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Interactive comment on "Responses of soil physico-chemical properties to combustion: a space for time substitution study to infer how changes in climate are likely to affect response of topsoil to fires" *by* S. N. Araya et al.

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Comments on the manuscript are followed by our responses. Text locations in the manuscript are indicated by a combination of page number and line number (page#:line#).

General Comments

Comment 1. Title: The title does not well reflect the content of this paper. It does not seem appropriate to refer to this study as a space-for-time substitution study as there is no discussion of the vegetation or how it may change in the future (no context for

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the soils). Nor is there sufficient discussion for how the climate is projected to change fire regimes specifically in the study area. Surely it would be more valuable instead to have the words “climosequence” and “Sierra Nevada” in the title?

Author response: We agree with this comment and we have revised the title to better reflect the experiment as, “Thermal alteration of soil physico-chemical properties: A systematic study to infer response of Sierra Nevada climosequence soils to forest fires.”

Comment 2. Introduction: The introduction could benefit from being expanded to include the current vegetation (and soils) and current fire regimes (intensity, severity, frequency etc.) specifically of the Sierra Nevada study area, and how these may change with anticipated climate warming. This additional information would then provide better context and rationale for this study.

Author response: We have expanded the discussion on vegetation and fire regimes of study site by adding a paragraph in section 2.1.

Comment 3. Use of term fire intensity: Page 1, line 22 (and throughout): Suggest the term “fire intensity” is removed throughout the paper. Fire intensity (as defined by Keeley, 2009; Int. J. Wildfire; v.18) is an energy flux, and has been shown to be only weakly correlated with maximum temperatures or heating duration. The intensity classes in this paper have been based on maximum surface temperatures reached in various wildfires (page 5, line 25) yet there is no discussion of the duration these temperatures were held at, and whether (or not) this compares to the 30 minutes heating duration used in the muffle furnace experiments. Also, wildfires cannot be represented by a singular temperature (i.e. the muffle furnace) as the temperature varies widely both spatially and temporally (see Alexander 1982, Can. J. Bot. v.60; Finney et al., 2015, PNAS). It is therefore more appropriate to refer to furnace temperatures alone, not intensity, throughout this paper.

Author response: We agree with this comment. While maximum surface temperature is often used as a metric of fire intensity, especially for studies of direct fire effect on soil (e.g. Neary D.G. et al. (1999) Forest Ecology and Management), it is more accurate to directly refer to the temperature. We have clarified statements where maximum temperature is used to loosely infer fire intensity.

Comment 4. Materials and Methods: Please clarify how soil sieved at 2mm can represent actual topsoil in the field. Also, does this sieving and drying process change any of the intrinsic soil properties?

Author response: We have followed these steps to essentially extract soils in the strict definition, and to remove large rock fragments and undecomposed organic matter. The sieving and oven drying processes do alter soil some soil properties but we think these alterations have minimal effect on the soil properties we measured. The measurement procedures for these properties themselves often introduce more alterations. The significant effect of drying has been discussed and we used dry samples to control for moisture effects that are known to cause aggregate stability changes and we have acknowledged this in the discussion of aggregate stability (5:16-21).

Comment 5. Use of a muffle furnace for combustion experiments As stated in the other referee comments, a muffle furnace does not fully capture the combustion process (only pyrolysis) that occurs during a wildfire and therefore the charcoals that are produced using this method should not be used to describe fire intensities (see comment above).

Author response: The pyrogenic products that would be produced from this experiment are necessarily derived from soil organic matter. We have avoided the use of the term fire intensity except where we use 'intensity' in the general term as maximum temperature is a matric of intensity.

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Comment 6. Discussion: Given the above comments on the use of charcoals produced in a muffle furnace to describe fire intensity, any subsequent interpretations of fire intensity should therefore be re-evaluated. The discussion section "4.2 climate change implications" could benefit from being expanded to discuss whether (and how) both the vegetation, and therefore soil, is expected to change in Sierra Nevada in the future in response to warming. If the rain-snow transition zone will move to higher altitudes, then will the treeline/ ecosystem boundaries in this climosequence also shift upwards? Vegetation is an important part of soil formation, yet other than in the study site and soil description section of the methods there is little to no discussion of the vegetation in this study area. This needs to be included in the text as fire behaviour is, in part, dependent on vegetation, so projected changes in vegetation first need to be discussed in order to comment on how the fire regimes in the study area may be altered in the future.

