

Zhang et al. “Holocene fire regimes around the Altai-Sayan Mountains and adjacent plains: interaction with climate and vegetation types”

General comments

This study reconstructs Holocene fire activity in western Mongolia and examines spatiotemporal variations across vegetation zones, linking these to forest community structure, as paleofire dynamics in western Mongolia and regional biomass burning patterns remain poorly understood. Results indicate a decline in biomass burning since the Holocene, driven by temperature-related changes in woody biomass in the central Altai and a reduction in combustible species (e.g., *Larix*, *Abies*) in the Sayan and northern Altai. A resurgence of fires after ~4 cal. Kyr BP correlates with archaeological cultural complexes, particularly in moisture-limited regions (e.g., the West Siberian Plain) and arid areas (steppe/desert-steppe). Since ~2 cal. kyr BP, human activities (agriculture, pastoralism) have increased fire frequency in the Altai, West Siberian Plain, and forest zones, while overgrazing likely decreased burning in the Khangai Mountains. These findings shed light on long-term fire-vegetation feedbacks and offer insights into human-fire-ecosystem interactions in arid Central Asia, supporting sustainable ecological management.

The manuscript is comprehensive and well-structured, presenting a detailed analysis of Holocene fire history and its relationship with vegetation across multiple regions. However, although the authors state “these outputs provide empirical foundations for developing climate-responsive fire management strategies in the Central Asian montane ecosystems under the future scenarios,” there has not been enough analysis of the relationship between climate and fires over the study areas. The research topic is very interesting and appropriate for this journal, but I believe further analysis of the link between climate and fire is necessary before publication.

Specific comments

Abstract

- I think the second sentence in the Abstract should be written as follows in the main text: “However, paleofire dynamics in western Mongolia remain poorly understood, and a regional synthesis of biomass burning patterns across the Altai-Sayan ecoregion is lacking.” Or, “However, two key gaps hinder understanding: paleofire dynamics in western Mongolia are understudied, and no comprehensive regional synthesis exists for biomass burning patterns across the Altai-Sayan ecoregion.”
- Regarding “Since ~2 cal. Kyr BP, ...”, this study does not offer a thorough analysis that separates the impacts of human disturbance from natural variability.
- The final sentence of the Abstract emphasizes practical implications, but it appears disconnected from the title. “The findings provide a long-term perspective on fire-vegetation-climate interactions, offering critical insights for sustainable land management in arid Central Asia.” is better, but the authors should include more analysis about climate.

Introduction

- The authors can consider making it even more impactful by emphasizing the global climate relevance of Eurasian boreal carbon stocks.

- Regarding the transition to the Altai-Siberian ecotone, the authors could include a sentence explaining why this region is a key case study for understanding broader boreal fire-climate interactions.
- What is “a pyrogeographic hotspot”? The authors need a brief explanation.
- The authors should describe the current relationship between fires and climate in the North Europe-Siberia-Altai region before presenting the content in paragraph 4. If relevant research is unavailable, they could conduct their own study first.
- The transition from modern observations to paleoecological approaches (paragraph 4) is logical, but the authors could be more explicit about why the lake sediment cores from (especially Achit Nuur) are the best solution for addressing the knowledge gap. Then, the authors can consider briefly mentioning proxy limitations (e.g., charcoal vs. other fire proxies).
- What is “ecotonal heterogeneity” in fire regimes? The authors need a brief explanation.
- The authors should define “primary forest cover” to prevent confusion. How does it differ from “forest cover”?
- The three research dimensions are well-defined, but the broader implications (e.g., how findings inform future fire management) could be emphasized more strongly in the final sentence. Regarding the final paragraph, the authors explicitly state how this study advances paleofire reconstruction methods beyond previous work.

