

Interactive comment on “Strong warming of subarctic forest soil deteriorated soil structure via carbon loss – Indications from organic matter fractionation” by Christopher Poeplau et al.

Anonymous Referee #2

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General comments:

The manuscript by Poeplau et al., investigates the effects of long-term soil warming on SOC fractions. Their carbon content as well as their relative distribution in response to warming are being discussed for two different soil depths and ecosystems. As I myself am working on warming effects on soil microbial communities in connection to biogeochemical cycles, I was very pleased to read about warming effects on the abiotic components of soil. Especially long-term in-situ warming experiments are rare and extremely valuable to study the mechanisms and concepts behind various warming effects. I completely agree with the authors that strong systematic gradients in SOC

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content (in the same soil) can provide an important framework to improve our understanding of SOC dynamics. I believe that this study adds some very valuable aspects to the research field of soil warming. This paper and some there presented ideas could also provide the basis for hypotheses that could be targeted in other future mechanistic studies. The manuscript is well written and structured. Most parts of it are easy to follow, however I hereby want to suggest some minor and detailed revisions in order to improve the manuscript in terms of its readability and understandability.

Personal comments:

Out of personal interest, I would like to ask if you have a suggestion to why both ecosystem types approach to more or less the same SOC content in response to long-term warming (Fig. 4 and 5)? The levelling off of (absolute) SOC losses from different soil types (with different native C contents) to a sort of threshold level is very interesting to me.

I also like the idea of decreasing pore space with warming (due to aggregation loss). I myself often observed a decrease in microbial biomass with warming, which I now start considering to link to the suggested decrease in pore space and microhabitats. Therefore, one can see the need of better exploring structural soil changes upon warming in order to better interpret biotic responses.

Out of curiosity I also want to ask if you observed any changes in the vegetation cover after several years of soil warming? And if yes, if there is data on plant communities available or a paper covering that aspect? As far as I know, changes in vegetation with warming are quite often observed and I wonder about associated impacts on SOC contents and fraction distribution. E.g. if observed effects like the loss of aggregation could be associated with a change in the vegetation structure?

Out of personal interest, is the light ultrasonic treatment more effective and more representative for natural conditions than the slacking treatment?

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Specific comments:

Short comment to the title: I am not sure if you can really call it a “deteriorated” soil structure. I would rather use the term “changed” or “affected” because it does not imply a judgement. Also. The authors sometimes refer to boreal systems throughout their manuscript. However, I much better like the term subarctic in the context of the study site. Throughout the manuscript, I found an inconsistency in terms of SOC terminology as it is stated on page four and also within the use of associated units. In order to improve the readability and the understandability of the text, I would also welcome to be more specific and explicit when writing about SOC changes e.g. SOC contents, concentrations, fractions, mass et cetera. For detailed comments about alternative phrasing suggestions see below.

Page 1:

Line 14: Five different SOC fractions were isolated and their re-distribution as well as the amount of stable aggregates was assessed to link SOC to soil structure changes.

Line 16: Soil warming had depleted SOC concentrations in forest bulk soil by...

Line 24: ...indicating an indirect protective effect of SOC on aggregates...

Line 25: Topsoil changes in total SOC content and fraction distribution...

Line 27: ...in the response of subsoil SOC content and fraction distribution... The authors write in the abstract that no ecosystem effect was observed. However, this was confusing to me, as in my understanding Tab. 3 shows significant effects.

Line 32: Could you please specify if the stated temperature increase refers to air or soil temperature?

Page 2

Line 3: I believe that the statement about permafrost soils is out of place here as no permafrost is occurring at the investigated site.

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Page 3

Line 32: It was a bit hard to understand to how many samples you refer in your manuscript. Could you please state the explicit number of samples taken? Also, are all mentioned five transects situated in the investigated forest? Please also indicate the number of samples in your graphs.

Page 4

Line 6: Distinct responses to warming were thus expected. Could you make an explicit statement what you were expecting?

