

Interactive comment on “Soil respiration in a fire scar chronosequence of Canadian boreal jack pine forest” by D. R. Smith et al.

Anonymous Referee #1

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GENERAL COMMENTS There are still few measurements of soil respiration from fire chronosequences in boreal forests (Amiro et al., 2003), and hence the present study could extend that scarce knowledge. The present paper reports that soil respiration increased with successional time in a fire scar chronosequence of Canadian boreal jack pine forest. This topic is within the scope of Biogeosciences. However, I have major reservations with the data analysis and presentation as well as the structure of the article in its present form. Specifically, I want to point out the following aspects: 1) The raw data of the measurements (soil respiration data) are not reported in the manuscript, but only flux data which has already been subjected to further calculations (e.g. adjustment to soil temperature) is given. Therefore, the reader can not compare the soil CO₂ effluxes observed in this study with values from the literature. 2) In my opinion there are too many figures and unnecessary tables, and the structure of the manuscript

C2013

should be improved: Results are repeatedly reported throughout the results section, results are repeated in the discussion section, the structure of the introduction should be improved and the discussion does not provide a well-structured line of arguments. The cited bibliography is too large. 3) The statistical analysis should be improved and be concentrated on the main differences of interest. 4) I don't see that the main result (soil respiration from a fire chronosequence) is convincingly reported and discussed but, unfortunately, these interesting results are currently lost within an extensive presentation of co-results of the study. Last, I want to mention that there are limitations of the experimental design and methodology, which are addressed and discussed by the authors but remain (i.e. small sample size, little temporal replication and change in methodology of soil CO₂ flux measurements between the first and second field campaign). I suggest that major revisions need to be conducted before publication of this manuscript. I hope that the specific comments I am giving below may help to improve the presentation of the data and structure of the manuscript.

SPECIFIC COMMENTS - This study cites an extensive bibliography of 88 references, which is a high number for a primary research article. Please critically evaluate if all the references you are giving are substantial for understanding your study, or if in some instances you may combine and shorten references, or cite reviews and scientific reports. Please also check if in some instances you can use more recent studies as a reference (you have some pretty old references earlier than 1980/1990). I suggest to aim for <65 references for a primary research article. - Please include your studies' main finding in the title to make it more comprehensive, e.g. 'Soil respiration increases with successional time in a fire scar chronosequence of Canadian boreal jack pine forest'

Throughout the article: - Please do not write 'statistically significant' or 'statistically highly significant' when reporting your results, just give the P-value for your significant results (as soon as you talk about differences the reader expects that those are statistically significant) - Please avoid repetition when reporting your results, e.g. do not

C2014

report the same results in a table and a figure, do not write values in the text which can be found in a table, do not repeat results in the discussion section. - Please give the units for all variables and parameters of your equations such that the reader can check the correctness of your formulas.

Abstract - P 8726/ L 12: Please give the R^2 of the relationship - P 8726/ L 17-20: What are the differences? This sentence is hard to understand. Where is soil respiration larger, where smaller? - Please add one introductory sentence to the abstract (first sentence), e.g. Why is it important to conduct this study? Is this a representative forest type for the boreal zone? Are fires frequent in this forest type? Is the fire frequency increasing? Give some motivation for the study. - Please also add in the abstract your main result regarding soil OC content (is not mentioned at all) - Please include that you measured your response variables on 3 sampling days during summer and give the number of plot replicates to provide the reader with background of the extent of your study.

Introduction - General comment: Please go through each paragraph and check for the structure. You may improve substantially by simply resorting your statements such that you don't change back and forward between topics within one paragraph. Please include in the introduction how fire is expected to change soil respiration and soil organic C content (based on the literature). - I suggest to exchange the first and second paragraph: First, give your general introduction to boreal forests, its role in the C cycle and the expected changes; add one sentence to the next paragraph on soil respiration (e.g. soil respiration is the second largest flux in the global terrestrial C cycle) in order to improve the transition between the introduction to the C cycle and your introduction of soil respiration.

