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16th Jan 24

Dear Dr Girardin,

Your manuscript titled "Historical boreal forest cover loss under climate warming and recurring wildfires" has now been seen by 2 reviewers, and we include their comments at the end of this message. They find your work of interest, but some important points are raised. We are interested in the possibility of publishing your study in *Communications Earth & Environment*, but would like to consider your responses to these concerns and assess a revised manuscript before we make a final decision on publication.

We therefore invite you to revise and resubmit your manuscript, along with a point-by-point response that takes into account the points raised. Please highlight all changes in the manuscript text file.

We are committed to providing a fair and constructive peer-review process. Please don't hesitate to contact us if you wish to discuss the revision in more detail.

Please use the following link to submit your revised manuscript, point-by-point response to the referees' comments (which should be in a separate document to any cover letter), a tracked-changes version of the manuscript (as a PDF file) and the completed checklist:

[link redacted]

** This url links to your confidential home page and associated information about manuscripts you may have submitted or be reviewing for us. If you wish to forward this email to co-authors, please delete the link to your homepage first **

We hope to receive your revised paper within six weeks; please let us know if you aren't able to submit it within this time so that we can discuss how best to proceed. If we don't hear from you, and the revision process takes significantly longer, we may close your file. In this event, we will still be happy to reconsider your paper at a later date, as long as nothing similar has been accepted for publication at *Communications Earth & Environment* or published elsewhere in the meantime.

Please do not hesitate to contact us if you have any questions or would like to discuss these revisions further. We look forward to seeing the revised manuscript and thank you for the opportunity to review your work.

Best regards,

Alienor Lavergne, PhD
Associate Editor
Communications Earth & Environment

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REVIEWER COMMENTS:

Reviewer #1 (Remarks to the Author):

The manuscript "Historical boreal forest cover loss under climate warming and recurring wildfires"

addresses the possible effects of climate change on the boreal forest – prairie ecotone of Northern America. While the ongoing climate change doubtlessly affects all ecosystems on Earth, its effects are especially pronounced for ecotones between open and forested biomes. In these regions, the impact of direct climatic drivers can, by inducing changes in secondary ones (such as wildfires), be amplified. Furthermore, it must be kept in mind, that boreal forests are a vital part of the Earth's carbon-cycle and have high commercial value.

The authors address the fate of the present-day hemiboreal ecosystem of North America employing datasets representing millennia-long observations of vegetation and burning dynamics associated with changing environmental conditions revealed by numerous palaeoecological records, which are still heavily underused as a data source in modern ecological research.

The text is well written and grammatically correct, the references are up to date, the datasets and analytical methods are well suited and appropriate, and the overall quality of the figures and tables is high.

Specific comments:

1. While the usage of pollen data, which allows one to obtain a long-term perspective of vegetation change, is an advantage of this study, the presented relative-change-based diagrams are somewhat out of date. Modern palaeoecological studies generally rely on pollen accumulation rates (PAR = grains/cm²/year) which can be related to plant biomass (e.g Knight et al 2022) and used to track changes in a specific taxon or alternatively to use some pollen-based vegetation reconstruction techniques (e.g. Sugita et al 2010 or Fyfe et al 2015). The usage of PARs is especially recommended for environments like the ones described in the current study – with sparse vegetation cover and/or a high rate of change. According to the methods chapter (lines 455-456), the pollen preparation included adding exotic marker pollen enabling the authors to calculate the PARs. Furthermore, the PAR-based vegetation biomass estimate could be an excellent addition to the burnt biomass estimates presented in this study.

2. There are both palaeo-record- and model-based datasets used in the study. The authors could consider making it more clear which data source was used before the reader reaches the methods chapter. For example, the first line (125) of “Historical wildfire activity” or (152) of the chapter “Vegetation history” clearly state that the information source was the palaeo-record. However, the following chapters (“Changes in climate” and “Human population history”) and figure 4 do not make it clear which data source was used.

3. line 199 - consider rewording the end of the sentence.

4. The authors' intentions with the discussion from line 244 to the end of the chapter are somewhat difficult to follow. The general impression from the text seems to be that the conifer dominated forests are fire-prone communities, and that the fire activity spiked during the Late Holocene. This seems to not be in accordance with the results of the current study. The especially confusing part starts at line 258 – I wonder if the described pulses should be visible in some figure (figure 6?) – could these be marked there in some way? It is also difficult to see in which way these pulses mirror the fluctuations of Picea and Poaceae (lines 262-263) and especially where the emergence of a positive relationship between biomass burning and these species' pollen abundance is seen (lines 267-268)? While the RegBB curve seems to follow the Poaceae curve, it seems to have an opposite trend to the Picea curve. Furthermore, according to figure 5, Picea has a clearly negative relationship with biomass burning. Altogether, the authors could consider rephrasing the section to convey the intended message more clearly.

5. The reconstruction of human population dynamics is interesting and beneficial for the study. However, the authors note the scarcity of the records for certain time intervals and its possible effect at the results (lines 285- 287). The authors could consider adding markers of the observed data-points to the Figure S6.

6. The statement in line 302 seems to be missing a reference.
7. Table 1 – in its current state the table seems to be somewhat overcrowded. Authors could consider removing some columns giving similar information (e.g., Acc. Rate and Sed. Rate) or merging columns giving complementary information (e.g. KB and LS).
8. Figure 1 – Consider marking the different parts of the figure with letters/numbers; re-drawing the general map (upper right corner) to depict a larger part of the North American continent – it would be easier for readers from other continents to relate to study area; adding a rectangle depicting the position of the map with site numbers (lowermost left side, missing scale and north arrow) to the large map at the right-hand side; adding a scale to the satellite images of the investigated lakes.
9. Figures 2, 3, 4 and 6 have timescales starting at different times (12000 or 10000) – consider using the same timescale and similar tick mark intervals for all figures; using the sub-epochs of the Holocene division for all figures to simplify the comparisons.
10. Figure 5 is very well executed and informative. However, the authors could consider increasing the difference in line thickness for the entity relationship diagram and removing Pinus from the diagram to make it more compact and easier to read.

Reviewer #2 (Remarks to the Author):

See attached review.

Review of “Historical boreal forest cover loss under climate warming....”

This well-written manuscript reflects significant research efforts. It calls on proxy data to describe post-glacial changes in vegetation and fire activity, and it places these changes in the context of changing climate and human population levels. Below, I highlight key components of the manuscript, in the context of the journal’s “[Criteria for publication](#).” The detailed suggestions that follow are intended to increase clarity or readability to a wide audience; comments proceeded by * indicated important suggestions for rationale, methods, or inferences.

The proxy records of climate, vegetation, human population levels, and fire activity **are generally “processed at a state-of-the-art level,”** and relationships among proxies are assessed for correlations over millennial time scales. Some of the statistically significant correlations are highlighted, and potential causal mechanisms are proposed.

The main “conclusions are novel,” largely because they stem from a unique combination of existing and new datasets, adding important nuance to previously reported changes in post-glacial climate, vegetation, and fire activity. Specifically, the addition of proxy data reflecting changes in human population sizes is significant, as is the increased density of fire and vegetation proxies. However, I note below where the motivation and specific questions on human activity would benefit from increased specificity.

As written, **the manuscript will be important to paleoecologists studying forest ecology and fire ecology.** In this context, it clearly fits disciplinary journals in these fields, e.g. *Quaternary Science Review*, *The Holocene*, *Quaternary Research*. **The manuscript has the potential to be of broader significance to Earth and environmental science communities, if it provides more details on the mechanisms supporting the main conclusion,** “climate[-]change-driven wildfires are expected to echo transformations observed 7,000 years ago, reducing boreal forest extent and impacting land use.” This is the only main conclusion highlighted in the summary; the bulk of the summary presents patterns and correlations, not implications of the findings. Two suggestion to bolster this conclusion:

- (1) *Clarify and refine the inferred mechanisms causing the patterns and correlations highlighted in the proxy datasets.* Explicitly place these mechanisms into the context of spatial and temporal scales of relevant drivers, to help link to contemporary observations and anticipated future change.
- (2) *Clarify and refine if and how the mechanisms shaping Holocene dynamics are (not) similar to the mechanisms influencing contemporary and anticipate future changes in the hemi-boreal zone.* The primary conclusion will have added significance if readers can clearly identify if, how, when, and why past dynamics can help us understand contemporary and anticipated future dynamics. For example, how do contemporary rates of climate change, post-fire climate conditions, land uses, fire management options, human ignitions, etc., differ between the past and the present? Highlighting just some key similarities and differences would help readers more legitimately use the past to help contextualize the present and anticipate the future. Otherwise, the implications remain generic.

Specific comments

L 28: Terminology varies, but generally “wildfire” implied unplanned fires (e.g., from lightning or human ignition sources). If the historical record includes human-set fires, then just use “fire”?

L 29: Eventually (in the results) “calibrated years before present” is presented, with the shortening to “cal. yrs. BP.” Readers may not inherently know what “BP” stands for here in the summary, so either write out the entire abbreviation, or consider just replacing “BP” with “years ago” – “...pivotal shift around 7,000 years ago saw the boreal forest...”

L 30: Change to “mid-Holocene”? This is seen in most papers coming up via a Google Scholar search for “Mid-Holocene”, including the text of this *Science* paper: <https://doi.org/10.1126/science.286.5444.1485>

L 33: *This is the first place in the text where the presentation as the past as useful for understanding anticipated anthropogenic climate-change-driven wildfires seems too simplistic. Read by researchers not intimately familiar with this field, this implies that the past is an analog for the future. What elements of the past do we expect to be similar, and what elements do we expect to be different in the future?

L 55: Opinion: I strongly suggest avoiding the use of another TLA (three-letter acronym). TLAs make text less accessible to broad audiences, and if one forgets what a TLA stands for, then the flow is disrupted. This TLA is only used c. 8 times in the entire manuscript. Spelling out prairie-forest ecotone only adds one word each use, and it should be worth the improved readability.

