

Thank you very much for your comments and critics on the manuscript. In the following, I tried to answer the issues you raised during the review process. Please find my answers highlighted in italics. I am looking forward to further discussing your interesting suggestions! It seems like you uploaded your review twice – as anonymous reviewer and again under your clear name. I will upload only one response, if this is fine with the editor.

Kempf uses current climate data, satellite NDVI, paleoenvironmental proxies and historical written sources to compare and evaluate the landcover change and land degradation in the Mongolian Plateau. The major source of data for evaluating the land degradation is the NDVI values for current time period, although it is unclear what indices were used to evaluate the land degradation for the historical time period.

Reconstructing past surface cover over large areas by means of historical data (mostly written sources and spot-light palaeoenvironmental proxy) cannot generate indices in the very sense of the term 'index' – and particularly taking into account that NDVI by design shows values between -1 and 1 on a continuous scale. The evaluation of historical data cannot produce continuous data but rather discrete values, such as bare (0), grassland (1), forest (2). That is also a major limitation in terms of quantitative statistics because discrete values were not supported by some of the packages implemented in R software.

I commend the author for putting so much effort in deriving meaningful information from historical written records.

Thanks!

Main findings of the study were that vegetation change was not related to any climate variables and therefore the authors attributed grassland degradation to increasing livestock density in the region.

That is probably a very condensed summary of the output and I would rather distinguish the two chronological timeframes, which support the results. The historical landcover change was certainly triggered by LIA temperature decline and local to regional decrease in total precipitation. On the other hand, modern precipitation and temperature records in the region are continuously increasing – at least over the period discussed in the paper. Furthermore, I am discussing the governmental restrictions and the political programme to fight land degradation in northern China. From the vegetation index data, no immediate result can be observed - despite increased precipitation totals and the attempt to mitigate desertification.

The manuscript is generally well written (although there were few places where I found too long sentences)

Thanks for that! You were right with the sentences (particularly in the beginning). I changed some of them in the current (potential) revision, which I am preparing.

and within the scope of the *Climate of the Past* journal. However, there are several methodological issues, clear hypothesis, linkage between historical data and current land surface conditions and the overall findings of the study. Therefore, substantial revision is necessary prior to improve the manuscript.

1. The author uses four different data sources (historical written sources, paleoenvironmental data, remote sensing products and current gridded

climate data) to find the relationship between the climate data and vegetation indices. It is unclear how the connection between past environmental changes and current land degradation rates, desertification and grassland productivity is made in the study.

While I commend the authors approach and time in analyzing the historical records based on Gerbillon in year 1688, there is no connection made between 1688 and current land degradation rates. The only connection the author made was the linkage between climate data and NDVI for current conditions. I was left wondering whether there is a need to examine the year 1688 (with all the work put forward), which does not add any information to the relationship between climate and NDVI for current conditions.

Thank you for your comment, but could you specify your concerns a bit more? Do you mean the temporal interval between 1688 and today? As I have pointed out also in the answer to reviewer 2, continuous and extensive surface data is not available, and the spotlight sample locations cannot be interpolated over large areas without creating data narratives. If you mean the conceptual connection between the two chronological periods, I would like to emphasize the potential (as you highlighted) of historical data and written sources to understand landcover-climate feedbacks, which allow to draw conclusions also for current climate change and human impact scenarios. The results I am presenting here are, by nature, based on qualitative analyses for the historical period. If you suggest that historical data analyses or the evaluation of past written sources cannot contribute to current climate change debate, I would like to refer to Historical Geography, Historical Climatology, History itself, and also archaeological research, that significantly contribute to the understanding of past human-landscape and past climate-landcover feedbacks and interactions. The investigation of Pater Gerbillon (subjective because individual) and his perception of the landcover and climate conditions as well as socio-cultural interactions, droughts, crop failure, and livestock perish add an invaluable note to the current understanding of LIA landcover change. And that further allows for the comparison to modern datasets to understand the feedbacks of climate-sensitive regions of the world. Particularly during the LIA, where low temperature and decreased precipitation rates triggered surface degradation, the climatic signal was the major determinant. During current climate change and increasing temperature and precipitation totals, the anthropogenic landcover change is probably the main driving factor of desertification. It is only because of the comparison data that we can further distinguish into an anthropogenic and an environmental component in the signal (and of course they are interlinked!). However, correct me if I am wrong and please add comments to this because this is the most important interface of interdisciplinary research.