- P 8727, L 18: Is there a more recent reference for the areal extent of boreal forests than from 1989? Maybe you can find more recent information in the FAO reports, e.g. FAO Forest Resources Assessment? - P 8727, L 21-23: This is repetitive information; I suggest to exclude it - P 8727, L 25: Why do you give this statement for Siberia? You

C2015

are not working in Siberia. I suggest to exclude it. I also suggest to cite IPCC instead of Kattenberg, 1996 - P 8728, L 1: It is sufficient to cite the most recent IPCC report, I suggest to exclude IPCC 2001 - P 8727, L 5ff.: I suggest to write: Principal factors controlling R_s include (otherwise it sounds as if the factors you listed are complete which is not the case, e.g. nutrient availability is a further important factor) - 3rd paragraph: Please improve the structure of this paragraph and try to make it more concise, e.g. combine your statements where possible. - P 8728 L 19: What is the difference between 'mature' and 'older' forest? I think you explain that in the field site section, but here it is not understandable. - P 8728 L22/23: I don't think that this is a good final sentence of this paragraph; please mention earlier that there are uncertainties about the scenarios if you want to mention it - The 4th paragraph of the introduction does not give relevant information. Please reconsider which information you want to give in this paragraph. Don't say that there has been extensive investigation but, if necessary, mention the most relevant studies together with their main results. You have a high amount of references in this paragraph but it is not clear to me what you want the reader to learn in this section. This paragraph should give an overview about relevant earlier studies, which will then lead to your hypotheses. - P 8729, L 12/13: lots of references for this statement. Which one is relevant, which one gives the area? Can this statement be combined with the earlier statement to shorten? - P 8729 Ls 21-27: Instead of mentioning what has not yet been done and what your study is doing please rewrite to clearly state the objectives of your study. - P 8729, last paragraph: Please include the hypotheses of your study. Based on the literature, what results (for soil respiration and soil OC content) do you expect from your study and why?

Material and methods - It is important to clearly state that your measurements were conducted during the summer/growing period, which did not become clear to me upon reading the first pages of your manuscript. Please write a sentence concerning that aspect. - Section 2.1: Please include general characteristics of your field site to give the reader more background (mean temperature, mean precipitation, soil texture and type (this is important because later on you assume a porosity value for sand!), forest age,

C2016

...) - Figure 1: I suggest to rename your plots for the presentation in your manuscript, e.g. in consecutive numbering, because the current plot labels (mixture of numbers and letters) are confusing for people that did not work at this site. Please add a scale to this graph such that the extent of the site and the distances between the plots can be inferred. - I suggest to combine Figures 1 to 4 into one figure plate as those are all illustrations of your field site (i.e. combine it to Figure 1a to d). Please mark in Figure 1 which is the area that is covered by the aerial photo of Figure 2 (this can be deduced but it would be a nice addition). Please include in Figure 2 all the plot labels that are given in Figure 1. You don't need to repeat in the legend of Figure 2 when those plots have been burned as this is stated in Figure 1. Is the location of the pumps and the weather-station (weather data not reported) a necessary information? I think that not and suggest to exclude them from Figure 2. I am not sure if Figures 3 and 4 are necessary. If you want to present them please guide the reader what you want him to see on the photographs. - P 8730/ L 9: Please give the scientific name of jack pine. - P 8730/ L 12: That the site is dominated by jack pine is a repetitive statement, please exclude. - P 8730/ L 24ff: To which age can jack pine naturally grow? When are your age categories becoming important? If in Sharpsand Creek the trees are harvested after 70-80 years how does this influence your age categories? - P 8731/ L 15/16: Please add which range of CO₂ concentrations you encountered during your field measurements. Please include the time period of chamber closure. Please already write here how many chambers per plot you used and if the chambers were permanently installed or installed prior to measurements. You are giving this information later on when you describe your field campaigns, but I think that it would improve the structure of the manuscript if you would concisely describe all information regarding gas flux measurement methodology in this paragraph 2.2. P 8731/ L 16/17: It would be more important to know how well the linearity assumption was fulfilled during your own measurements then to get instrumental data. - P 8731/ L 21: Please give the exact P-value of the test. - P 8731/ L 27: Please give details about the quality of your calibration (e.g. P-value, R², RMSE) - P 8732/L 4-7: Not clear what you want to