Study region

- The authors should briefly explain why the Altai-Sayan region is significant for paleoclimate/fire regime research, including the transition between steppe/taiga, sensitivity to Holocene climate variability, or anthropogenic influences.
- The authors should mention any known climatic gradients (e.g., precipitation, temperature, and other fire-related climatic variables) across the study regions to justify spatial comparisons.
- What was the basis for dividing the seven areas from A to G? For example, were geographic features like climate and vegetation considered, or were factors related to recent fires used? This information should be included in Table 1.
- To improve geographic precision, for mountain ranges, the authors could add brief descriptors (e.g., “the Mongolian Altai (peaks >#### m a.s.l.)” or “the low-relief West Siberian plain”).
- The authors could consider a brief interpretation of lithological changes.
- Regarding chronological details, the authors could explicitly state why a 2100-year reservoir correction was applied (e.g., local carbonate influence or old carbon from groundwater).
- About chronological details, the authors should note any potential age-model uncertainties, such as reversals or plateaus in the calibration curve.
- Table 1 could include key metadata, such as core length, temporal coverage, and proxies analyzed, to facilitate comparison.

- The authors should emphasize that the climatic and ecological gradients across the Altai-Sayan region will reinforce the reason for comparing fire regimes across different sites.
- The unit for MGS is " μm ", not "mm".

Methods

- This section is currently described too simple, but it must be a critical methodology. Every step requires: 1. Justification (Why this method? Why these parameters?), 2. Validation (How were errors/assumptions tested?), and 3. Transparency (Exact settings, code, and uncertainties).
- The authors mention “modifications for the charcoal analysis” but do not specify them. A brief note would help (Section 3.1).
- Why is it necessary to detect more than 300 particles? Is this based on a statistical threshold or prior studies (Section 3.1)?
- The authors could clarify the concentration calculation method to ensure readers understand it (Section 3.1).
- Section 3.2 lacks sufficient statistical rigor: The authors should consider briefly justifying the choice of the quasi-Poisson distribution (e.g., to account for overdispersion in count data). The authors should also consider quasi-Poisson models over alternatives (e.g., negative binomial) with tests for overdispersion.
- The authors should justify why these taxa/forest cover were chosen (e.g., "... selected based on variance inflation factors <#") (Section 3.1).
- Regarding smoothing terms, were the smoothing parameters (knots, basis functions) manually set or automatically selected? When the authors manually set, how were the selected (e.g., knots = #, chosen via generalized cross-validation)?
- Regarding model validation, a sentence on how the model fit was assessed would be helpful to Section 3.1.
- Regarding data processing for comparison, the authors should briefly describe and justify each process or step/step because some readers may not be familiar with specific methods, such as the Mini-Max transformation and the Box-Cox transformation. Then, we would like to know why multiple transformations (Mini-Max, Box-Cox, Z-scores) were applied.
- Regarding the division of the Holocene interval, the boundaries (8.2 and 4.2 cal. kyr BP) are standard; however, citing a benchmark would align with community conventions.

Results and Discussions

- This is a strong, data-based study that makes an important contribution to paleofire research. To improve it further, the authors should balance description with interpretation by clearly explaining "why" and by providing specific evidence that distinguishes between human and climate influences. If possible, the authors could add a brief mechanistic explanation to strengthen the overall narrative.
- In the final sentence of 4.1, the relationship between fire and vegetation (*P.sibirica* and *Betula*) is statistically significant, but what does this imply ecologically? Does this indicate a difference between crown fires and ground fires?

- Regarding anthropogenic versus climate signals, human influence is frequently invoked (e.g., agro-pastoral expansion and grazing), but it could benefit from more critical evaluation: How do the authors differentiate between anthropogenic burning and climate-driven fires?
- In 4.2.1, the "anomalous biomass burning peaks" are associated with *Cerealia* pollen, but is there supporting archaeological evidence?
- In 4.3, the late-Holocene increase in fires is attributed to humans, but could climate (in some regions) also contribute? A more detailed discussion of confounding factors would be valuable.
- The regional synthesis (4.3) is adequate but could benefit from clearer visual support. The authors should develop a summary table or a conceptual diagram illustrating key drivers such as climate, vegetation, and human activities for each region and period.