L 55: The term “integrity” is vague. Ecosystem integrity is an amorphous concept, loaded with implicit values. If used here, provide some examples to help specify what “integrity” is referring to.

L 57: Carefully consider the use of the term “catalyst”. Is the intention that fire is a significant cause (driver) of ecosystem change, or that fire accelerates changes that would otherwise happen more slowly, e.g., due to climate change? The latter is generally what “catalyze” refers to – accelerating a reaction or change that would otherwise happen more slowly. See the 4th paragraph in this review paper on wildfire-driven forest conversion in western North America, in BioScience: <https://doi.org/10.1093/biosci/biaa061>

L 67: A risk of what? Can this be specified? Invasive species increase the risk of many phenomena – is this focused specifically on increasing the risk of fire ignition and spread? Or...?

L 73: “...modified the development of the PFE...” – modified the development, from what other path of development? Consider “shaped the development of” instead.

L 79: “open- and closed-canopy forests”

L 80: “...the past millennia...” – singular (“the”) or plural (“millennia”)? “over past millennia...”??

L 84: “...around 4,250-3,000 [yr] BP” – Consider “between” instead of around, for this > 1000- yr period.

L 85: If the focus here is on human-planned burning, consider “Frequent *intentional* burning ...”

L 86-87: “...obtaining a green flush...” – a little bit vague. Is this simply for “improving forage”?

L 89: Again, what does “integrity” mean here? This is vague.

***L 93:** This sentence – “On the other hand...” – is setting on an apples-to-oranges comparison, between “impacts on the structure and location of the...ecotone” and “large-scale ecosystem alterations.” The scale of these two comparisons is vastly different, such that one could envision mechanisms making both of these statements true. Ultimately, this weakens the set up and motivation for the current study.

***L 97:** Conclusions on what key question? The reader is largely left to infer any key questions from the above text, and different readers will inevitably infer different questions. It would be helpful to frame the specific questions that this study sought to address, with respect to human population sizes and the datasets utilized. This inevitably requires specifying the scale at which the questions are constrained to, and the potential mechanisms that can and cannot be resolved from the data used in the current study. See some of the work by Christopher Roos et al. on scale in detecting and inferring Indigenous fire use in the paleo record: e.g., <https://www.nature.com/articles/s41893-020-0579-5>

L 100: Opinion: Given the decades-long history of work focusing on wildfire-vegetation-climate interactions, and more recently adding human components, ideally this would specify some more highly resolved questions, instead of framing the paper around the goal of just “shed[ding] light on...complex interactions and feedbacks.” The specificity to “centennial to millennial time scales” here is helpful, to distinguish this work (and potential mechanisms) from fire-specific work focused on smaller scales.

L 102-103: "...over a significant time period" is vague. Specify what's intended: over periods of significant changes in climate and human populations (?), or...? Why is it significant?

L 103: "...vegetation response to fire..." – specifying the time scale here would be helpful. At this point, it's not clear if this work is going to look at post-fire vegetation change (i.e., looking at pollen samples every c. decades, for the century or so following reconstructed fires) OR look at how vegetation changes with fire activity over millennial time scales and post-glacial changes in climate and human populations.

L 106: The move from "archaeological records" to "human activities" is abrupt. What types of activities are inferred from the archaeological data? Can they be specified, OR are the data simply used as an indicator of human presence/absence or population size? I strongly suggest quickly just referring to "human activities" as what the proxy is ultimately interpreted as (e.g., Fig. 4) -- "human population size."

L 107: By contrasting "human activities" with "natural processes" this text implicitly takes a philosophical stance that humans and "nature" are separate entities. This is a sticky topic, not necessary to wade into this in this paper. An alternative is to just focus on what mechanisms are intended under the term "natural" – fire activity (or lightning-ignited fire activity), and ecosystem dynamics.

L 110: Here and throughout "between" is used when "among" should (arguably) be used instead, since the comparisons are among three or more nouns.

***L 113:** The results section is written as if it comes after the methods section, following the I-M-R-D format. It would be helpful to "pepper in" some methods, so readers do not have to flip between sections, or are left wondering how something was done or how results could/should be interpreted. For example, in the section "Changes in climate" – I didn't know where the climate data came from, first assuming they were from paleoclimate proxies, but then realizing they came from climate simulations after reading the methods. Starting out that section (L 163) with "Simulated mean annual temperatures..." or "Mean annual temperature, as simulated in X models, gradually increased..." would help significantly, e.g..

L 115: Same comment as above, with respect to TLAs. Lake of the Woods Ecoregion could simply be introduced as the study area, and from then out, either reference the study area/region/ecoregion, or just spell out Lake of the Woods Ecoregion. It appears to only used 8 times in the text.

L 119: The literature typically uses the term "Livingstone-type sampler" (as revealed via a Google Scholar search) – particularly when paired with the reference to Wright et al. 1984 (as in the methods).

L 120: This is the first definition of "cal. yrs. BP". It would be useful if the abbreviation was used throughout (vs. just "BP"), and it would be useful to specify that "present" is CE 1950.

L 126: Can the term "pulses or bursts of activity" be clarified, or described in a more objective way? What's the difference between "bursts" and "(significant) increases"? What make a "pulse" different from "variability"? These are just terms that don't get used often when describing summary statistics.

L 130: This is a good example of where not knowing that the records were 210-Pb dated could/should significantly impact the way the reader interprets this finding. Not knowing that the records were 210-Pb dated, my first thought here was that this change likely reflected increased sediment accumulation, and dilution of charcoal concentrations. One could write, above "...as inferred from pooled, 14C- and 210Pb-dated lacustrine charcoal records, displayed..." to sneak in that these records have strong chronologies.

L 131: Opinion: Again, "irregular pulsating behavior" is pretty odd text used to describe summary statistics of a time series. The more the reader is left to wonder what this means, the less the reader will follow the specific patterns that are intended to be highlighted in the text.

L 130: Here and throughout, please specify when the numbers are referring to individual fire return intervals, vs. the mean fire return intervals. Here, should this be "...a gradual shortening of the mean fire return interval.." or "...from a mean of approximately 400 years..."?

L 162: As noted above, the reader needs to know something about where this information comes from. Here, just using the word "simulated" would help. Otherwise, this text does not make sense. It wasn't clear whether this was a result from this study, or just calling on existing data, or what.

L 177: It would help to explicitly note what aspect(s) of "human population" is(are) being inferred here: relative changes in population size?

***L 185:** (1) This section is largely based on correlations, so those statistics should be reported here – e.g., following each statement of a significant correlation, include (parenthetically) “Spearman rho = X, n = X, p = X). This is increasingly the standard in many journals (e.g., PNAS), because it increases clarity.

(2) “Relationships among fire, climate, vegetation, and human population levels” – (a) “interaction” implies statistical relationships; (b) “human demography” is more general than what’s inferred.

L 187: “relative abundance” instead of “species abundances,” since the latter is not actually inferred from the pollen data? Again, readers not familiar with palynology will think this means actual abundance of plants on the landscape (vs. abundance of pollen produced by these plants).

L 188: It’s critical to specify the time scale of “temperature variations” – decadal, centennial, millennial?

L 191: I don’t think the reader knows yet what these acronyms stand for (RegBB, RegFRI, RegFS).

L 193: “highly positive” -- Better to report the statistics here -- correlation coefficient -- and let the reader determine the subjective qualifier. Also, it would be worth noting somewhere in the results that autocorrelation, from the smoothing of the time series, was accounted for; otherwise, readers will wonder how sample size was determined, and if/how that impacts the p-values.

L 202: Suddenly the archeology data is used to infer “land-use dynamics” – a more complicated and nuanced phenomenon, vs. population size. A few lines below (L 204) “human activities” is used. Ideally use a consistent term to reference what the archeological data are standing in for, as a proxy.

L 207-213: This starts with introduction-type text. Consider leading with results from this study, then linking to previous predictions, etc. E.g., the sentence on L 216 seems like a strong start.

L 225: A “significant decrease in the *mean* fire return interval”? Please make sure to define how significant changes are identified, in the methods.

L 231: Consider “twice as much burning” instead of a “gradual reduction in the [mean?] fire return interval.” Note that many reader will forget that decreasing FRIs mean more burning; with the mean (presumably) FRI being cut in half, this represents twice as much burning (per unit time).

L 233: Use of “simulated” here is helpful – this is what would also be helpful in the results text.

L 238: “decline in recorded fire events” – readers will appreciate if “fire activity” is presented consistently, at least in the discussion. Consider avoiding moving from FRI to frequency, if possible. Choose one; frequency is more intuitive to non-specialists.

L 242: Is the intention to highlight changes in the *seasonality* of incoming solar radiation due to changing orbital parameters? Changes in total (annual) insolation largely call on other mechanisms.

L 244: “...the late-phase fire trajectory” – is vague. I don’t know what this means.

L 248: The parenthetical reference to “bottom-up driver” make sense to me, but I suspect for many this will not make sense. This seems particularly true since this term was not used in the introduction, for example to set up any prior mechanistic hypotheses guiding the study. It is only used here, once. Delete?

L 259: Again, “irregular pulses or bursts of activity” is vague.

L 263: “...quite accurately...” – is accuracy really the term intended here? This is not a model making a prediction. Is the pattern highlighted here reflected by a strong/high correlation?

L 264: “fire regime limited by fuel availability” -- Do the time scales align here? The contrast between the potential mechanisms describe (“fire regime limited by fuel availability vs. oscillatory behavior tied to fire-conducive weather”) is not clear, in part because of a mix of time scales (e.g., regime vs. weather).