C2017

say here. What irregularities? Is this important? Did it bias your data? - P 8732 L 8: Why did you remove the litter prior to R_s measurements? You are excluding the CO₂ production from litter decomposition by doing this. - P 8733 L 3/4: You only explain how you adjust R_s to soil temperature in section 2.4.1, but the reader needs this information here. Either refer to section 2.4.1 or move that section forward. - P 8733/ L 19: Did you measure soil temperature at 2 cm depth in this sampling, and in 11.7 cm during your first campaign? Why? - Section 2.3.4: Please reconsider your structure. You first gave methodology of soil respiration measurements in section 2.2. These were valid for the field campaign 1? Now you repeat or give modified R_s methodology in 2.3.4. Why? Please clarify and be consistent, e.g. when did you insert the chambers for your FC 1? What are the differences in methodology between the FCs if there are any? Please make that more clear and easy understandable, e.g. combine the information you give in the separate paragraphs into one paragraph and avoid repetition. - P 8734 L 13-20: Please give the units for all parameters of your equations, including the unit of the final variable, such that the reader can easily reproduce that your calculations are correct. I would calculate volumetric soil water content using gravimetric water content and soil bulk density, and I can not unambiguously reproduce if your current formula is correct. So, please clarify such that it becomes clear that your formulas are correct! (... Couldn't you calculate your soils bulk density and porosity from your sampled cores instead of using an assumed value, or are your soil cores no undisturbed samples?) - P 8734/ L 23/24: OC expressed as bulk density? What does this mean? Please also give the units. - Section 2.4.1. The title of the section should include that you adjust for soil temperature, moisture and carbon (not only for soil temperature). Again, give all units in all formulas of this section, including the unit of the final variable! - P 8735/ L 3-5: What is the reference for formula (5)? Please mention here that your reference temperature T₀ is 10 degrees, which you only report in a later part of your manuscript. Why did you chose that reference temperature (argue for it, please also see below and consider the criticism raised by Davidson et al., 2006) - P 8735/ L 11: Your reference sounds to me as if formula (7) could be found in Davidson and Janssens 2006, which is

C2018

not the case. Instead, these two authors are critically discussion the concept of Q10 on soil respiration, as they also do in (Davidson et al., 2006). You want to use the modified van't Hoff equation, but then the last term must be an exponent (printing error I guess as the $\hat{}$ is plotted). Please correct and give the reference for that equation. The concept of Q10 for field measurements of soil respiration has recently been criticized (above mentioned article). The criticism includes that there may be confounding effects of plant phenology on soil respiration, the calculated Q10 may differ with the depth where the soil temperature has been measured, and the calculated Q10 frequently depends on the basal respiration rate. If you still calculate Q10 please address the criticism raised in that article, discuss implications for your study and include in the discussion why in your case a calculation of Q10 is justified, or what you learn from it. - P 8735/ L 15 ff: You are first making an exponential regression between Rsc and soil temperature. Next, you are checking if some remaining variance is explained by soil moisture. You conclude, after having deleted the driest and wettest dates, that this is not the case (I doubt that this exclusion of the driest and wettest dates is justified, see below). I suggest to conduct an additional multiple regression analysis to unambiguously check whether soil moisture is a relevant explanatory variable for your (raw/ unadjusted) soil respiration data. - P 8735/ L 17/18: The common relationship with soil moisture is that CO2 efflux is small under dry conditions which depress root and microbial activity, reaches a maximal rate at intermediate soil moisture, and decreases again when anaerobic conditions prevail. Now you are excluding your driest and wettest measurement days. Why is that justified? Is there any reason to believe that those measurements are not accurate? Do you have a relationship with soil moisture if you use your complete data set? How many measurements are in your range 0.21 to 0.77 soil moisture (unit?), how many data points did you exclude? Please reconsider. - P 8735/ L 19/20: Sentence not necessary, repetition. - P 8736/ L 2: Why does equation 8 account for soil moisture? I think that this is not correct. It seems that you are using in eq. (8) the Q10 which you derived based on a regression with Rs adjusted for carbon content? Why that? How is the Q10 for the unadjusted Rs data? Why do you use the Q10 based on Rsc? If you

