and estimating the eroded volume. It briefly touches on POC export to the ocean through coastal erosion in Section 4.4 but lacks a deeper discussion.

Response14.

We recognize that this comment is like Q15. To further our discussion, we have included a comparison of POC fluxes in tropical humid region watersheds in Section 4.4 of the preprint manuscript. Additionally, in the revised manuscript, we have updated Fig. 25 to include the estimated carbon exports from biodegradation, coastal erosion, PMMs, and groundwater for the target watershed of this study.

Q15. In Section 4.4, there is insufficient comparison to meaningful reference values that could emphasize the significance of the rate or amount of organic carbon (OC) exported via erosion. Additionally, whether these localized findings have broader implications for peatland coastal erosion globally is unclear. Another important consideration is the timescale: how do they align when comparing CO_2 emissions from peatland degradation to exported OC? It is also important to note that peat-derived OC may oxidize during transport before being buried on the ocean floor. This oxidation could lead to additional CO_2 release into the atmosphere, meaning that exported OC is not equivalent to the amount ultimately buried. My suggestion is to focus on comparisons with data from other regions around the globe to

help readers understand the significance of the reported values. Following this, discuss the potential fate of the exported OC and its role in the global carbon cycle.

Response15.

Thank you for your important insights. We recognize that to convey the broader significance of our research, it is necessary to illustrate the global relevance of our local findings in the context of peatland coastal erosion. To address this, we have added a global peatland distribution map to Fig. 1, along with examples of coastal erosion and PMMs from different regions, highlighting the global distribution of peatlands adjacent to coastlines. In Bengkalis Island, our study area, exposed peat cliffs undergo oxidative decomposition, while floating peat particles degrade in the marine environment, and deposited peat accumulates and decomposes on the seabed. These represent possible pathways for peat degradation. Regarding the fate of POC during transport to the ocean, we added literature showing that oxidative decomposition occurs during the Amazon River transport of biospheric carbon from lowland ecosystems, resulting in the release of CO_2 into the atmosphere. However, the fate of peat-derived POC in marine environments are still lack of knowledge and data. In the revised manuscript, we have updated Fig. 25 to include the estimated carbon exports from every sources. However, the fates of peat derived POC in the marine environment did not include.

Q16. Detailed comments: Fig. 12: Please use color-coded axis labels for different data.

Response16.

Thank you for your valuable advice. In response to your suggestion, we have revised the axis labels in Fig. 21 at L752 of the revised manuscript to use color-coded labels corresponding to different datasets for improved clarity.

Q17. Line 476-477: This statement is not right; it primarily depends on the sediment accumulation rate.

Response17.

Thank you for your insightful comments. There was a possibility that I had misunderstood the literature. Therefore, I carefully reviewed the relevant references again and made the necessary corrections accordingly.