L 272: Was fuel limiting fire occurrence, or was it lowering/reducing fire severity? As the authors know, it’s hard to imagine an oak- and/or grass-dominated fire regime having the same mFRI as a boreal forest. The discussion may warrant an explicit statement about just what types of fire the FRI record reflects – e.g., high-severity fires primarily, likely missing smaller, low-severity fires.

L 280: “...low-level surface burns...” – consider “low-intensity surface fires” for general terminology.

L 281: The contrast here (“However...”) is not clear. The absence of low-intensity surface fires being detected or reflected in the RegFRI record would actually be consistent with these data, no? It would/could resolve the apparent lack of / little difference in mean FRI between oak/grass-dominated vegetation during the mid-Holocene and spruce- and pine-dominated vegetation of the late Holocene.

Note also that papers on detecting fire events with peaks in charcoal accumulation also highlight that these records best reflect high-severity fires. E.g., the referenced paper, Higuera et al. (2010).

L 284-286: This seems like an important limitation for 2/3 of the time period presented in the paper. Given that the correlations (e.g., Fig. 5) are over the past 10,000 years, any series-wide trends in human population that reflect a “fading record” (towards the past) would tend to make it correlated with overall increases of temperature and charcoal accumulation. It would be useful to give the reader a little more help in how to interpret this timeframe – over ½ of the 0-10 ka record, and 2/3 of the entire record.

L 301: What is the “slight dip” in the prairie-forest ecotone mean? Dip south, decrease in...?

L 312: I know what is intended here, but this text does not sound great and could be misinterpreted. Consider: “...deposits left by Indigenous cultures...”

L 314: “...data provide...”

***L 318:** If this text remains in the discussion – “...valuable knowledge to predict potential reactions to future climate shifts” – then there should be more specific predictions actually discussed. What does this work reveal about the ongoing mechanisms of changing fire activity, vegetation, and human behavior?

L 319: Suggestion: just spell out “...mitigation and adaptation...” as these are two distinct, important strategies for confronting climate change.

L 320: “...the adaptability of forest ecosystems and land uses” – is in fact “adaptation”.

***L 325:** HOW could the fire community and society derive insights from paleoenvironmental sources? Can the authors provide those insights here?

***L 327:** “...represent the natural state for the hemi-boreal in a warm climate context” – is the reader to take this to mean that a “warm climate context” is what we are in now, or what we are heading to in upcoming decades? Is there any way to help the reader compare how the present and anticipated future is

similar or different from the past? E.g., how do projected changes in temperature and precipitation compare to those illustrated in Fig. 4a? The text here is a bit oversimplified.

L 381: “Livingstone-type piston corer”

L 387: Somewhere in here – either in age-depth models, or in specific proxy record development -- it should be clear the average time intervals represented by each sample AND the time between samples. This is key for interpreting the pollen and charcoal data.

L 436-437: Please add the time scale over which fire events were summarized for the pooled records.

L 439: Shouldn't the RegFS index have a reference...? I recall a PNAS paper that first introduced it.

L 448: Can this 10-cm interval be reported in terms of time-between-samples too? That's highly relevant for interpreting what the records can and cannot resolve.

L 506-507: “relationships among...” and isn't “land-use” here really relative human population size?

L 543: Data and code availability: I expect and hope that publication in a Nature journal requires that data and code be housed in a publically available repository. This is widely recognized as “best practice” now.

L 933: Table 1: suggest including units in the last three columns – as in the earlier columns.

***Figures, in general:** The figures are well developed and clear. There is never, however, one figure that has all of the elements of environmental change reported on in this study – i.e., climate, fire, vegetation, and human population size. This makes it challenging to compare and see some of the correlations highlighted in the text and in Fig. 5. For example, pollen data are illustrated with time on the vertical axis, while all other figures have time on the horizontal axis; Fig. 3 and 4 have the sub-epoch boundaries on them to facilitate comparisons, but Fig. 2 does not have any sub-epoch boundaries.

Fig. 3: What are the grey horizontal lines in this figure? On my screen at least, I can't quite tell if they are just grid lines, equally spaced for visualization, or something else (e.g., fire events – but I don't think so).

***Fig. 5:** This is an interesting figure! Many correlations make mechanistic sense -- e.g., AnnTemp and RegBB. Other correlations do not, however, make mechanistic sense: e.g., why is RegFS negatively correlated with Picea and positively correlated with Quercus? This is the opposite of what one would expect by reading a fire ecology text book (e.g., high-severity fire in boreal forest; lower severity fire in oak-dominated forests). It would be useful to point out, briefly, why some associations may not make sense. For example – using pollen percentages here, some increases (or positive correlations) with fire activity and/or temperature will automatically be paired with decreases (or negative correlations) with other taxa. It would help for the reader to know a bit more how and what to “lean on” here and what else are likely artifacts of the proxies and methods (e.g., correlations using pollen percentages).

Response to reviewers

☒ **[Reviewer #1]:** The manuscript "Historical boreal forest cover loss under climate warming and recurring wildfires" addresses the possible effects of climate change on the boreal forest – prairie ecotone of Northern America. While the ongoing climate change doubtlessly affects all ecosystems on Earth, its effects are especially pronounced for ecotones between open and forested biomes. In these regions, the impact of direct climatic drivers can, by inducing changes in secondary ones (such as wildfires), be amplified. Furthermore, it must be kept in mind, that boreal forests are a vital part of the Earth's carbon-cycle and have high commercial value. The authors address the fate of the present-day hemiboreal ecosystem of North America employing datasets representing millennia-long observations of vegetation and burning dynamics associated with changing environmental conditions revealed by numerous palaeoecological records, which are still heavily underused as a data source in modern ecological research.

☒ **[Authors]:** We sincerely thank Reviewer #1 for diligently capturing the essential elements of our manuscript and for underscoring the scientific significance of historical and archaeological data in the context of our research.

☒ **[Reviewer #1]:** The text is well written and grammatically correct, the references are up to date, the datasets and analytical methods are well suited and appropriate, and the overall quality of the figures and tables is high.

☒ **[Authors]:** We thank the referee for dedicating time to evaluate our work and for providing constructive comments.

☒ **[Reviewer #1]:** 1. While the usage of pollen data, which allows one to obtain a long-term perspective of vegetation change, is an advantage of this study, the presented relative-change-based diagrams are somewhat out of date. Modern palaeoecological studies generally rely on pollen accumulation rates (PAR = grains/cm²/year) which can be related to plant biomass (e.g Knight et al 2022) and used to track changes in a specific taxon or alternatively to use some pollen-based vegetation reconstruction techniques (e.g. Sugita et al 2010 or Fyfe et al 2015). The usage of PARs is especially recommended for environments like the ones described in the current study – with sparse vegetation cover and/or a high rate of change. According to the methods chapter (lines 455-456), the pollen preparation included adding exotic marker pollen enabling the authors to calculate the PARs. Furthermore, the PAR-based vegetation biomass estimate could be an excellent addition to the burnt biomass estimates presented in this study.

☒ **[Authors]:** We appreciate the referee's comment regarding the use of pollen data in our study. While we acknowledge the benefits of PAR in providing a long-term perspective of vegetation change, we would like to clarify our approach in the context of our study. As we are working on regional averages, the large range of values and high variability of PAR, and the non-normal distribution will skew the regional means of pollen records, making the comparison less robust. Meekin's variability (stdev) in total PAR is three times larger than that of O15 and 1.5 times larger than M15, which indicates that Meekin's data has substantially greater variance compared to our sites. To use PAR would require adjusting the variance of each record by applying transformations, such as square-root and normalization. By opting for a relative percentage scale, we aimed to simplify averaging and minimizing the potential impact of individual records and spikes

on the overall regional analysis. We believe that our decision to present the results in relative percentages was a careful consideration based on the specific constraints. Although we are aware of the large research programs quantifying accumulation rates and using models such as REVEALS (and indeed, some of us have been working on this project), we feel this is one approach of many equally valid ones to provide a long-term perspective of vegetation change. Of note, however, is that the PAR data of our sampled lakes were not presented in the Supplementary Information in our original submission. We corrected this by presenting PAR values in the revised Fig. S5. One will note from comparing Fig. S5 with Fig. S4 that the general trends of individual lake PAR records are very similar to their corresponding % relative abundances, but also that the PAR are, as is well known, more “noisy” making averaged curves more difficult to interpret. We see the same overall increase of *Poaceae* and *Quercus* during the mid-Holocene and a decrease in *Picea*. The percentages are still widely used and published today.

☑ **[Reviewer #1]:** 2. There are both palaeo-record- and model-based datasets used in the study. The authors could consider making it more clear which data source was used before the reader reaches the methods chapter. For example, the first line (125) of “Historical wildfire activity” or (152) of the chapter “Vegetation history” clearly state that the information source was the palaeo-record. However, the following chapters (“Changes in climate” and “Human population history”) and figure 4 do not make it clear which data source was used.

☑ **[Authors]:** Agreed. The following introductory sentence was added to the section on Vegetation history: “*Climate variations are herein documented through the utilization of paleoclimate model simulations spanning the past 12,000 years*”. For human history, we modified the introductory statement to “*Populations of archaeological radiocarbon dates suggest that the oldest records of human presence in the study area date back to 12,000 - 11,000 years BP*”.

☑ **[Reviewer #1]:** 3. line 199 - consider rewording the end of the sentence.

☑ **[Authors]:** Corrected for: “*Population sizes showed a tendency to rise during periods characterized by longer fire return intervals and decline during periods marked by active fire activity.*”

☑ **[Reviewer #1]:** 4. The authors’ intentions with the discussion from line 244 to the end of the chapter are somewhat difficult to follow. The general impression from the text seems to be that the conifer dominated forests are fire-prone communities, and that the fire activity spiked during the Late Holocene. This seems to not be in accordance with the results of the current study. The especially confusing part starts at line 258 – I wonder if the described pulses should be visible in some figure (figure 6?) – could these be marked there in some way? It is also difficult to see in which way these pulses mirror the fluctuations of *Picea* and *Poaceae* (lines 262-263) and especially where the emergence of a positive relationship between biomass burning and these species’ pollen abundance is seen (lines 267-268)? While the RegBB curve seems to follow the *Poaceae* curve, it seems to have an opposite trend to the *Picea* curve. Furthermore, according to figure 5, *Picea* has a clearly negative relationship with biomass burning. Altogether, the authors could consider rephrasing the section to convey the intended message more clearly.