Line 15: Unit is missing for SPT (1.8 g cm³ -1)

Line 33: Out of personal interest - what is the variability to the average mass recovery?

Page 5

Line 11: Would you assume a positive or negative correlation between the poured bulk density and SOC in the SA fraction?

Line 31: Do you think that absolute SOC losses are higher in topsoil because of a higher “native” C concentration?

Page 6

Line 1: Please state here that you talk about SOC contents in bulk soil.

Line 11: The depletion of SOC content lead to a changed relative distribution...

Line 12: The ANOSIM revealed... Please state here that you talk about topsoil findings.

Line 13: ...fraction distribution was only significant from the unwarmed reference at a warming intensity of 5.8°C. I was wondering about the + 2.7 °C treatment (see Tab. 2)?

Line 15: ...SOC in the POM and SA fractions, which were strongly depleted with warming (Fig 1). Please mention here, that this was the case in both depth increments.

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Line 28: ...the relative mass proportion of rSOC was expected to increase...

Line 30: Could you please give the p-value for the mentioned regression between rSOC and total SOC in the SC fraction?

Line 36: Could you please state the p-value for the significant negative relationship between the proportion of SOC in SA and the proportion of SOC in DOC

Page 7

Line 5: You mention similar SOC contents for subsoil forest and grassland soils. Is there more information about that e.g. an ANOVA?

Line 14: You mention that POM in forest soils responded more negatively to warming than POM in grassland soils. Was this normalized to their respective C contents?

Line 17: I would have appreciated it, if you mentioned earlier on that the warming in the grassland soils was only 6 years compared to the 10 years of warming in the forest.

Line 20: ...we found a strong negative correlation of bulk soil SOC content and poured BD. Please also give the R2 here.

Line 34: According to Tab. 1 the relative change in topsoil SOC content is -3.6% not -2.7% as stated.

Line 36: Do you think that the + 5.8°C is a realistic warming intensity for soil or air temperatures?

Page 8

Line 17: You write, that the present study did not reveal tipping points. However, if I look at e.g. Fig 1. it seems to me that +5.8°C causes some abrupt changes in SOC contents and SOC proportions in fractions? Please also specify "tipping points for SOC" here (e.g. SOC contents).

Line 22: You write that climate change is likely to strongly affect SOC stocks of boreal

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forests. Generally, I strongly agree to that statement. However, would question the comparability of the relatively young investigated forest on volcanic bedrock material to the biome of naturally old grown boreal forests. Upscaling to the regional or global context might be a slight over interpretation.

Page 9

Line 17: In the unwarmed reference soil, it accounted for the highest proportion of soil mass and SOC content.

Line 29: ...we found a very strong positive correlation of SOC mass and ...

Page 10

Line 2: I did not understand the context of the sentence about carbon desorption from the mineral phase. It seemed a bit out of place to me.

Line 8: According to your definition on page 4 the unit of SOC content should be (g C kg⁻¹).

Page 11

Line 7: You might rephrase the sentence to: Changes in SOC concentrations and the relative distribution of fraction masses in the grassland soils have been previously investigated.

Line 8 to Line 11: The fact that there is no difference in subsoil SOC dynamics ... might indicate that the same mechanisms of SOC depletion were involved in both ecosystems.

Line 23: The sentence is very long, maybe you could split it apart.

Line 37: You might rephrase the sentence to: Differences in the relative distribution of SOC fractions and their respective SOC concentration in response to warming have only been found in the topsoils of both examined ecosystems.