2. The authors conclusion that if there is no environmental and land degradation relationship, current land degradation rates is likely due to intensive livestock grazing needs to be reconsidered. In this study, the authors did not show any relationship between NDVI and livestock grazing, although such data are available at province level from FAO and other sources. While I agree that livestock grazing is likely the cause of current land degradation, there is still a debate on the contribution of land degradation from climate and livestock grazing. It is hard for me to believe that the author used precipitation totals and maximum temperature data to point out no changes in precipitation and an

increase in t_{max} . The reason is NDVI values does not really work in desert areas or areas that is heavily degraded. Yet, the author tried to establish a relationship between NDVI and climate.

Please apologize but I am a bit confused with this statement, which probably needs some clarification (?). There is a huge debate in literature, which acknowledges the two potential (and often contradictory) views of a) climate and b) human impact on land degradation processes and I included a review of this literature in the paper. What exactly do you mean with "It is hard for me to believe that the author used precipitation totals and maximum temperature data to point out no changes in precipitation and an increase in t_{max} "? I described the dataset, cited its origin, and showed the method I used to visualize the data to make it reproducible. I am furthermore not convinced that NDVI is not applicable in degraded or arid environments and there is plenty of research and literature available that use this method to model vegetation response to climate/human impact.

3. Another issue with the paper is the lack of clear understanding of the contributing factors to desertification or land transformation in Mongolia and Inner Mongolia. The political system of Inner Mongolia and Mongolia have diverged greatly since the collapse of Soviet Union. As a result, land cover change is taking place more rapidly in Inner Mongolia than in Mongolia.

That is a good point, which I will integrate more intensely in the potential revision of the paper!

Shifts in policy between inner Mongolia and Mongolia had led to differences in grassland response to climate change and grazing pressure (Chen et al. 2015). I think this should be highlighted in this study and assuming that the Inner Mongolia and Mongolia had similar response to grazing pressure and environmental changes would be questionable given that land response has been increasingly linked to political and policy changes in the region.

I will include this in the paper with a literature review, thanks for pointing this out to me! My main goal was to show (from a case study) that despite a local increase in total precipitation and the governmental restrictions, no immediate positive vegetation response can be observed. I am sure that both countries experienced different land-use policies during the end of the 20th century and up to now but these differences are not always observable. See e.g. and also for another opinion: (Guo et al. 2021)

4. It is also unclear how the desertification process or the land degradation rates are estimated in this study. To my understanding, the author is using NDVI values with low NDVI denoting land degradation/desertification. I have serious concern about using NDVI as an indicator of degradation particularly in arid and semi-arid grasslands. I at least want the author to show or cite some previous work that the NDVI can actually detect grassland or ecosystem degradation in arid and semi-arid regions.

As mentioned earlier, there is plenty of literature and current research – particularly in northern China and Mongolia – that integrates NDVI value analyses and remote sensing techniques in arid and semi-arid landscapes and I have cited some of them. In a potential revision, I will include more recent literature to show the potential of the method.

5. The relationship between precipitation variability, tmax increase and river runoff is unclear. The author need to justify how increase in tmax and a decline in vegetation cover had no effect on river runoff in the region.

I am sorry, I do not completely understand this issue. In this paper, reconstructed river runoff derived from palaeoenvironmental proxy based on (Davi et al. 2013; Davi et al. 2006) and I used the data to understand the environmental response to a cooler and drier period during the LIA. Would you mind going into detail here and point out more precisely what you mean? That would be very helpful – thank you!