☑ **[Authors]**: Reviewer #2 also had similar remarks and provided specific recommendations. We believe these changes have improved the text. See answer provided to reviewer #2 below.

☑ **[Reviewer #1]**: 5. The reconstruction of human population dynamics is interesting and beneficial for the study. However, the authors note the scarcity of the records for certain time intervals and its possible effect at the results (lines 285- 287). The authors could consider adding markers of the observed data-points to the Figure S6.

☑ **[Authors]**: A rug plot illustrating the data points was added to Fig. S6

☑ **[Reviewer #1]**: 6. The statement in line 302 seems to be missing a reference.

☑ **[Authors]**: Added Briere and Gajewski 2023

☑ **[Reviewer #1]**: 7. Table 1 – in its current state the table seems to be somewhat overcrowded. Authors could consider removing some columns giving similar information (e.g., Acc. Rate and Sed. Rate) or merging columns giving complementary information (e.g. KB and LS).

☑ **[Authors]**: Done. Acc. Rate was removed as not discussed in text. KB and LS were merged.

☑ **[Reviewer #1]**: 8. Figure 1 – Consider marking the different parts of the figure with letters/numbers; re-drawing the general map (upper right corner) to depict a larger part of the North American continent – it would be easier for readers from other continents to relate to study area; adding a rectangle depicting the position of the map with site numbers (lowermost left side, missing scale and north arrow) to the large map at the right-hand side; adding a scale to the satellite images of the investigated lakes.

☑ **[Authors]**: The addition of scale to the satellite images would make it too dense for the figure as each image would require its own scale. But readers may consult Table 1 to have an idea of the lake size. The following was added to the figure caption: “Refer to Table 1 for lake coordinates and sizes”. The general map was modified to depict a larger part of North America. Lettering i, ii, and iii were also added to each part of the figure.

☑ **[Reviewer #1]**: 9. Figures 2, 3, 4 and 6 have timescales starting at different times (12000 or 10000) – consider using the same timescale and similar tick mark intervals for all figures; using the sub-epochs of the Holocene division for all figures to simplify the comparisons.

☑ **[Authors]**: The timescales were corrected (except in Fig. 3 to avoid having a large blank area on the left side).

☑ **[Reviewer #1]**: 10. Figure 5 is very well executed and informative. However, the authors could consider increasing the difference in line thickness for the entity relationship diagram and removing *Pinus* from the diagram to make it more compact and easier to read.

☑ **[Authors]**: Thank you for the positive comment. Regarding the suggestion to remove *Pinus* from the diagram for a more compact view, we find *Pinus* ecologically significant and prefer to retain it in the graph. As for the line thickness, we acknowledge the challenge in adjusting it due to limitations in R, where increasing thickness may impact

visibility by altering dash distances. The current settings represent a compromise to balance line visibility, clarity and compactness.

☑ **[Reviewer #2]:** This well-written manuscript reflects significant research efforts. It calls on proxy data to describe postglacial changes in vegetation and fire activity, and it places these changes in the context of changing climate and human population levels. Below, I highlight key components of the manuscript, in the context of the journal's "Criteria for publication." The detailed suggestions that follow are intended to increase clarity or readability to a wide audience; comments preceded by * indicated important suggestions for rationale, methods, or inferences.

☑ **[Authors]:** We would like to thank the reviewer for their time in conducting the review. We have seriously considered the suggestions.

☑ **[Reviewer #2]:** The proxy records of climate, vegetation, human population levels, and fire activity are generally "processed at a state-of-the-art level," and relationships among proxies are assessed for correlations over millennial time scales. Some of the statistically significant correlations are highlighted, and potential causal mechanisms are proposed. The main "conclusions are novel," largely because they stem from a unique combination of existing and new datasets, adding important nuance to previously reported changes in post-glacial climate, vegetation, and fire activity. Specifically, the addition of proxy data reflecting changes in human population sizes is significant, as is the increased density of fire and vegetation proxies. However, I note below where the motivation and specific questions on human activity would benefit from increased specificity.

☑ **[Authors]:** Thank you. Please see detailed responses below.

☑ **[Reviewer #2]:** As written, the manuscript will be important to paleoecologists studying forest ecology and fire ecology. In this context, it clearly fits disciplinary journals in these fields, e.g. Quaternary Science Review, The Holocene, Quaternary Research. The manuscript has the potential to be of broader significance to Earth and environmental science communities, if it provides more details on the mechanisms supporting the main conclusion, "climate[-]change-driven wildfires are expected to echo transformations observed 7,000 years ago, reducing boreal forest extent and impacting land use." This is the only main conclusion highlighted in the summary; the bulk of the summary presents patterns and correlations, not implications of the findings. Two suggestion to bolster this conclusion:

☑ **[Authors]:** Thank you for the suggestions. We attempted to address most of these comments. Of note is that we are very limited in the length of the summary (170 words), which prevents from elaborating all of the mechanisms. We hope that the changes made help improve the Summary.

☑ **[Reviewer #2]:** (1) Clarify and refine the inferred mechanisms causing the patterns and correlations highlighted in the proxy datasets. Explicitly place these mechanisms into the context of spatial and temporal scales of relevant drivers, to help link to contemporary observations and anticipated future change.

☑ **[Authors]**: The Summary was modified: "... Postglacial biomass burning exhibited episodes of persistent elevated activity, and a pivotal shift around 7,000 years ago saw the boreal forest transition to an oak-pine barren ecosystem for about 2,000 years before reverting. This mid-Holocene shift occurred during a context of lower fire return intervals and matched a sudden increase of annual temperatures. Population size of Indigenous peoples mirrored these wildfire fluctuations, increasing during longer fire intervals and decreasing during elevated fire activity. Anticipated increases of fire activity with climate change are expected to echo transformations observed 7,000 years ago, reducing boreal forest extent and impacting land use."

☑ **[Reviewer #2]**: (2) Clarify and refine if and how the mechanisms shaping Holocene dynamics are (not) similar to the mechanisms influencing contemporary and anticipate future changes in the hemi-boreal zone. The primary conclusion will have added significance if readers can clearly identify if, how, when, and why past dynamics can help us understand contemporary and anticipated future dynamics. For example, how do contemporary rates of climate change, post-fire climate conditions, land uses, fire management options, human ignitions, etc., differ between the past and the present? Highlighting just some key similarities and differences would help readers more legitimately use the past to help contextualize the present and anticipate the future. Otherwise, the implications remain generic.

☑ **[Authors]**: As mentioned earlier, we are limited in length for the summary. With the modification stated above, we hope people interested in the mechanism can be led to the Discussion.

☑ **[Reviewer #2]**: L 28: Terminology varies, but generally "wildfire" implied unplanned fires (e.g., from lightning or human ignition sources). If the historical record includes human-set fires, then just use "fire"?

☑ **[Authors]**: Corrected for 'fire data', since past fires are of unknown origin.

☑ **[Reviewer #2]**: L 29: Eventually (in the results) "calibrated years before present" is presented, with the shortening to "cal. yrs. BP." Readers may not inherently know what "BP" stands for here in the summary, so either write out the entire abbreviation, or consider just replacing "BP" with "years ago" – "...pivotal shift around 7,000 years ago saw the boreal forest..."

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 30: Change to "mid-Holocene"? This is seen in most papers coming up via a Google Scholar search for "Mid-Holocene", including the text of this Science paper: <https://doi.org/10.1126/science.286.5444.1485>

☑ **[Authors]**: Corrected throughout manuscript.

☑* **[Reviewer #2]**: L 33: This is the first place in the text where the presentation as the past as useful for understanding anticipated anthropogenic climate-change-driven wildfires seems too simplistic. Read by researchers not intimately familiar with this field, this implies that the past is an analog for the future. What elements of the past do we expect to be similar, and what elements do we expect to be different in the future?

☑ **[Authors]**: To increase clarity, we reworded to “Anticipated increases of fire activity with climate change are expected to echo transformations observed 7,000 years ago, reducing boreal forest extent and impacting land use”.

☑ **[Reviewer #2]**: L 55: Opinion: I strongly suggest avoiding the use of another TLA (three-letter acronym). TLAs make text less accessible to broad audiences, and if one forgets what a TLA stands for, then the flow is disrupted. This TLA is only used c. 8 times in the entire manuscript. Spelling out prairie-forest ecotone only adds one word each use, and it should be worth the improved readability.

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 55: The term “integrity” is vague. Ecosystem integrity is an amorphous concept, loaded with implicit values. If used here, provide some examples to help specify what “integrity” is referring to.

☑ **[Authors]**: Corrected for “functioning of the ecosystems”.

☑ **[Reviewer #2]**: L 57: Carefully consider the use of the term “catalyst”. Is the intention that fire is a significant cause (driver) of ecosystem change, or that fire accelerates changes that would otherwise happen more slowly, e.g., due to climate change? The latter is generally what “catalyze” refers too – accelerating a reaction or change that would otherwise happen more slowly. See the 4th paragraph in this review paper on wildfire driven forest conversion in western North America, in BioScience: <https://doi.org/10.1093/biosci/biaa061>

☑ **[Authors]**: Corrected for “cause of”

☑ **[Reviewer #2]**: L 67: A risk of what? Can this be specified? Invasive species increase the risk of many phenomena – is this focused specifically on increasing the risk of fire ignition and spread? Or...?