Author response: We have revised the title and the objectives of the paper to clarify our objectives as a study focused on first order effect of heating on soils. Hence, we expect our findings to provide primary information that should be of vital interest in detailed fire and ecological studies. However, given the limited level of depth our experiment goes into exploring fire in the ecosystem we believe the level of detail in discussion section on Sierra Nevada ecology is sufficient.

Specific Comments

Throughout: As several statistical tests have been used in this study where p values are given, or the term "significant" is used in the text, this should be followed by the statistical test used and the p value in brackets.

Author response: Because the statistical tests in this study are the same type, we had decided to mention the statistical analysis methods in the methods section to avoid repetition. However, to address this comment, we have added details of the statistical analysis and placed the statistical analysis in its own subsection (as Section 2.4).

Page 2, line 3: what is the evidence for prescribed fires having temperatures <250 °C? Is this soil temperature? Please provide a reference.

Author response: We have removed the reference to prescribed fires. While fire intensity of prescribed fires is typically kept low, a 250 °C cutoff may not be appropriate for forest ecosystems (for example: Busse et al. (2005) Int. J. of Wildland Fire; Garcia-Corona et al. (1999.) Geoderma).

Page 2, line 5-6: there is no discussion of climate change scenarios or how fire intensity in this study area is anticipated to change in the future. Please remove this sentence or expand the discussion.

Author response: We have rewritten the section to clarify our objectives. Page 2, line

25: insert reference for fires "maintaining the health of ecosystems"

Author response: We have added a reference.

Page 4, line 1-3: suggest the study aims are rephrased as it is not possible to scale up muffle furnace experiments to the field, let alone to predict effects of different fire intensities on soil.

Author response: Given that the impact of fire on soil is primarily by the input of heat (which is dependent on temperature and also the duration), we believe such muffle furnace simulations can provide valuable data that can be useful to infer the effect of fires. We believe that such research and our findings provide valuable information on the first order effects of heat input into soils which provides at least a baseline information of how soils respond to different temperature. In addition to giving insight into different fires, our findings can also give insights on soil response across the vertical temperature gradient that occur with vegetation fires.

Page 6, line 24: please explain what a can is

Author response: The cans are part of the wet-sieving apparatus into which the sieve is immersed for wet-sieving. As they have no unique use in the procedure, the paragraph has been rewritten without mention of the cans.

Page 6, line 27-28: please rephrase this sentence. It is difficult to understand.

Author response: The paragraph has been rewritten to clarify the procedure.

Page 7, line 7: please explain what a seven point measurement is.

Author response: The sentence has been rewritten to indicate that seven measurement points are taken to calculate specific surface are using the N2-BET isotherm. The seven-point measurement is an accuracy configuration within the instrument software setup which internally calculates the specific surface area.

Page 10, line 18-19: please clarify what is meant by kaolinite experiences loss at >550 C.

Author response: The sentence is rewritten to clarify that from all the minerals, kaolinite concentration showed the largest decrease and that decrease happened at temperatures above 550 $^{\circ}$ C.

Page 12, line 30: add the temperature ranges of SOM combustion

Author response: The temperature ranges where SOM combusts has been added.

Page 14, line 7: Please give a temperature range for “higher temperatures”.

Author response: We have indicated a temperature above which thermal alterations were noted.

Page 15, line 23 and page 18, line 4-8: misuse of term “fire severity”

Author response: We have removed the reference to fire severity.

Page 16, line 6: please insert a reference for prescribed fires not contributing to soil C loss.

Author response: We have rewritten the preceding sentence to clarify that we are discussing the implication of our findings. We are not citing from literature.

Page 18, line 18-23: suggest this paragraph is either re-phrased or removed. The rest of the paper refers to “fire intensity”. There is no discussion of fire severity in this paper, or how different fire severities affect the physical properties of soil.

Author response: The paragraph has been rewritten for clarity.

Technical and Typographical corrections

We have accepted all technical and typographical comments given.

We appreciate the thoughtful comments from the reviewer. Thank you!

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