C2019

use the Q10 from your regression with Rsc, why do you later state that your eq. (8) does not take C into account (P 8736/ L 2)? Please be more concise regarding your procedures and calculations which you describe in that whole paragraph. Is the R0 in equation (8) the RsT you refer to e.g. on P 8738/ L 10? Please check for consistency. - P 8736 L 5: Soil respiration has not been adjusted for soil moisture as you state that there was no effect. This sentence is therefore not correct.

- Section 2.4.2: First aspect: How many 'outliers' did you detect? Were -except for thestatistical measure you state, i.e. $> 1.5 \cdot IQR$ - there reasons to believe that these measured values are erroneous? This statistical quantity is used to detect conspicuous data points. Still I believe that those data points should not uncritically be removed but each point should be checked. Was there failure of equipment or any other reason to believe that the specific point is erroneous? If so I agree that it may be excluded from the data analysis but should still be included (grey) in the figures. If there is no reason to believe that the value is inaccurate I think it should remain in the data set. Even if the point does considerably deviate from the mean this does not immediately imply that it is wrong and can be excluded. This especially holds true considering that you have a small sample size and are dealing with soil respiration data, which always have high variance and are often rightly-skewed. Please consider these aspects and re-check whether exclusion of your 'conspicuous points' was justified. Second aspect: I strongly recommend to repeat your analysis with superior statistical methods. You are first using the non-parametric Kruskal-Wallis test, justifying that by arguing that your data-set exhibits unhomogeneous variance. However, the assumption which needs to be fulfilled in order to conduct an ANOVA is not (as you test it) that the raw data are normally distributed with homogeneous variance, but that the residuals of the model fulfill these requirements. Thus, you could first run an ANOVA with your data and test your residuals. If they reveal unhomogeneous variance and/or non-normal distribution you may try to transform your data (gas flux data are often rightly-skewed so you would perform a square-root or log-transformation prior to analysis), repeat the ANOVA and check if the behavior of the residuals of your model improves. If this is not the case,

C2020

or alternatively, you may use linear mixed-effects models. In those you can include a variance function to account for non-constant variance between your fire scars, if necessary. I further suggest to run a Tukey-HSD test which would allow you to calculate simultaneous confidence intervals for all pairwise differences between means. You may use this as alternative to your pair-wise t-tests with Ryan-Holm step-down Bonferroni-corrections, or as addition to compare the results gained from these two statistical methods. - P 8737/ L 1-6: Unclear. What does this mean? What did you do? Please make clear what you mean.

Results - You are only presenting data which have already been subjected to calculations, e.g. adjustment to temperature. Please add a paragraph where you present the raw/unadjusted Rs data! - Table 2: The legend is written in a complicated way, please rewrite to make it clear. - The content from section 3.2 ('Soil organic carbon analyses') is missing. Figure 5: Why do you plot 2 standard errors instead of 1 standard error? Significant differences are usually marked with different letters instead of same letters as you do, please change. As there is only one difference at $\alpha=0.1$ please give the exact P-value. Table 3 and Figure 1 have ~ the same content. Please choose if you want to present these data in either a figure or a table but avoid repetition. Table 4 lists statistical parameters, however, I don't think that this information is relevant, and I suggest to eliminate this table. There is only one significant difference (between 1948B vs. 1975B). This should be mentioned in the text instead of giving the table. - P 8738/ L 17-20: Again, why do you calculate Q10 based on Rs already adjusted for OC, and not on the raw RS measurements? Is that Q10 comparable to values obtained from the raw data? Please argue for your procedure. Where does the unit of soil respiration in Figs. 6 and 7 come from? I am astonished that, considering that all of your measurements were conducted during summer, you have such a large range in soil temperature (i.e. ~5 to 25 degrees celcius, Fig. 6)? Please give a note on that. - P 8738/ L 1-4: First, you are only testing for a relationship of RscT with soil moisture in an intermediate moisture range. I would like to know if there is a relationship between the raw Rs data and soil moisture? Or if soil moisture is a relevant explanatory

