6 February 2025

Dear Editor,

Thank you for reviewing our revised manuscript. We sincerely appreciate the thoughtful suggestions and detailed comments provided by the two Reviewers that were helpful in improving the clarity of our manuscript, and we are pleased to address the minor revisions necessary for this manuscript to be published in SOIL. We agree with the Reviewers' general and specific technical comments and suggestions and believe we have addressed all of the comments in the revised manuscript. We also thank the Topic Editor, and we hope that our revisions will allow you to recommend the manuscript for publication.

Below, we provide our point-by-point responses to the referees' suggestions and comments, with the line numbers corresponding to the marked-up manuscript version. According to the key points that you summarized in the decision letter, the title has been shortened, and the methods section has been supplemented with additional clarifications regarding the sampling and laboratory procedures. We believe that the results and discussion sections have been significantly improved by incorporating the referees' feedback. The concluding section of this manuscript has been enhanced to better summarize the findings of this study and to include remarks for future research.

Reviewer's comments are in black text. Our responses are in blue text.

Thank you for your time and consideration.

Sincerely,

Eunji Byun (On behalf of authors)
Department of Earth System Sciences
Yonsei University, Seoul, Korea

Responses to Reviewer #1

The authors investigate the effects of nutrient enrichment on soil CO2 and CH4 production in peatlands in Canada. This is a revised version of the manuscript. The authors answered the reviewers' questions and took their comments serious. Overall, the manuscript clearly benefited from the revision. There are still some flaws that need to be revised, but the manuscript is now well structured and clearly addresses its limitations.

We greatly appreciate your previous comments and this review and suggestions, which have improved the quality of our study. The revised version of the manuscript has been further improved by addressing the additional comments and detailed suggestions, as well as those by Reviewer#2. Kindly refer to the following for detailed responses to your comments.

See my detailed comments below (line numbers refer to the revised manuscript w/o track changes):

Title:
The title fits much better now. However, as SOIL asks the title to be "concise but informative", you might shorten it a little.

Completed. Thank you for your feedback. We have revised the title to "Effects of nitrogen and phosphorus amendments on CO_2 and CH_4 production in peat soils of Scotty Creek, Northwest Territories: Potential considerations for wildfire and permafrost thaw impacts on peatland carbon exchanges"

Abstract:
l. 16 I wonder if "anthropogenic emissions" is the correct expression here - as you are primarily interested in inputs into the soil.

Completed. Thanks for your comment. As the reviewer suggested, "anthropogenic emissions" here may be ambiguous in this context, so we have changed it to "anthropogenic inputs" in the revised manuscript [l. 17].

l. 24 You don't need "a series of" here.

Completed. Thanks for your suggestion. Corrected [l. 25].

l. 25 "...both...together" is redundant.

Completed. Thanks for noting this. We have revised the sentence to "dissolved N and P together" for clarity [l. 26].

l. 31-32 I suggest to omit the last sentence here. It is not necessary to state in the Abstract that further investigation is needed.

Completed. Thanks for your comment and we agree with you. We have deleted the previous version of the last sentence in the Abstract ("Our preliminary … requires further investigation.")

but instead added a different point (according to the Referee #3's suggestion) in the revised manuscript [l. 32-36].

Introduction
l. 36 I suggest "...across these regions..." - so that this part clearly refers to the subarctic regions you named before.

Completed. Thanks for your suggestion. Corrected in the revised manuscript [l. 40].

l. 35-37 This is still confusing. I already asked in my first review why you first name "subarctic regions" and then name western Canada, Siberia and Alaska in addition - as if these regions are something completely different. What is your point here? Do you want to express that these regions are particularly affected by wildfires? Or do you want to express that it is not only the subarctic that is affected? Please revise this sentence and clarify it.