☑ **[Authors]**: Corrected for “Invasive species also pose a risk to plant community structure, as they can outcompete native species and alter ecosystem processes”

☑ **[Reviewer #2]**: L 73: “...modified the development of the PFE...” – modified the development, from what other path of development? Consider “shaped the development of” instead.

☑ **[Authors]**: Done

☑ **[Reviewer #2]**: L 79: “open- and closed-canopy forests”

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 80: “...the past millennia...” – singular (“the”) or plural (“millennia”)? “over past millennia...”??

☑ **[Authors]**: Corrected for plural

☑ **[Reviewer #2]**: L 84: “...around 4,250-3,000 [yr] BP” – Consider “between” instead of around, for this > 1000-yr period.

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 85: If the focus here is on human-planned burning, consider “Frequent intentional burning ...”

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 86-87: “...obtaining a green flush...” – a little bit vague. Is this simply for “improving forage”?

☑ **[Authors]**: Wording changed to “promote growth of herbaceous vegetation”

☑ **[Reviewer #2]**: L 89: Again, what does “integrity” mean here? This is vague.

☑ **[Authors]**: The sentence was shortened to “Although there is today a notable impact of human activities on these ecosystems, consequences on the landscape of burning practices by Indigenous peoples during the Holocene are less well known”

☑* **[Reviewer #2]**: L 93: This sentence – “On the other hand...” – is setting on an apples-to-oranges comparison, between “impacts on the structure and location of the...ecotone” and “large-scale ecosystem alterations.” The scale of these two comparisons is vastly different, such that one could envision mechanisms making both of these statements true. Ultimately, this weakens the set up and motivation for the current study.

☑ **[Authors]**: Our text wasn’t clear and we were referring to the prairie-forest ecotone in both cases. These statements were revised as follow: “An extensive literature has argued that Indigenous burning had significantly influenced the structure and location of the prairie-forest ecotone in North America (e.g., Higgins, 1986; Stewart, 2002). However, other literature and a recent analysis of paleoenvironmental and paleodemographic data across the Northern American prairie-forest ecotone challenged the notion of large-scale Indigenous alteration of past ecosystems of the region (Briere & Gajewski, 2023). The integration of archaeological data with paleoecological and paleoclimate records for inferring human, fire, and vegetation interactions is constrained by incomplete archaeological and paleoecological records, temporal misalignments among data sources, mismatches with the scale at which Indigenous people lived, and reliance on proxies with limitations, introducing uncertainties in the interpretation of past ecosystems in this region (e.g. Delcourt and Delcourt, 2004; Gajewski et al., 2019; Munoz et al., 2014; Roos, 2020).”

☑* **[Reviewer #2]**: L 97: Conclusions on what key question? The reader is largely left to infer any key questions from the above text, and different readers will inevitably infer different questions. It would be helpful to frame the specific questions that this study sought to address, with respect to human population sizes and the datasets utilized. This inevitably requires specifying the scale at which the questions are constrained to, and the potential mechanisms that can and cannot be resolved from the data used in the current study. See some of the work by Christopher Roos et al. on scale in detecting and inferring Indigenous fire use in the paleo record: e.g., <https://www.nature.com/articles/s41893-020-0579-5>

☑ **[Authors]**: The statement was revised to add clarity (see reply to the above comment). We agree that this is a complex issue that depends greatly on scale, and hope

we make it clear that we are restricting our analysis to the region of the prairie-forest border where we have extracted paleo-population data. The citation to Roos (2020) as well as other studies that have commented on this issue were added.

☑ **[Reviewer #2]:** L 100: Opinion: Given the decades-long history of work focusing on wildfire-vegetation-climate interactions, and more recently adding human components, ideally this would specify some more highly resolved questions, instead of framing the paper around the goal of just “shed[ding] light on...complex interactions and feedbacks.” The specificity to “centennial to millennial time scales” here is helpful, to distinguish this work (and potential mechanisms) from fire-specific work focused on smaller scales.

☑ **[Authors]:** The statement was revised to “In this study, we document the centennial to millennial time scales wildfire, vegetation, climate, and land-use dynamics at the prairie-forest ecotone of the hemi-boreal zone in North America, in order to shed light on the complex interactions and feedback between these factors at such long-time scales.”

☑ **[Reviewer #2]:** L 102-103: “...over a significant time period” is vague. Specify what’s intended: over periods of significant changes in climate and human populations (?), or...? Why is it significant?

☑ **[Authors]:** Changed to: Specifically, using macro-charcoal found in sediment samples from six lakes, we investigated changes in the frequency, size, and severity of fire occurrences over a period spanning 12,000 years.

☑ **[Reviewer #2]:** L 103: “...vegetation response to fire...” – specifying the time scale here would be helpful. At this point, it’s not clear if this work is going to look at post-fire vegetation change (i.e., looking at pollen samples every c. decades, for the century or so following reconstructed fires) OR look at how vegetation changes with fire activity over millennial time scales and post-glacial changes in climate and human populations.

☑ **[Authors]:** Clarifications were added about the time scale.

☑ **[Reviewer #2]:** L 106: The move from “archaeological records” to “human activities” is abrupt. What types of activities are inferred from the archaeological data? Can they be specified, OR are the data simply used as an indicator of human presence/absence or population size? I strongly suggest quickly just referring to “human activities” as what the proxy is ultimately interpreted as (e.g., Fig. 4) -- “human population size.”

☑ **[Authors]:** Indeed, this is an important point. It is the population size that we are investigating. The terminology was changed to “human population size”

☑ **[Reviewer #2]:** L 107: By contrasting “human activities” with “natural processes” this text implicitly takes a philosophical stance that humans and “nature” are separate entities. This is a sticky topic, not necessary to wade into this in this paper. An alternative is to just focus on what mechanisms are intended under the term “natural” – fire activity (or lightning-ignited fire activity), and ecosystem dynamics.

☑ **[Authors]:** Yes, we do not wish to wade into this philosophical issue. The statement was modified to: “Finally, by integrating archaeological records with historical climate,

vegetation, and fire data, we analyzed relationships between post-glacial human population size, climate drivers, and ecosystem dynamics.”

☑ **[Reviewer #2]:** L 110: Here and throughout “between” is used when “among” should (arguably) be used instead, since the comparisons are among three or more nouns.

☑ **[Authors]:** Corrected

☑* **[Reviewer #2]:** L 113: The results section is written as if it comes after the methods section, following the I-M-R-D format. It would be helpful to “pepper in” some methods, so readers do not have to flip between sections, or are left wondering how something was done or how results could/should be interpreted. For example, in the section “Changes in climate” – I didn’t know where the climate data came from, first assuming they were from paleoclimate proxies, but then realizing they came from climate simulations after reading the methods. Starting out that section (L 163) with “Simulated mean annual temperatures...” or “Mean annual temperature, as simulated in X models, gradually increased...” would help significantly, e.g..

☑ **[Authors]:** This comment aligns with another comment from Referee #1. Following his/her recommendation, we modified the introductory statement of each section to clarify the types of data under use.

☑ **[Reviewer #2]:** L 115: Same comment as above, with respect to TLAs. Lake of the Woods Ecoregion could simply be introduced as the study area, and from then out, either reference the study area/region/ecoregion, or just spell out Lake of the Woods Ecoregion. It appears to only used 8 times in the text.

☑ **[Authors]:** Corrected as suggested by eliminating the LWE acronym.

☑ **[Reviewer #2]:** L 119: The literature typically uses the term “Livingstone-type sampler” (as revealed via a Google Scholar search) – particularly when paired with the reference to Wright et al. 1984 (as in the methods).

☑ **[Authors]:** Corrected for Livingstone-type here and throughout text

☑ **[Reviewer #2]:** L 120: This is the first definition of “cal. yrs. BP”. It would be useful if the abbreviation was used throughout (vs. just “BP”), and it would be useful to specify that “present” is CE 1950.

☑ **[Authors]:** Done

☑ **[Reviewer #2]:** L 126: Can the term “pulses or bursts of activity” be clarified, or described in a more objective way? What’s the difference between “bursts” and “(significant) increases”? What make a “pulse” different from “variability”? These are just terms that don’t get used often when describing summary statistics.

☑ **[Authors]:** Corrected for “displayed episodes of persistent elevated activity”

☑ **[Reviewer #2]:** L 130: This is a good example of where not knowing that the records were 210-Pb dated could/should significantly impact the way the reader interprets this finding. Not knowing that the records were 210-Pb dated, my first thought here was that this change likely reflected increased sediment accumulation, and dilution of charcoal concentrations. One could

write, above "...as inferred from pooled, ^{14}C - and ^{210}Pb -dated lacustrine charcoal records, displayed..." to sneak in that these records have strong chronologies.

✓ **[Authors]**: Corrected for "...as inferred from pooled ^{14}C - and ^{210}Pb -dated lacustrine charcoal records, displayed..."

✓ **[Reviewer #2]**: L 131: Opinion: Again, "irregular pulsating behavior" is pretty odd text used to describe summary statistics of a time series. The more the reader is left to wonder what this means, the less the reader will follow the specific patterns that are intended to be highlighted in the text.

✓ **[Authors]**: Changed to "Examination of individual site records indicated that fluctuations in the level of biomass burning was present at many sites, although not necessarily in phase"

✓ **[Reviewer #2]**: L 130: Here and throughout, please specify when the numbers are referring to individual fire return intervals, vs. the mean fire return intervals. Here, should this be "...a gradual shortening of the mean fire return interval.." or "...from a mean of approximately 400 years..."?

✓ **[Authors]**: Corrected for mean fire return interval

✓ **[Reviewer #2]**: L 162: As noted above, the reader needs to know something about where this information comes from. Here, just using the word "simulated" would help. Otherwise, this text does not make sense. It wasn't clear whether this was a result from this study, or just calling on existing data, or what.

