Response to Reviewer 3 Comments

This manuscript presents a millennial-scale reconstruction of carbon emissions from land-use change in China using a bookkeeping model approach. While the study addresses an important research gap and provides valuable historical context for understanding China's carbon budget, there are several major concerns that must be addressed before this work is suitable for publication.

Response: Thank you very much for taking the time to review our manuscript and for your positive and encouraging comments. We have carefully considered the four main areas for revision or questions you raised. We have made detailed modifications and responses to each opinion or suggestion, and these changes have been marked in red font in the main text. Thank you again for your hard work; your comments have significantly improved the scientific quality of our manuscript.

Point 1. The conversion rules in Figure 3 appear somewhat arbitrary. I recommend testing the uncertainty in your transition matrix calculations. While your rule-based priority system is clear, how would results differ if you used an area-weighted approach instead? For example, allocating transitions proportionally based on the relative magnitude of area changes between different biomes rather than using predetermined priorities. This uncertainty analysis would be valuable given the millennium-long timeframe of your study, where even small methodological differences could compound into significant variations in results.

Response: Thank you for this comment. We apologize if our previous explanation of the land-use transition rules in Figure 4 was not detailed enough and caused confusion. We have further clarified this section in the revised manuscript, and these revisions are marked in red font. For details, please see lines 305-326.

Please allow me to briefly explain.

Firstly, the conversion rules are determined based on the attributes of the published data used, which is a prerequisite for establishing the land use transition rules in this study. Specifically, when reconstructing historical grassland data in western China, it reflects the occupation of grassland due to the reclamation of cropland in history. In eastern China, historical grasslands mainly consist of secondary grasslands resulting from the secondary succession of deforested lands. The reconstruction rules for historical grassland data are the basis for formulating grassland-related land use conversion rules in this study.

After the land use transition rules related to grassland were established, whether it was the conversion of forest to cropland or forest to other land, historically, the essence was deforestation for reclamation. After deforestation, if the land could be cultivated for a long period, it was converted to cropland. If it became temporary cropland due to reasons such as loss of fertility, it is defined as other land in this study. According to Table B2 in the appendix, in the bookkeeping model used in this study, the disturbance response curves for the conversion of forest to cropland and forest to other land are identical. Therefore, once the land use conversion rules related to grassland are established, regardless of whether we use our set priorities or other methods (such as area weighting) to handle forest-related land use conversions, the final carbon emission calculation results will not be affected by the specific classification of forest conversion into cropland or other land.

The excerpt is as follows:

"First, the conversion rules were determined based on the attributes of the published data used, which was a prerequisite for establishing the land-use transition rules in this study. The land-use change data revealed the changes in grassland area and their conversion relationships were the most clearly defined. The reconstruction rules for historical grassland data formed the basis of the grassland-related land-use conversion rules in this study. Specifically, when reconstructing historical grassland data in western China, the data reflect the occupation of grassland due to the reclamation of cropland in history (He et al., 2024). Therefore, for western China, where grassland ecosystems dominate, changes in grassland areas primarily reflect the encroachment of croplands, and the conversion between grassland and cropland was determined first based on changes in grassland area (Fig. 4). Second, the reduction in forest area was prioritized for conversion to cropland, followed by conversion to other land. In eastern China, where forest ecosystems are predominant, historical grasslands mainly consisted of secondary grasslands because of the secondary succession of deforested lands (He et al., 2024). Hence, in eastern provinces dominated by forest ecosystems, the conversion between grassland and forest can be similarly determined based on changes in the grassland area. The remaining forest area was then prioritized for conversion to cropland, followed by conversion to other land. Based on these rules, we calculated the annual land-use change rates in China from 1000 to 2019.

Historical conversion of forest to cropland or forest to other land was primarily performed for land reclamation, and if the deforested land supported cultivation over a long period, it was converted to cropland. For cropland that failed to support cultivation due to reasons such as a loss of fertility, it was defined as other land in this study. According to Table B2 in the appendix, in the bookkeeping model used in this study, the disturbance response curves for the conversion of forest to cropland and forest to other land were identical. Therefore, once the land-use conversion rules related to grassland were established, regardless of whether the set priorities or other methods (such as area weighting) were used to handle forest-related land-use conversions, the final carbon emission calculation results were not be affected by the specific classification of forest conversion into cropland or other land."

Point 2. The authors state that "this study updated and improved the land-use change data, carbon density data, and disturbance response curves," but upon careful reading, it appears they did not actually update or improve the disturbance response curves themselves. Rather, they simply adopted the data from Houghton and Castanho (2023) without modification. To avoid misleading readers, I suggest the authors clarify that they utilized the most recently published parameters from the literature rather than implying they developed improvements to the response curve themselves.

Response: Thank you！

I completely agree with your opinion. Yes, we directly used the latest published disturbance-response curve from Houghton and Castanho (2023). Several statements in the original manuscript regarding this curve might have been misleading or ambiguous for readers and reviewers. Therefore, in the revised manuscript, we have amended the relevant descriptions to clarify that we directly used the latest published disturbance-response curve from Houghton and Castanho (2023) without any further modifications. For details, please see lines 25-27, 105-106, 475-476, and 587-590 in the main text, highlighted in red font.