Completed. Here, our aim is to connect the effects of permafrost thaw (and overlying peatland collapse) on carbon loss with the potential additional (and potentially severe) impacts of wildfires. While the permafrost thaw and peatland collapse are considered widespread phenomena across the subarctic regions (due to global climate warming), the recent occurrences and trends of wildfires are more complicated due to many factors, including hydroclimate, fuel load, and ignition source dynamics. We do not intend to say that the wildfires are increasing across the subarctic regions overall, as some parts may present different patterns in fire activity depending on how it is defined (*e.g.,* focusing on its extent, severity, frequency, and others). Thus, here we refer to these specific studies that have recently reported the increased cases of wildfire activities for each mentioned region, rather than proposing a general increase of wildfires for the entire region.

Given the comment, we have revised the sentence for clarity as follows:

"While permafrost thaw and peatland collapse is rapidly expanding across these regions (Porter et al., 2019; Quinton et al., 2019; Hugelius et al., 2020), some parts of the northern boreal and subarctic regions, such as western Canada (Gibson et al., 2018), Siberia (Talucci et al., 2022), and Alaska (Mekonnen et al., 2022), have also experienced increased wildfire activity in recent years likely further altering the effects of permafrost thaw on soil carbon stability" [l. 39-43].

l. 45 I suggest to omit "even" and rephrase the second part of this sentence: "...with high P concentrations persisting for several years..." or something similar.

Completed. Thanks for your comment. As suggested, we have omitted and rephrased accordingly in the revised manuscript. "… with high P concentrations possibly persisting for several years after a fire …" [l. 51-52].

l. 57 "poor-nutrient ecosystem" is not a common term. I suggest to rephrase it: "ecosystems poor (or low) in nutrients".
Completed. Thank you. We have rephrased the sentence to "While peatland soils tend to be generally poor in nutrients such as N and P, the magnitude of nutrient limitation of the soil microbial community …" [l. 63-64].

l. 60 I suggest to replace "comparatively" by "in comparison" or something similar.

Completed. Thanks for your suggestion. Replaced in the revised manuscript [l. 66].

l. 70 "...a lont-term P inputs"?

Completed. Thank you. We have revised to "P supply" according to the original study's terminology [l. 77].

l. 73 It should be either "...of the peatland ecosystem there" or "...of these peatland ecosystems".

Completed. Thank you and we have revised the sentence to "…of the peatland ecosystem there" [l. 80].

l. 76 In this context, "material" is usually used as plural form. And I guess it should be "...as substrate".

Completed. Thanks. We have revised it accordingly to "organic material" and "carbon substrate" [l. 82].

l. 82-83 I suggest to rewrite this sentence to better connect it with the previous one: "To address which strategy is activated, laboratory soil incubation experiments..."

Completed. We have revised the sentence to: "To address which strategy is activated, soil incubation experiments provide one approach to measure the changes in carbon gas production rates and net microbial biomass changes" [l. 88-90].

Methods
l. 107-110 You should add information on your sampling approach here. You only mention "shallow peat cores" that "were taken". Only in the next paragraph you mention the liners.
What type of liner did you use?

Completed. The liners were made of transparent plastic material from AMS, Inc. We have added this information in the Methods section of the revised manuscript [l. 115-116]. "The peat cores were collected in transparent plastic liners (3-inch inner diameter, AMS, Inc)."

l. 117 Do you mean "...to preserve initial porewater released upon..." here?
Completed. Yes, and this has been now corrected in the revised manuscript [l. 124].

l. 123, 124 You should not start a sentence with an abbreviation.

Completed. Corrected not to start with TOC, TN, or TP [l. 129-132].

l. 127 You should introduce abbreviations first (here: ICP-OES). Is there a reason you changed it during the revision?

Completed. Thanks for noting this. No, this was a mistake that occurred during the earlier revision. We have re-checked the whole manuscript to identify all abbreviations at their first occurrence [l. 134-135].

l. 146 No comma needed here.

Completed. Removed [l. 154].

l. 165-167 You changed the temperature every three days and performed gas sampling every third day after the chamber was set to a new temperature? Does this mean you performed gas sampling more or less at the same time as the temperature was changed? Please clarify.