✓ **[Authors]**: The title was changed to "Changes in simulated climate". The notion of simulation was also added in the introductory statement.

✓ **[Reviewer #2]**: L 177: It would help to explicitly note what aspect(s) of "human population" is(are) being inferred here: relative changes in population size?

✓ **[Authors]**: Corrected for 'population size levels'

✓ **[Reviewer #2]**: L 185: (1) This section is largely based on correlations, so those statistics should be reported here – e.g., following each statement of a significant correlation, include (parenthetically) "Spearman rho = X, n = X, p = X". This is increasingly the standard in many journals (e.g., PNAS), because it increases clarity.

✓ **[Authors]**: Done, all statistics are now reported in text

✓* **[Reviewer #2]**: L 185: (2) "Relationships among fire, climate, vegetation, and human population levels" – (a) "interaction" implies statistical relationships; (b) "human demography" is more general than what's inferred.

✓ **[Authors]**: Corrected for "Relationships among fire, climate, vegetation, and human population levels"

✓ **[Reviewer #2]**: L 187: "relative abundance" instead of "species abundances," since the latter is not actually inferred from the pollen data? Again, readers not familiar with palynology will

think this means actual abundance of plants on the landscape (vs. abundance of pollen produced by these plants).

☑ **[Authors]:** Corrected for “relative abundances of pollen genera”

☑ **[Reviewer #2]:** L 188: It’s critical to specify the time scale of “temperature variations” – decadal, centennial, millennial?

☑ **[Authors]:** Changed to “centennial to millennial-scale temperature variations”

☑ **[Reviewer #2]:** L 191: I don’t think the reader knows yet what these acronyms stand for (RegBB, RegFRI, RegFS).

☑ **[Authors]:** Indeed, these were added in the preceding section “Historical wildfire activity”

☑ **[Reviewer #2]:** L 193: “highly positive” -- Better to report the statistics here -- correlation coefficient -- and let the reader determine the subjective qualifier. Also, it would be worth noting somewhere in the results that autocorrelation, from the smoothing of the time series, was accounted for; otherwise, readers will wonder how sample size was determines, and if/how that impacts the p-values.

☑ **[Authors]:** ‘highly’ was deleted. The following indication was added at the end of the statement: (where p accounted for temporal autocorrelation)

☑ **[Reviewer #2]:** L 202: Suddenly the archeology data is used to infer “land-use dynamics” – a more complicated and nuanced phenomenon, vs. population size. A few lines below (L 204) “human activities” is used. Ideally use a consistent term to reference what the archeological data are standing in for, as a proxy.

☑ **[Authors]:** Agreed. The terms were changed to population size and presence.

☑ **[Reviewer #2]:** L 207-213: This starts with introduction-type text. Consider leading with results from this study, then linking to previous predictions, etc. E.g., the sentence on L 216 seems like a strong start.

☑ **[Authors]:** We added an introductory statement for this section: “Through retrospective analysis of historical ecosystem transformations, we gain significant insights into potential trajectories for ecosystems amongst prevailing environmental changes. Increasing temperature and aridity are anticipated to affect the distribution and growth of many species, leading to potential changes in the forest structure and composition in this transitional zone (Chaste et al., 2019; McKenney et al., 2007).” While we appreciate the suggestions to reorganize the text, we’ve experimented with a few options and found that the current logic, presenting the current state and placing the past into that context, seems to work best for conveying the information effectively.

☑ **[Reviewer #2]:** L 225: A “significant decrease in the *mean* fire return interval”? Please make sure to define how significant changes are identified, in the methods.

☑ **[Authors]:** Corrected to “The presence of the oak-pine barrens ecosystem coincides with a significant increase of biomass burning (RegBB) and shorter fire return intervals (RegFRI), ...”. The definition of significant was added to the Methods: “Changes in these

fire metrics are considered significant if the 90% BCI do not overlap between two periods.”

☑ **[Reviewer #2]:** L 231: Consider “twice as much burning” instead of a “gradual reduction in the [mean?] fire return interval.” Note that many reader will forget that decreasing FRIs mean more burning; with the mean (presumably) FRI being cut in half, this represents twice as much burning (per unit time).

☑ **[Authors]:** Agreed. The statement was revised to: “During the early-Holocene, our study area exhibited twice as much burning, shifting from a mean fire return interval of approximately 400 years at 11,000 cal. yrs. BP to less than 200 years by 7,000 cal. yrs. BP.”

☑ **[Reviewer #2]:** L 233: Use of “simulated” here is helpful – this is what would also be helpful in the results text.

☑ **[Authors]:** Done, see earlier comments.

☑ **[Reviewer #2]:** L 238: “decline in recorded fire events” – readers will appreciate if “fire activity” is presented consistently, at least in the discussion. Consider avoiding moving from FRI to frequency, if possible. Choose one; frequency is more intuitive to non-specialists.

☑ **[Authors]:** Corrected for ‘frequency’

☑ **[Reviewer #2]:** L 242: Is the intention to highlight changes in the *seasonality* of incoming solar radiation due to changing orbital parameters? Changes in total (annual) insolation largely call on other mechanisms.

☑ **[Authors]:** Corrected for “...driven by changing orbital forcing and incoming seasonal solar radiation”

☑ **[Reviewer #2]:** L 244: “...the late-phase fire trajectory” – is vague. I don’t know what this means.

☑ **[Authors]:** Corrected for “However, the mid- to late-Holocene fire trajectory distinctly diverges when compared to eastern boreal mixed forests.”

☑ **[Reviewer #2]:** L 248: The parenthetical reference to “bottom-up driver” make sense to me, but I suspect for many this will not make sense. This seems particularly true since this term was not used in the introduction, for example to set up any prior mechanistic hypotheses guiding the study. It is only used here, once. Delete?

☑ **[Authors]:** Agreed. We deleted “bottom-up driver” here and elsewhere in Discussion.

☑ **[Reviewer #2]:** L 259: Again, “irregular pulses or bursts of activity” is vague.

☑ **[Authors]:** Corrected here and throughout for “episodes of persistent elevated activity”.

☑ **[Reviewer #2]:** L 263: “...quite accurately...” – is accuracy really the term intended here? This is not a model making a prediction. Is the pattern highlighted here reflected by a strong/high correlation?

✓ **[Authors]:** Corrected for “These episodes mirror the fluctuations in relative pollen abundance of *Picea* (decreasing with RegBB) and *Poaceae* (increasing with RegBB) (Fig. 6; Remy et al., 2017).”

✓ **[Reviewer #2]:** L 264: “fire regime limited by fuel availability” -- Do the time scales align here? The contrast between the potential mechanisms describe (“fire regime limited by fuel availability vs. oscillatory behavior tied to fire-conducive weather) is not clear, in part because of a mix of time scales (e.g., regime vs. weather).

✓ **[Authors]:** The temporal and spatial scales involved were clarified: “These episodes mirror the fluctuations in relative pollen abundance of *Picea* (decreasing with RegBB) and *Poaceae* (increasing with RegBB) (Fig. 6; Remy et al., 2017). This pattern could indicate either a fire regime limited by fuel availability (Boulanger et al., 2017; Parisien et al., 2020), where ups and downs in biomass burning would parallel the fluctuations in fuels, or an oscillatory behavior in synoptic-scale fire-conducive climate conditions (Girardin et al., 2006).”

✓ **[Reviewer #2]:** L 272: Was fuel limiting fire occurrence, or was it lowering/reducing fire severity? As the authors know, it’s hard to imagine an oak- and/or grass-dominated fire regime having the same mFRI as a boreal forest. The discussion may warrant an explicit statement about just what types of fire the FRI record reflects – e.g., high-severity fires primarily, likely missing smaller, low-severity fires.

✓ **[Authors]:** The message was clarified: “Still, the interaction between biomass burning and species' pollen abundances, particularly during warmer periods with shorter fire return intervals, suggests a nuanced interplay. In the context of climate change during the Holocene sub-epochs, the highs and lows in biomass burning, coupled with taxon-specific pollen abundances, hint at the potential influence of fuel limitation on overall fire severity. This implies that, alongside climatic conditions, fuel availability may play a crucial role in shaping the fire regime dynamics within the study area.”

✓ **[Reviewer #2]:** L 280: “...low-level surface burns...” – consider “low-intensity surface fires” for general terminology.

✓ **[Authors]:** Corrected

✓ **[Reviewer #2]:** L 281: The contrast here (“However...”) is not clear. The absence of low-intensity surface fires being detected or reflected in the RegFRI record would actually be consistent with these data, no? It would/could resolve the apparent lack of / little difference in mean FRI between oak/grass-dominated vegetation during the mid-Holocene and spruce- and pine-dominated vegetation of the late Holocene. Note also that papers on detecting fire events with peaks in charcoal accumulation also highlight that these records best reflect high-severity fires. E.g., the referenced paper, Higuera et al. (2010).

✓ **[Authors]:** Agreed. The statement was revised “This recognized limitation (Higuera et al., 2010) could potentially account for the observed absence of significant differences in RegFRI during the transitions from boreal to oak-pine barrens ecosystems during the mid-Holocene.”

☑ **[Reviewer #2]:** L 284-286: This seems like an important limitation for 2/3 of the time period presented in the paper. Given that the correlations (e.g., Fig. 5) are over the past 10,000 years, any series-wide trends in human population that reflect a “fading record” (towards the past) would tend to make it correlated with overall increases of temperature and charcoal accumulation. It would be useful to give the reader a little more help in how to interpret this timeframe – over ½ of the 0-10 ka record, and 2/3 of the entire record.

☑ **[Authors]:** Done. Note we applied the standard taphonomic correction, so we believe that the population really was low for this time period. We changed the text to: “Although the overall sample size of archaeological radiocarbon dates was low, adhering to the sufficiency criteria outlined by Williams (2012), caution is warranted, particularly in the early- and mid-Holocene periods. Records dating between 12,000 and 4,000 cal. yrs. BP, constituting two-thirds of the entire record, are limited to only 112 data points.”