C2021

variable in a multiple regression analysis? Secondly, you are testing for a linear relationship while indeed you would not expect a linear relationship between soil moisture and Rs. If there is a relationship, a ~ quadratic response (i.e. moisture limitation at low and high moisture values, maximal soil respiration at intermediate soil moisture) is expected. Did you check for that? That leads back to my earlier question why you excluded the dry and wet dates. Please include in Fig. 7 the data points which you excluded from the analysis (i.e. below 0.21 or above 0.77 soil moisture) at least as grey points such that the reader can see how soil respiration behaved at that moisture conditions. - Figure 8: What do all the different letters above your bars denote? You do not explain that in your legend. It is not self-explanatory and the figure looks confusing. Please improve. - Figure 9: Please extend the x-axis at its left-hand side such that the data point at 0 years after fire becomes well visible. What do the different small letters indicate? - Table 5: I suggest to give only means and standard errors in this table, and to include the raw Rs measurements (unadjusted!) as well! - P 8738/ L 7-16: I wonder if the coefficients of variation from such a small sample size (soil respiration has always a high spatial variability) are so meaningful? - P 8738/ L 17ff.: I don't think that this paragraph contains relevant information. You repeatedly state that, due to your small sample size, your values are subject to uncertainty -which is a well known fact. Just state this once and make a statement how representative and robust your values are. - Table 6: This table is not very well-arranged. It is hard to gain an overview based on the arrangement in column 1. Please try to improve. I don't consider columns 2-7 necessary. If at all they may be supplementary material. - P 8739/ L 13-15: These values are given in Table 5. Please avoid repetition and report either in the text or in the table.

Discussion - P 8740/ L 5-17 up to P 8741/ L 10: This is not discussion but repetition of results. - P 8742/ L 12-21: No clear conclusion is drawn, I don't see a clear line of argument in that part of the discussion (4.1.2). Basically you say that your results are similar to some earlier but different to some other results. How do you resolve that? What conclusion to you draw based on that? - Section 4.2.2: Please consider

C2022

the recent criticism of the Q10 concept for soil respiration measurements from the field (Davidson et al., 2006). What do you want the reader to learn based on the fact that your Q10 is similar to the one calculated in some studies, and different to others? What is your conclusion? - P 8744/ L 12/13: Again, based on your small sample size, do you think you can state that these are outliers? - P 8745/ L 11-16: This is unnecessary repetition of results. - P 8745/ L 17/18: I don't understand what you mean when stating here that in FC 1 soil collars were absent? That didn't become clear to me in your description of methodology. - P 8745/ L 20-23: Please avoid repetition of results.

TECHNICAL CORRECTIONS - P 8728, L 19: I think the first coma should be excluded - P 8729, L 23-27: These sentences are not grammatically correct, please rewrite - P 8732 L 20: an area of 30x30m - P 8733 L 10: soil moisture (0-6 cm depth) - P 8733 L 12: suggest to write chamber instead of SRC (abbreviation confusing at this point, need to go back to understand) - P 8733 L 17: exclude coma - P 8733 L 18: from those areas which the fire did not. . . - P 8734 L 9: air-tight - P 8736 L 12: something is missing here in the brackets - P 8750/ L 20: The P-value should not be used as 'abbreviation' for statistical significance - P 8751/ L 2: vs. is a common abbreviation which does not need to be defined - P 8751/ L 5-6: All these explanations (e.g. μmol , $<$, $>$ and symbols) don't need to be defined here - P 8726, L 22: second coma should be excluded; sentence is not well formulated

References Amiro BD, MacPherson JI, Desjardins RL, Chen JM, Liu J (2003) Post-fire carbon dioxide fluxes in the western Canadian boreal forest: evidence from towers, aircraft and remote sensing. *Agricultural and Forest Meteorology*, 115, 91-107. Davidson EA, Janssens IA, Luo Y (2006) On the variability of soil respiration in terrestrial ecosystems: moving beyond Q10. *Global Change Biology*, 12, 154-164.

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