Completed. Thank you for this comment: We collected the gas samples and then changed the temperature. This has been corrected in the revised manuscript to explicitly state "after" in the sentence [l. 176].

Results and Discussion
l. 250-253 Equations and approaches (including explanations) should be mentioned in the Methods section.

Completed. Thanks for your suggestion. We have now moved them to the Methods section [from l. 266-270 to l. 235-239].

l. 254-2554 "...except for the only N addition" sounds strange, please rephrase. Only "...except for N addition to the bog soil" should be fine.

Completed. Thanks for your comment. It was written this way during the previous revisions, as it may be confusing for some readers (*e.g.,* whether N addition includes the case of both N and P addition). After some additional thought, we have decided to change it according to the current suggestion, as it should be obvious enough in Table 2 [l. 272].

l. 258 Again, you don't need "N only addition" here - you introduced N addition, P addition and NP addition. This is sufficient to distinguish between the treatments.
Completed. Thanks for your suggestion. We have revised this in the manuscript [l. 275].

l. 314 Same here.
Completed. Thanks for your suggestion. We have revised this in the manuscript [l. 332].

l. 337 "...could best enhance..." sounds not very scientific. I suggest to replace best here by some expression that indicates that NP addition enhanced microbial CUE the most.

Completed. Thank you for this comment. The sentence has been revised, addressing the comment below [l. 355-356].

l. 337 Please avoid "...while...while..." constructions within one sentence.

Completed. Thanks for your comment. We have revised the sentences to: "The largest net microbial biomass growth was observed with the NP addition in the bog peat, presumably because of enhanced assimilation of DOC instead of auxiliary respiration (Giesler et al., 2011; Manzoni et al., 2012; Sinsabaugh et al., 2013; Lin et al., 2014). This is consistent with the reduced CO_2 production observed following the NP addition (Fig. 3), despite the larger drop in DOC relative to the N and P additions (Fig. 4). Overall, this implies that NP addition promoted the degradation of soil organic carbon that, under the anaerobic conditions in the soil environment, resulted in the higher cumulative CH_4 production" [l. 353-360].

Figure 4 Please take care that captions include all necessary information needed to understand the figure, this includes abbreviations.

Completed. Thanks for your suggestion. We have revised the caption accordingly [l. 365-367].

Table 4: Same here. Please check all captions if they include all necessary information.

Completed. Thank you for this comment. We have revised the captions to clarify and include necessary information [l. 380-381].

l. 371-384 Obviously, something went wrong with formatting here.

Completed. Thanks for noting this. Yes, it was a formatting error, which has been now corrected [l. 392-393].

Future research suggestions
I'd suggest to replace this part by a conclusion of your work that includes future research suggestions.

Completed. Thanks for your suggestion. In the revised manuscript, the following paragraph summarizing the main results of this study has been added, followed by suggestions for future research, and the title of the section was changed to 'Conclusions' [l. 407-413].

"This study demonstrated that the addition of dissolved N and P to short-term laboratory soil incubations causes changes in microbial C, N, and P cycling with marked differences between fen and bog peat soils. The added availability of dissolved N and P changes the temperature sensitivity (Q_{10}) of the soil carbon gas production rates, with an overall decrease in apparent Q_{10} values, which we attribute to a compensatory effect of microbial activity under low-temperature conditions. Given the vast amount of organic-rich peat deposits in northern permafrost regions, where the landscape is rapidly thawing and increasingly experiencing wildfires, scaling up potential perturbations of increased nutrient N and P inputs and changes in nutrient ratios, as well as the long-term consequences for peatland-atmosphere carbon exchanges, will require further research."

l. 385 As far as I understand it, a pulse is something that recurs periodically - so something different than a one-time addition.

Completed. Thanks for your comment. We have now removed "pulsed" from the sentence in the revised manuscript. [l. 416]

l. 393 I guess with "pulsed" you mean a one-time input in contrast to the continuous input. I suggest to replace it (compare my comment to line 385) as it is too easy to be misunderstood.