☑ **[Reviewer #2]:** L 301: What is the “slight dip” in the prairie-forest ecotone mean? Dip south, decrease in...?

☑ **[Authors]:** Corrected: “Interestingly, even the slight decrease in the prairie-forest ecotone population size observed between 2600- and 2200-cal. yrs. BP aligns with trends in the southern region (Briere & Gajewski, 2023).”

☑ **[Reviewer #2]:** L 312: I know what is intended here, but this text does not sound great and could be misinterpreted. Consider: “...deposits left by Indigenous cultures...”

☑ **[Authors]:** Indeed... Corrected

☑ **[Reviewer #2]:** L 314: “...data provide...”

☑ **[Authors]:** Corrected

☑* **[Reviewer #2]:** L 318: If this text remains in the discussion – “...valuable knowledge to predict potential reactions to future climate shifts” – then there should be more specific predictions actually discussed. What does this work reveal about the ongoing mechanisms of changing fire activity, vegetation, and human behavior?

☑ **[Authors]:** Corrected to: “These reconstructions play a pivotal role in elucidating factors that control species and vegetation-types range shifts, biogeochemical cycling, and measuring and quantifying ecological resilience under rapid climate change (Seddon et al., 2014).”

☑ **[Reviewer #2]:** L 319: Suggestion: just spell out “...mitigation and adaptation...” as these are two distinct, important strategies for confronting climate change.

☑ **[Authors]:** Corrected

☑ **[Reviewer #2]:** L 320: “...the adaptability of forest ecosystems and land uses” – is in fact “adaptation”.

☑ **[Authors]:** Corrected

☑* **[Reviewer #2]:** L 325: HOW could the fire community and society derive insights from paleoenvironmental sources? Can the authors provide those insights here?

☑ **[Authors]**: Clarification were added: “Paleoenvironmental data also contribute insights into risks, taking, for example, the knowledge gained from paleo-hydrological reconstructions informing flood vulnerability assessments (Nolin et al., 2023) or from paleoseismology for the recurrence intervals of earthquakes (Atwater et al., 2003). The fire community and society could derive valuable insights from paleoenvironmental sources, aiding in the development of informed decisions regarding fire management, ecological conservation, and community resilience in the face of changing climate or environmental conditions (Seddon et al., 2014; Waito et al., 2018).”

☑* **[Reviewer #2]**: L 327: “...represent the natural state for the hemi-boreal in a warm climate context” – is the reader to take this to mean that a “warm climate context” is what we are in now, or what we are heading to in upcoming decades? Is there any way to help the reader compare how the present and anticipated future is similar or different from the past? E.g., how do projected changes in temperature and precipitation compare to those illustrated in Fig. 4a? The text here is a bit oversimplified.

☑ **[Authors]**: The wording was clarified: “Our findings indicate that open-landscape mosaics, characterized by short-interval fire regimes, represent the natural state for the Lake of the Woods Ecoregion in a warmer climate context than present.” ... “This assumes even greater importance given the area's current low wildfire activity resulting primarily from cooling during the mid- to late-Holocene, allowing for the development of fuel and old growth forest (Girardin et al., 2013; Waito et al., 2018). In the long-term, increasing aridity and a rise in wildfire disturbances anticipated with climate change will reduce the southern extent of the boreal forest (Chaste et al., 2019; Gaboriau et al., 2023), similar to changes experienced approximately 7,000 years before present.”

☑ **[Reviewer #2]**: L 381: “Livingstone-type piston corer”

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 387: Somewhere in here – either in age-depth models, or in specific proxy record development – it should be clear the average time intervals represented by each sample AND the time between samples. This is key for interpreting the pollen and charcoal data.

☑ **[Authors]**: Agreed. The following statement was added at the beginning of the Results section, with statistics presented in Table 1: “Median time intervals between pollen subsamples ranged from 164 years (M15) to 280 years (Meekin) (Table 1).”

☑ **[Reviewer #2]**: L 436-437: Please add the time scale over which fire events were summarized for the pooled records.

☑ **[Authors]**: Done: “spanning 12,000 cal. yrs. BP to present”

☑ **[Reviewer #2]**: L 439: Shouldn't the RegFS index have a reference...? I recall a PNAS paper that first introduced it.

☑ **[Authors]**: Corrected with (Ali et al. 2012)

☑ **[Reviewer #2]**: L 448: Can this 10-cm interval be reported in terms of time-between-samples too? That's highly relevant for interpreting what the records can and cannot resolve.

☑ **[Authors]**: Yes, the information was added in Table 1 and at the beginning of the Results section.

☑ **[Reviewer #2]**: L 506-507: “relationships among...” and isn’t “land-use” here really relative human population size?

☑ **[Authors]**: Yes, corrected.

☑ **[Reviewer #2]**: L 543: Data and code availability: I expect and hope that publication in a Nature journal requires that data and code be housed in a publically available repository. This is widely recognized as “best practice” now.

☑ **[Authors]**: Yes, upon publication data will be placed in figshare upon publication.

☑ **[Reviewer #2]**: L 933: Table 1: suggest including units in the last three columns – as in the earlier columns.

☑ **[Authors]**: Done

☑* **[Reviewer #2]**: Figures, in general: The figures are well developed and clear. There is never, however, one figure that has all of the elements of environmental change reported on in this study – i.e., climate, fire, vegetation, and human population size. This makes is challenging to compare and see some of the correlations highlighted in the text and in Fig. 5. For example, pollen data are illustrated with time on the vertical axis, while all other figures have time on the horizontal axis;

☑ **[Authors]**: Corrected Fig. 3 by rotating the plot.

☑ **[Reviewer #2]**: Fig. 3 and 4 have the sub-epoch boundaries on them to facilitate comparisons, but Fig. 2 does not have any sub-epoch boundaries.

☑ **[Authors]**: Corrected by adding the sub-epoch boundaries on all figures

☑ **[Reviewer #2]**: Fig. 3: What are the grey horizontal lines in this figure? On my screen at least, I can’t quite tell if they are just grid lines, equally spaced for visualization, or something else (e.g., fire events – but I don’t think so).

☑ **[Authors]**: Added in caption: “Grey horizontal lines are equally spaced 100-yrs. intervals for visualization.”

☑* **[Reviewer #2]**: Fig. 5: This is an interesting figure! Many correlations make mechanistic sense -- e.g., AnnTemp and RegBB. Other correlations do not, however, make mechanistic sense: e.g., why is RegFS negatively correlated with Picea and positively correlated with Quercus? This is the opposite of what one would expect by reading a fire ecology text book (e.g., high-severity fire in boreal forest; lower severity fire in oak-dominated forests). It would be useful to point out, briefly, why some associations may not make sense. For example – using pollen percentages here, some increases (or positive correlations) with fire activity and/or temperature will automatically be paired with decreases (or negative correlations) with other taxa. It would help for the reader to know a bit more how and what to “lean on” here and what else are likely artifacts of the proxies and methods (e.g., correlations using pollen percentages).

 **[Authors]:** The following note was added in Numerical analyses of the Methods section: “Of note is that some correlations may appear counterintuitive, potentially stemming from the use of relative metrics, such as pollen percentages, or arising as a product of two metrics, as is the case with RegFRI. The reader is encouraged to consider the potential influence of such methodological artifacts on the observed associations.”

1st Mar 24

Dear Dr Girardin,

Your manuscript titled "Historical boreal forest cover loss under climate warming and recurring wildfires" has now been seen by our reviewers, whose comments appear below. In light of their advice we are delighted to say that we are happy, in principle, to publish a suitably revised version in Communications Earth & Environment under the open access CC BY license (Creative Commons Attribution v4.0 International License).

We therefore invite you to revise your paper one last time to address the remaining concerns of our reviewers. At the same time we ask that you edit your manuscript to comply with our format requirements and to maximise the accessibility and therefore the impact of your work.

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We hope to hear from you within two weeks; please let us know if you need more time.

Best regards,

Alienor Lavergne, PhD
Associate Editor
Communications Earth & Environment

REVIEWERS' COMMENTS:

Reviewer #1 (Remarks to the Author):

The manuscript "Historical boreal forest cover loss under climate warming and recurring wildfires" addresses the possible effects of climate change on the boreal forest – prairie ecotone of Northern America. While the ongoing climate change doubtlessly affects all ecosystems on Earth, its effects are especially pronounced for ecotones between open and forested biomes. In these regions, the impact of direct climatic drivers can, by inducing changes in secondary ones (such as wildfires), be amplified. Furthermore, it must be kept in mind, that boreal forests are a vital part of the Earth's carbon-cycle and have high commercial value.

The authors address the fate of the present-day hemiboreal ecosystem of North America employing datasets representing millennia-long observations of vegetation and burning dynamics associated with changing environmental conditions revealed by numerous palaeoecological records, which are still heavily underused as a data source in modern ecological research.

The authors have thoroughly addressed all concerns and suggestions expressed by the reviewers, further improving the quality of the manuscript.

Reviewer #2 (Remarks to the Author):

See attached PDF.

Review of revision: “Historical boreal forest cover loss...”

The authors have thoroughly responded to the constructive criticism from the two reviews. I am generally satisfied with the changes made in response to my review, including the added or modified text that provides useful clarification and discussion on potential mechanisms at play, and specifying spatial and temporal scales involved. I also recognizing that the authors had a lot to respond to (now that I re-read my own review!). Well done. For what it’s worth, I also agree with the authors’ rationale for using pollen percentage, rather than changing the main text to report and display pollen accumulation rate.