Point 3. I also noticed that the bookkeeping model used in this study does not account for wood harvest pools, which is understandable given that it would require reconstructing additional historical wood harvest data. However, this limitation should be explicitly stated in the methodology section. The authors should clarify this omission and briefly discuss its potential implications for carbon flux estimates, especially since wood harvest can be a significant component of land-use change emissions in forested regions of China.

Response: Yes, I completely agree with your point.

We have clarified this in the methods section of the revised manuscript: Due to data limitations, this accounting does not consider carbon emissions from wood harvest. For details, please see lines 186-187 of the manuscript.

Simultaneously, in the discussion section, lines 574-580 (marked in red font), we re-emphasized that the current accounting does not include wood harvest, as well as the potential impacts arising from the omission of wood harvest. By integrating existing relevant literature, reference values for carbon emissions from wood harvest were provided. The excerpt is as follows:

"We reiterate that the carbon emission accounting method in the present study does not include wood harvesting. Considering that wood harvesting represents a significant historical source of anthropogenic emissions, the absence of these data may lead to a certain degree of underestimation in the corresponding carbon emission fluxes. Fortunately, Houghton and Castanho (2023) estimated China's long-term carbon emissions from wood harvesting and found values of 5 Tg C yr^{-1} for 2011–2020, approximately 20–30 Tg C yr^{-1} around the 1950s, approximately 5–10 Tg C yr^{-1} in the 1900s, and less than 5 Tg C yr^{-1} values before 1900. These estimates can serve as a reference when regional long-term reconstructed data on wood harvesting and their corresponding carbon emission estimates are unavailable."

Point 4. The explanation of differences between NGHGI and bookkeeping estimates should focus on carbon accounting boundaries rather than restoration projects (Gidden et al., 2023, Nature; He et al., 2024, Nature Communications). For DGVMs vs. bookkeeping models, note that DGVMs include the loss of additional sink capacity, leading to higher emission estimates, alongside differences in LUC forcing data (Gasser et al., 2020, Biogeosciences). I suggest the authors provide a more systematic discussion to avoid misleading readers about these differences.

Response: Thank you very much for your comments. Your opinions are accurate and highly valuable, helping us to revise the relevant content in section 4.2 Comparison with previous estimates, strengthen the comparison between different results, and make the relevant explanations more scientific and persuasive. Thank you again.

We have collected and consulted relevant literature and content. Incorporating your suggestions, we have revised this part, detailed in lines 510-538, and marked the changes in red font. We are not entirely certain if our revisions have fully addressed and alleviated your concerns regarding our manuscript. If there are any further questions or if our explanations are not adequate, please raise them in the next round of evaluation. We will further strive to understand your opinions to improve the manuscript. The relevant revisions are excerpted as follows:

"The estimates from the other three bookkeeping models aligned more closely with the trends in the DGVM estimates, which were markedly different from our estimations. This discrepancy primarily stems from two key aspects. First, DGVM estimates often account for the "loss of additional sink capacity". This concept refers to the diminished carbon absorption that occurs when the land-use type of a parcel of land that could have absorbed more carbon dioxide under current environmental conditions if left in its original natural state (e.g., as a forest) is altered by human activities (e.g., conversion to cropland), thereby reducing its actual carbon dioxide uptake. This “reduction in absorbed amount” constitutes the loss of additional sink capacity. Gasser et al. (2020) revealed that the inclusion or exclusion of loss of additional sink capacity leads to significant differences in estimated values. Second, disparities in land-use change forcing data represent another significant factor contributing to divergent estimates among different models. DGVM estimates are typically driven by long-term global land-use datasets, such as LUH2 (Obermeier et al., 2024; Friedlingstein et al., 2019; Hansis et al., 2015). Thus, these models that differ due to the inclusion of loss of additional sink capacity and the use of varying land-use change data tend to significantly overestimate the carbon emission flux from land-use changes relative to the results of this study.

Additionally, the estimates from this study differed considerably from national report-based data (e.g., NGHGIs and FAOSTAT) (Fig. 10) (Obermeier et al., 2024). The core difference between NGHGIs and bookkeeping models in land-use change carbon flux estimation lies in the carbon accounting boundary, especially regarding the attribution of indirect fluxes on managed land (Gidden et al., 2023; He et al., 2024). NGHGIs tend to consider all carbon fluxes on managed land (including both direct fluxes and indirect fluxes triggered by environmental changes) as anthropogenic contributions. In contrast, bookkeeping models primarily account for direct fluxes generated by direct human activities but exclude indirect fluxes, which are considered natural ecosystem responses, from anthropogenic inventories of land-use change. The fact that national reports specifically account for afforestation and ecological restoration projects with high carbon removal potential might also influence the results. The most direct example is the similarity between our estimated carbon emissions (1900–1980) and the results of Yu et al. (2022) (Table 3) because of the lack of significant or widespread land management or engineering projects in China during this period. However, the estimates for 1980–2019 differed greatly because land management practices during this period had a substantial impact. As revealed by Yue et al. (2024), land management has played a crucial role in China's land-carbon balance since 1980."

We are very grateful for your numerous valuable and constructive suggestions. In accordance with your comments, we have diligently revised the manuscript. We remain open to any new questions you may have in the subsequent round of review and are committed to further improving the paper. Thank you for your consideration.