Completed. We have revised it to "one-time" in contrast to the continuous input. [l. 424]

Responses to Reviewer #3

I enjoyed reading the manuscript and I found the study well-designed and the manuscript overall written well and definitely worthy consideration for publication. It still, nevertheless, requires some careful revision and (sometimes) restructuring, to better lead the readers through the complex methodology and comprehensive (hence, also confusing) results and especially discussion. I recommend the manuscript for publication, after a further revision, and I encourage the authors to complete the great task they started so well. Please see my more detailed comments below:

Thank you for your careful review and positive and constructive feedback on our study. We have carefully addressed each of your comments and made the necessary revisions to improve the manuscript as well as improved the clarity and structure of the methods, results, and particularly the discussion sections. We sincerely appreciate your insights, which have contributed to improving the quality of our work, and we hope the revisions address your concerns effectively. Please refer to the following sections for detailed responses to your comments.

Title: I find is somewhat long, even though I understand it was corrected based on previous comments. Nevertheless, it is strikingly informative, so I suppose it is mostly for the editor and the authors to decide if to leave it so long or maybe cut the last part following the colon.

Completed. As it was also suggested by Reviewer#1, we have carefully considered the suggestions for the revised title and decided to shorten it to: "Effects of nitrogen and phosphorus amendments on CO_2 and CH_4 production in peat soils of Scotty Creek, Northwest Territories: Potential considerations for wildfire and permafrost thaw impacts on peatland carbon exchanges"

Abstract: overall well written, well summarises the project and presents its aims. The only sentence I would recommend reconsidering is the last one – all our studies are not final, and more research can always help, but I doubt this is the only strong conclusion you can make out of this experiment. I can see that in the previous round of reviews you received some harsh criticism, which I found unmerited. Your findings have an important value and should have a corresponding concluding sentence in the end of the abstract.

Completed. Thanks for your comment and your positive feedback is much appreciated. We have omitted the last sentence of the abstract according to the Reviewer #1's recommendation and added a concluding sentence as: "Our results demonstrate that porewater nutrient availability and soil carbon cycling interact in complex ways to change CO_2 and CH_4 production rates in peatland soils,

with potentially far-reaching implications for the impacts of wildfires and permafrost thaw on peatland-atmosphere carbon exchanges" in the revised manuscript [Lines 34-36].

Introduction: overall good, I only have one comment related to Table 1 and the style of presenting the references
Line 45. I would contest the need of the Table 1 to prove your point here, and I would recommend moving the table to supplementary materials. While the table shows important examples of nutrient enrichment after wildfires, it is sightly out of scope for your study's objectives, and I doubt you must have it there, in the main text, to justify your experiment. You are doing an excellent justification with your introduction text already. I would rather focus on more clear presentation of the references for the first sentences of this paragraph.

Completed. We appreciate this point and have revised the related sentence for a better connection with the references by removing the phrase to connect in with Table 1 [Line 52]. Additionally, the table is now moved to the Methods section [Line 164] to help understanding of the experiment procedure as well as to be more relevant to the purpose of this table.

This comment is applicable for the entire text – the reader is often left with lengthy stretches of text without references, followed with a bunch of references in one place (e.g., Emelko et al., 2016; Van Beest et al., 2019; Emmerton et al., 2020; Orlova et al., 2020). In such cases, readers might be left confounded – do all these mentioned studies prove one statement (as it is in line 50; in which case, it is not necessary to show that many references, 1-3 is usually enough) or all 3 to 5 statements before that (as in lines 45, 80, etc… in which case, it would be beneficial to attribute the references to their corresponding statements).

Completed. Thank you for your comment and making this point to improve the manuscript. We believe the revised manuscript has been improved by rephrasing those lengthy statements and adding more context to the references cited, for example, "While permafrost thaw and peatland collapse is rapidly expanding across these regions (Porter et al., 2019; Quinton et al., 2019; Hugelius et al., 2020), some parts of the northern boreal and subarctic regions, such as western Canada (Gibson et al., 2018), Siberia (Talucci et al., 2022), and Alaska (Mekonnen et al., 2022), have also experienced increased wildfire activity in recent years likely further altering the effects of permafrost thaw on soil carbon stability. For example, …" [l. 39-43].