The text still seems lacking a bit in providing a more specific, quantitative, comparison of if and how ongoing and projected climate change compares to the Holocene. The value of the paper hangs strongly on the rationale that understanding the past will help us respond to ongoing change. The paper does this in its current form...BUT...it is still missing significant opportunity to clarify what’s similar or different between the past and the present. See in part the conceptual framework presented by [Williams, Ordonez, and Svenning \(2021\)](#), in [Nature Ecology & Evolution](#), also referenced below. Can the text highlight what aspects of past change we can or cannot reference to help anticipate ecological changes in response to global warming – more so than just stating “expect more fire when it’s warming”? As noted below, it appears that expected rates of climate change are an order of magnitude higher than what was experienced in the region studied here (at least as based on the paleoclimate simulations). What does this mean...?

Detailed comments:

Abstract:

*Consider, for clarity: remove references to return intervals – keep references consistent to fire occurrence, fire frequency, or fire activity.

L 31: “...occurred during a period of more frequent burning...” OR “...higher fire frequency...”

L 33: Consider this, if not opposed to using parentheses like this: “...increased (decreased) during period with less (more) frequent burning...” OR Consider: “...increasing during periods of less fire activity and decreasing during period of elevated fire activity.”

L 65: Consider: “...affecting ecosystem functioning.”

L 71: Consider: “...and other human activities is...”

L 128: Suggestion: “...the notion that Indigenous societies [significantly] altered past ecosystems of the region.” The term “Indigenous alteration of past ecosystems” is odd, vague.

L 131: “...over time” not “overtime” This five-line sentence could be shortened, simplified.

L 134: “...we document centennial- to millennial-scale variability in wildfire,...” and then delete “dynamics”. OR, just add “...at centennial to millennia time scales” at the end of the sentence. The time scale reference only needs to be in there once.

L 139: Note that in L 28 the term used is “postglacial” where as “post-glacial” is used here (and both are modifying something).

L 227-228: Suggestion: “During the early Holocene, mean fire return intervals shortened gradually, from 400 years at 11,000....to below 200 years at 7000...”

L 269: THIS rate of change -- (+0.11°C per century) – is what one would want to compare to current and anticipated/projected rates of change. Let the reader know (not necessarily here) if/how this past rate of change compares to current and future rates – are we exceeding this, not exceeding this, maybe exceeding this? For example, see this paper, Fig. 1:

<https://www.nature.com/articles/s41559-020-01344-5/figures/1> Nearly all IPCC scenarios of climate change through 2100 have a rate of change that is one order of magnitude higher than what’s cited here: > 0.1 deg. C per decade = > 1 deg. C per century.

L 374: And THIS is where it would be very helpful to note the current and projected range of future climate change in this region. Are we even in the ballpark, or, like global temperatures, are we experiencing rates of change that are an order of magnitude greater than during any time periods in the Holocene? Framing the discussion in this context is critical, IF part of the motivation for this work is that we can use the past to understand our current and near-future context.

L 443: Could shorten: “...between biomass burning and pollen abundances...”

L 447-448: But don’t you think we know, pretty much for sure, that “fuel availability WILL play a crucial role in shaping the fire regime dynamics with the study area”? Consider highlighting how this study supports a longstanding relationship between fuel availability and fire activity, highlighting that mechanisms we see today were likely important in the past? Overall, it’s the “..may play a crucial role” that seems odd – I guess it might depend on how one interprets “crucial” – but we certainly know fuels will play an important role.

L 537: “...vegetation-types range shifts” – this sounds odd. Consider: “...factors that control vegetation types, range shifts, biogeochemical cycling...”

*Again, this is where you can and should actually quantify “rapid climate change” – what rates of change are we talking about here?

L 567: The use of “old growth forest” here, esp. in the context of Holocene time scales, does not make sense. A simple read of this could imply that existing trees date from the mid-Holocene. Suggestion: “...development of dense forests[OR vegetation] during long fire-free intervals.”

Again, in this paragraph, some type of comparison between the rates of past climate change and ongoing rates of change seems warranted. The fields of paleoecology, paleoclimatology, and climate modeling have advanced enough to support quantitative comparisons, vs. just noting “directional climate warming” also happened in the past / Holocene.

L 726: Consider including explicitly noting the highest rates of change -- e.g., deg. C per century – in the paleoclimate reconstructions, and/or if you think these rates of change are similar to, greater than, or less than what’s anticipated for the region broadly.

Response to reviewers

✓ **[Reviewer #1]:** The manuscript "Historical boreal forest cover loss under climate warming and recurring wildfires" addresses the possible effects of climate change on the boreal forest – prairie ecotone of Northern America. While the ongoing climate change doubtlessly affects all ecosystems on Earth, its effects are especially pronounced for ecotones between open and forested biomes. In these regions, the impact of direct climatic drivers can, by inducing changes in secondary ones (such as wildfires), be amplified. Furthermore, it must be kept in mind, that boreal forests are a vital part of the Earth's carbon-cycle and have high commercial value. The authors address the fate of the present-day hemiboreal ecosystem of North America employing datasets representing millennia-long observations of vegetation and burning dynamics associated with changing environmental conditions revealed by numerous palaeoecological records, which are still heavily underused as a data source in modern ecological research.

✓ **[Authors]:** We thank the referee for providing his/her perspective on our work.

✓ **[Reviewer #1]:** The authors have thoroughly addressed all concerns and suggestions expressed by the reviewers, further improving the quality of the manuscript.

✓ **[Authors]:** Thank you

✓ **[Reviewer #2]:** The authors have thoroughly responded to the constructive criticism from the two reviews. I am generally satisfied with the changes made in response to my review, including the added or modified text that provides useful clarification and discussion on potential mechanisms at play, and specifying spatial and temporal scales involved. I also recognizing that the authors had a lot to respond to (now that I re-read my own review!). Well done. For what it's worth, I also agree with the authors' rationale for using pollen percentage, rather than changing the main text to report and display pollen accumulation rate.

✓ **[Authors]:** Thank you for your appreciation. We aimed to address your feedback comprehensively and are pleased to hear that the modifications have enhanced the clarity and depth of our discussion.

✓ **[Reviewer #2]:** The text still seems lacking a bit in providing a more specific, quantitative, comparison of if and how ongoing and projected climate change compares to the Holocene. The value of the paper hangs strongly on the rationale that understanding the past will help us respond to ongoing change. The paper does this in its current form...BUT...it is still missing significant opportunity to clarify what's similar or different between the past and the present. See in part the conceptual framework presented by Williams, Ordonez, and Svenning (2021), in *Nature Ecology & Evolution*, also referenced below. Can the text highlight what aspects of past change we can or cannot reference to help anticipate ecological changes in response to global warming – more so than just stating “expect more fire when it's warming”? As noted below, it appears that expected rates of climate change are an order of magnitude higher than what was experienced in the region studied here (at least as based on the paleoclimate simulations). What does this mean...?

☑ **[Authors]**: We now provide such a comparison in the Discussion section: “Comparing historical data, the highest rate of temperature change observed in the paleoclimate context was +0.11°C per century around 7,500 years before present. However, current projections suggest a much higher expected rate of change, ranging from +0.31 to +0.47°C per decade from 1976–2005 to 2051–2080¹.”

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☑ **[Authors]**: Corrected for “occurred during a period of more frequent burning”

☑ **[Reviewer #2]**: L 33: Consider this, if not opposed to using parentheses like this: “...increased (decreased) during period with less (more) frequent burning....” OR Consider: “...increasing during periods of less fire activity and decreasing during period of elevated fire activity.”

☑ **[Authors]**: For improved clarity and readability, while using the term frequent burning, we modified the statement for: “Population size of Indigenous peoples mirrored wildfire fluctuations, decreasing with more frequent burning.”

☑ **[Reviewer #2]**: L 65: Consider: “...affecting ecosystem functioning.”

☑ **[Authors]**: The sentence was rewritten as “Habitat loss and forest fragmentation can diminish biodiversity, thereby impacting ecosystem functioning and the provision of ecological services”

☑ **[Reviewer #2]**: L 71: Consider: “...and other human activities is...”

☑ **[Authors]**: Corrected

☑ **[Reviewer #2]**: L 128: Suggestion: “...the notion that Indigenous societies [significantly] altered past ecosystems of the region.” The term “Indigenous alteration of past ecosystems” is odd, vague.

☑ **[Authors]**: Corrected

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☑ **[Authors]**: Corrected by shortening the sentence.

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☑ [Authors]: Corrected

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☑ [Authors]: Done, we provide a comparison in the Discussion section as suggested in the next comment.

☑ [Reviewer #2]: L 374: **And THIS is where it would be very helpful to note the current and projected range of future climate change in this region.** Are we even in the ballpark, or, like global temperatures, are we experiencing rates of change that are an order of magnitude greater than during any time periods in the Holocene? Framing the discussion in this context is critical, IF part of the motivation for this work is that we can use the past to understand our current and near-future context.

☑ [Authors]: Agreed. The following statement was added: Comparing historical data, the highest rate of temperature change observed in the paleoclimate context was +0.11°C per century around 7,500 years before present. However, current projections suggest a much higher expected rate of change, ranging from +0.31 to +0.47°C per decade from 1976–2005 to 2051–2080¹.

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☑ [Authors]: Corrected for “will play”

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☑ **[Reviewer #2]:** L 567: The use of “old growth forest” here, esp. in the context of Holocene time scales, does not make sense. A simple read of this could imply that existing trees date from the mid-Holocene. Suggestion: “...development of dense forests[OR vegetation] during long fire-free intervals.”

☑ **[Authors]:** Corrected for “development of dense forests”

☑ **[Reviewer #2]:** Again, in this paragraph, some type of comparison between the rates of past climate change and ongoing rates of change seems warranted. The fields of paleoecology, paleoclimatology, and climate modeling have advanced enough to support quantitative comparisons, vs. just noting “directional climate warming” also happened in the past / Holocene.

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☑ **[Authors]:** Added: We took note of the highest rates of change (°C per century) in this paleoclimate reconstruction.