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Specific comments about graphs and tables:

- 1) Tab. 2: In the table description you write about testing “differences in SOC fraction distribution”. Do you mean the relative mass distribution of SOC fractions?
- 2) Fig.1: is missing the a)b)c)d) notation in the individual graphs. Also the unit of the x-axis of a) and b) should be changed to SOC content (g C kg⁻¹).
- 3) Fig.3: For me, the graph would be easier to understand if the title of the x and y axis would be changed to “percentage of total SOC in SA” and “percentage of total SOC in DOC”. Also a p-value is missing in the graph as what is the depicted error range (95% confidence interval?).
- 4) Fig 4: I am a bit confused if the scatter plots show SOC masses or SOC contents of the fractions in response to warming. What is the depicted error range? Moreover, some relationships seem rather curvilinear to me than linear.
- 5) Fig 5: Please change the title of the the y axis to subsoil instead of topsoil. I moreover have the same small issues with the graphs as mentioned for Fig. 4.
- 6) Fig. 6 shows regression models. Please indicate the p-values here. 6a) The unit of SOC content should be (g C kg soil⁻¹). 6b) The unit of SOC concentration should be (g C kg fraction⁻¹). 6c) Please change the title of the x axis to “ soil mass in stable aggregates”. 6d) The shown relationship looks more curvilinear than linear to me.

Questions provided by SOIL:

- 1) Does the paper address relevant scientific questions within the scope of SOIL? Yes, I think so.
- 2) Does the paper present novel concepts, ideas, tools, or data? The paper shows new interesting data on physical soil structure changes in responses to warming. However, to my state of knowledge, no new tools were involved. The manuscript provides some new concepts and ideas e.g. the proposed mechanism of warming leading to SOC loss

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(via enhanced microbial activity) which then results in the loss of stable aggregates. I also very much appreciate the proposed idea that the slope of the regression line between SOC and bulk density might be a useful indicator for aggregation affinity in unmanaged soils.

- 3) Does the paper address soils within a multidisciplinary context? n.a.
- 4) Is the paper of broad international interest? The scope of physical soil fractions and their response to warming seems of broad interest. It represents a framework of many biological responses to higher temperatures.
- 5) Are clear objectives and/or hypotheses put forward? Three objectives are stated clearly on page three and then also addressed in the results and discussion of the paper.
- 6) Are the scientific methods valid and clear outlined to be reproduced? Yes. Especially the SOC fractionation protocol is described in great detail and could be repeated in our lab too.
- 7) Is the soil type/classification adequately described? Yes, most of the general information on soil types is given in the text.
- 8) Are analyses and assumptions valid? Yes.
- 9) Are the presented results sufficient to support the interpretations and associated discussion? Yes.
- 10) Is the discussion relevant and backed up? In general yes. For detailed comments see above.
- 11) Are accurate conclusions reached based on the presented results and discussion? Yes.
- 12) Do the authors give proper credit to related and relevant work and clearly indicate their own original contribution? Yes.

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13) Does the title clearly reflect the contents of the paper and is it informative? Yes. The title clearly reflects the later proposed mechanism of aggregate break-down which follows SOC loss that was caused by warming. I especially like that the title includes the term “subarctic” and not “boreal”.

14) Does the abstract provide a concise and complete summary, including quantitative results? Yes.

15) Is the overall presentation well structured? Yes, I like the tripartite structure of the paper (1-warming effects on forest SOC and its fractions, 2-forest vs. soil SOC in response to warming, 3- soil structural changes). The focus on those three topics can be found in the introduction, results and discussion part.

16) Is the paper written concisely and to the point? To my understanding the manuscript is mostly concise. However, sometimes the sentences were hard to follow (too long) and not precise enough to understand what the authors meant. This holds especially for “SOC-terminology and SOC units” – see detailed comments above).

17) Is the language fluent, precise, and grammatically correct? Mostly yes. However, some sentences are relatively long and thus hard to follow. This is especially the case in the discussion part.

18) Are the figures and tables useful and all necessary? The figures are nice and useful. For detailed suggestions see comments above.

19) Are mathematical formulae, symbols, abbreviations, and units correctly defined and used according to the author guidelines? Yes. In the context of units, please see detailed comments above.

20) Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? I think that the sampling procedure (amount of taken samples and analyzed) could be described in more detail.

21) Are the number and quality of references appropriate? Yes.

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22) Is the amount and quality of supplementary material appropriate and of added value? Yes.

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