Methods. It was detailed enough and mostly easy to follow. Adding a graphic summary or a table pointing to each step done before and during the experiment would greatly help readers, but I would not insist on adding one, it is just an idea.

Completed. Thank you for your suggestion. We have made every effort to describe the experimental steps as clearly as possible.

Section 2.1. I recommend adding some essential information that would help readers to make better interpretations of the results. Firstly, you mention that the study site is within the discontinuous permafrost area. It would be important to indicate whether the two peatlands you study are affected by permafrost, and most importantly, whether the coring sites are underlain by

permafrost. Secondly, you sampled in October, so it would be worth mentioning if the peat samples were already frozen when you sampled, and if they remained frozen during the travel to Waterloo.

Completed. The peat soils cored were not frozen at the time of sampling, as shown in the photos of the sampling borehole in Figure 1. We stored the samples frozen in the laboratory freezer until we were able to start the incubation experiment. The description of peatland types as thermokarst bog and channel fen indicates the thawed status of permafrost directly underneath the sites, although there could have been remnant permafrost in surrounding areas, given the discontinuous nature of the study region. To better reflect this, we have slightly modified the related sentence to "These peat cores were transported to the University of Waterloo, Waterloo, Canada, and then stored in a -20°C freezer until being thawed to start the experiment" [Lines 116-117].

Section 2.2. Line 121. Was the bulk density used anywhere in the study? Judging from the method you used to estimate it, it might not be the best variable to present. As I did not find any further mentions of density in the manuscript, I would recommend removing it from the methods as well – it slightly reduces the quality of the study, when mentioned like that. But if you used density somewhere else, then keep it.

Completed. Thanks for your comment and suggestion. For completeness, the bulk density values are given in the related dataset of this article.

Results and Discussion. I would recommend a detailed revision of this part. You have a good study design and diverse data to present. The latter often causes difficulties, when writing a clear discussion, and this was the main issue I identified while reading your manuscript. If it helps, you may consider separating results from discussion; otherwise, please carefully revise each section, and make sure you do not limit yourself to commenting on each particular detail of presented results but also expand into a larger context. In many cases, a presentation of what is normally expected for different variables would make the discussion clearer (not everyone reading the article will be as knowledgeable in all the domains you touch). Overall, I missed a discussion on the meaning of your findings – what did we learn from this, where do we go here? May we expect similar wildfire effects in other subarctic wetlands: what will be the effect of permafrost disappearance, or increasing peatland ground temperatures? Please, do not get discouraged by the previous reviewer's comments about your experiment being unrepresentative. While it is admirable that you carefully acknowledge the limitations of the study, we often must work with what we have, and careful interpretations (based on similar studies) are acceptable. P.S., fens and bogs are highly representative for boreal regions and comparing these two is a significant contribution to the scientific knowledge, even if you work with only one particular study site. Boreal/subarctic regions are strikingly similar across North America and Eurasia.

Completed. Thank you for your valuable feedback. While we understand the benefit of separating the Results and Discussion sections, we believe that combining them into a single section is more suitable for the structure of this short communication article. This format allows us to present the experimental results alongside the immediate insights they provide, making the connection between the findings and their implications more straightforward for the reader, who may not be familiar with this type of experiment.

We acknowledge that presenting the expected trends for different variables and their resulting effects could help readers better understand the new insights from this experiment. However, relatively few studies are available to clearly define the expected trends for each variable we discuss hitherto. We believe that a review article could be developed in the future to address these points while continuing laboratory experiments to further investigate the suggested effects from our experiment.

The additional paragraph [Lines 408-414] in the Conclusions section (previously titled 'Future research suggestions') in the revised manuscript summarizes the main findings of this study, as well as the additional last sentence in the abstract [Lines 34-36]. Although we much appreciate the suggestion to make more broad statements for the study's insights, we are cautious about making such statements in this article, given the concerns raised by previous reviewers and the topic editor. Still, we believe that interested researchers will gain valuable and broad enough insights for future research directions to investigate the important peatlands in boreal/subarctic regions.