Other minor comments

1. Figures: There are 10 figures and a lot of these figures are irrelevant in the main manuscript. For example, Figure 2 is unnecessary since the readers can visually get no information beside the fact that there is no overall change in precipitation between Mongolia and Inner Mongolia. The same applies to other figures.

I am sorry but I strongly disagree with this statement. Fig. 2 shows precipitation variability in the region and temporal peaks. Furthermore, it shows that there is no severe overall decrease in total precipitation, which is an important information in terms of vegetation response over the past 20 years. Could you please be more precise in your critics and point out which figures you consider irrelevant and unnecessary?

2. Texts: Some of the text are too long and probably need to be splitted into multiple lines. For example lines 28-30 have too many information, which can easily be divided into multiple lines. I also suggest the author to shorten the text just focusing on what the scope of this paper.

I will reconsider grammatical issues in a potential revision, depending on the editor's decision.

3. Lines 19-20: I thought precipitation did not change while there was an expansion of bare lands in modern Mongolia. This lines seems contradictory to the findings

You were right, there was a word missing, I added 'current' to the following sentence: "However, modern landcover data shows enhanced expansion of bare lands contrasting a current increase in precipitation (P_{total}) and maximum temperature (T_{max})"

4. Lines 21-22: Can you also add a line on why there was no relationship between P_{total} , tmax and NDVI values? Is it because of the previous year precipitation totals that the current year NDVI is higher? You can easily show this in scatter plot as well. I think climate is still a dominant factor that should define NDVI values given that there are little management activities in the region and given that they practice nomadic pastoralism.

I am really sorry but line 21-22 are part of the abstract and I cannot add a discussion there about the relationship of the data nor a scatterplot. The discussion part covers these relationships.

5. Line 42: I am wondering what makes an author really great. Can we just say "emphasized by other studies".

"A great many" means "a lot" and is not about emphasizing the impact of an author

6. Line 52: overprint or "footprint"

That is a good question. I would suggest “overprint” because it emphasizes the totally cultural aspect of what makes a landscape. A footprint would just be another (little) human contribution to global climate change, which I think is misleading...

7. Lines 96-98: I thought potential land cover maps should have been used here not the current aps.

Well, potential landcover maps exclude human impact and because this is an important feature of the entire planet, I think the actual maps are suitable for this analysis. I am convinced that potential maps can be misleading due to the fact that the whole region has undergone significant landcover change since the first human-environment interaction and latest since the Neolithic period. We cannot assume ‘natural’ conditions to model human behaviour in landscapes. That is generally a very interesting discussion and deserves a more methodological approach in another paper.

8. Lines 138-139: what does this line even mean? Are you implying that the NDVI values in this small section are similar to regional NDVI trend based on MODIS?

You are right, that was misleading! I deleted this part from the manuscript. These were preprocessing calculations I performed to evaluate the reliability of my data. Thanks for pointing this out to me!

9. Lines 157-159: I am lost here. How does elevation determine semi-arid conditions? Aridity is a function of precipitation and potential evapotranspiration.

10.

I am sorry but what do you mean with “you are lost here”? The lines you mention are:

“Forested zones are mostly abundant in lower elevated areas of the subhumid belt north of Beijing. With increasing elevation, semi-arid conditions prevail, which favour patterns of herbaceous grassland and shrubs. Towards the north-west, extensive sandy lands occur with a mean elevation of about 1000 m a.s.l.”

I do not say that elevation determines semi-arid conditions but that semi-arid conditions prevail with increasing elevation. Correct me if I am wrong because I am not a native English speaker. I am sure that further feedback will enhance the clarity of these issues and foster the overall quality of the general discussion and the paper.

Chen et al. Policy Shift influence the functional changes of the CNH systems in the Mongolian Plateau. *Env Res. Letters* 10 085003

references

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