I am aware that you have submitted for a short communication, so my preceding comments might overcharge the paper. In that case, I would strongly recommend revising which results you want to present (and discuss) in detail, and which could be left for supplementary information.

Completed. Thank you for this advice. We have carefully revisited our manuscript with the two Reviewers' comments and suggestions in mind.

Section 3.1. I have missed a broader discussion in this part (or did you mean to have this section as strictly results only?). You mentioned that fen peat had higher initial microbial biomass, but you may go further than that. What other differences in peat properties (decomposition level, density, organic matter and water quantities, ect) or the context of the peatlands itself? Maybe permafrost has some impact, maybe climatic conditions? You present a lot of important and interesting information in this section, but you do not comment more on it. Maybe more perspective globally or within the subarctic peatlands? Why would temperature and nutrient additions/limitations affect CO2 and CH4 production differently?
Overall, I recommend considering connecting this section with 3.2, in which you present same information, only different units. But the missing discussion questions remain.

Completed. Thanks for your comment and suggestion. The section 3.1 is intended to present the results of gas flux measurements as clearly as possible, despite the complexity of data we obtained (raw data are found in the related dataset). The context of adding nutrients for measuring the potential differences in resulting carbon gas production rates has been demonstrated in the Introduction section. However, there is no study to specifically associate with the current results as the experimental setting was different. Thus, the questions raised by this comment are not possible to be confidently addressed based on our relatively small-sample measurement results. We agree with connecting this section with 3.2 and the changes have been made in the revised manuscript [Line 264].

Section 3.3. Lines 283-285. I am not sure if I follow your interpretation here. CO2 and CH4 are, in large, produced by different mechanisms and different microorganisms. Combining the production of both these gases does not necessarily better explain the nutrient effects, but maybe

a better explanation of what you meant could suffice. Nevertheless, I would recommend discussing each gas separately, taking into account different needs of methanogens and other heterotrophic microbes; also, please consider a potential effect of gas consumption by other microorganisms (e.g., methanotrophs) or chemical reactions.

As the microbial production of CO_2 and CH_4 are influenced by various soil internal factors, including oxygen availability, we were not able to monitor all the detailed factors for the incubation of multiple jars at the same time with a limited amount of sample. Also, the CH_4 gas could be substrate for CO_2 production internally by methanotrophs as you mentioned, and thus the measurement of CH_4 at the certain time point is not fully representative the gross rates of CH_4 production but the net results over the three days in a new temperature. Therefore, we summarized the net loss of soil organic carbon through both gas production, which we think is more representative for the cumulative effects of added nutrients in overall microbial activity. To demonstrate the details about the microbial community dynamics, additional DNA extraction measurements will be necessary to monitor the potential shifts in dominant communities over time and with nutrient effects.

Line 294 "It is difficult to imagine that the observed CO2 and CH4 production throughout the incubation period could have occurred without microbes in fen soil samples". I understand you added this sentence following comments from previous reviewers, but I find it slightly excessive, and I would recommend removing it. The remaining explanation, as to why you do not present the results from fen, is sufficient. Alternatively, I would recommend reconsidering whether you need to present the microbial biomass changes at all (maybe move Table 3 into supplementary material?). The experiment results are informative and interesting without this part; moreover, it becomes confusing since you cannot compare fen with bog, as you do in other instances.

Completed. Thanks for your comment and suggestion, we have removed them in the revised manuscript [Lines 311-312].

Line 313. By "the use of solid organic particles", do you mean the microbial use, or the continuous leaching of DOC from the particles you have. I recommend considering (and clearly naming) both options.

Completed. While we cannot directly know which process was dominant in the use of solid organic particles, we assume both processes were involved. The sentence has been revised to suggest both possible processes in the parentheses "…production of DOC from particulate, either through microbial enzymatic decomposition or chemical leaching" [Lines 330-331].