Author response to Reviewers of Earth Surface Dynamics Manuscript egusphere-2023-62:

Past anthropogenic land use change caused a regime shift of the fluvial response to Holocene climate change in the Chinese Loess Plateau

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Summary:

The authors would like to thank the Reviewer, Dr. Amanda Schmidt, for the constructive and insightful comments on our manuscript, which were very helpful for us to significantly improve the manuscript and its readability.

Based on the Reviewer's suggestions, we carefully revised the manuscript to better present the processes of our modelling approach and to make readers easier understand the various steps in our simulations. We have added appropriate explanations for the setting of model parameters, detailed descriptions for the model structure and concise presentation for the model results. We also connect our works to other human-land use works in the Loess Plateau, as the reviewer suggested. Moreover, we modified the Discussion to better show the impact of the past anthropogenic land use change on the sensitivity of the Wei River catchment to climate change. Issues in the figures and tables are resolved.

Overall, in the new version of the manuscript, the comments and suggestions raised by Reviewer are fully considered. We think that the modified manuscript can meet reviewer's expectations.

In the following, we discuss in detail all Reviewer's comments and show how we have addressed them in the revised manuscript. Please note that the Reviewer's comments are in black, our responses are in blue, and the content of the revised manuscript is depicted in a frame.

Legend

RC: Reviewer Comment; AR: Author Response; □: Modified manuscript content

RC 1: It isn't clear to me why some decisions for model parameters were made based on totally modern agricultural practices. The model requires soil nitrogen content and this was set as constant based on modern fertilization levels. I don't understand why this amount was chosen when fertilization would have varied over history. Similarly, the crop is assumed to be irrigated twice, but irrigation would have been different at different points in history. Finally, why was winter wheat chosen for all time steps? Do we know that that is what people grew in the past? If not, do we have data that could provide better information for past crop growth?

AR 1: Thanks for your comments and suggestions. As you mentioned, we set some model parameters (soil nitrogen content and irrigation strategy) the same as the modern agricultural practices. These parameters could be different at different points in history, but we didn't have enough data to determine the value of these parameters during the Holocene. Therefore, we assume they are the same as the modern values and keep them constant during the Holocene.

We chose the winter wheat for our Holocene simulations since it occurred in the middle reaches of Yellow River since about 3000 BCE (Dodson et al., 2013). The earlier type of crop could be different, such as millet (Zhuang et al., 2014). However, we didn't have the data about the distributions of the millet during the Holocene in the Wei River. In addition, there are no millet's ecological parameters in previous studies that apply the Biome-BGC model, but they do have the winter wheat's ecological parameters (Hu et al., 2011). Therefore, we used the winter wheat as the crop during the Holocene simulations.

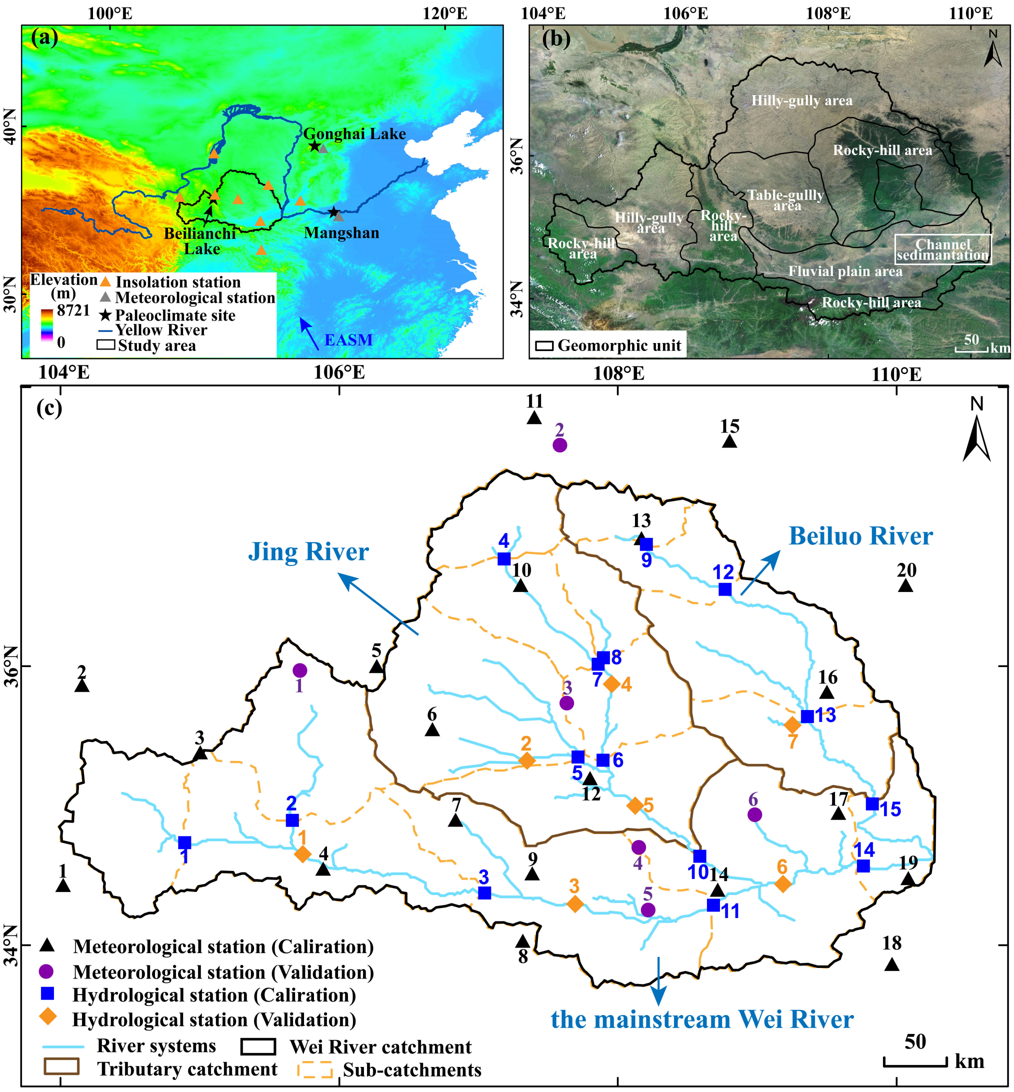
We have added a statement to explain the reason for setting these parameters in the main text (line 376-380).

> (line 376-380) The type of crop and its management parameters, such as soil nitrogen content and irrigations, were set the same as the modern values, because of lack of available data. This assumption is reasonable because wheat has been cultivated in the middle reaches of Yellow River as early as the mid-Holocene (Dodson et al., 2013; Zhuang and Kidder, 2014).

RC 2: I had a hard time following all the different geographic names, locations, watersheds, gauging stations, and so on. I know these data are available in figure 1, but it is such important information and so hard to read in such a small figure. It might help readers who are less intimately familiar with the area to have a larger context map with the rivers, gauging stations, and sub-catchments clearly delineated.

AR 2: Thanks for your comment and suggestions. We have modified Figure 1 accordingly.

> (Fig 1: The Wei River catchment a. Location of the Wei River and Yellow River; b. Landform types in the catchment; c. Meteorological stations, hydrological stations and rivers in and around the Wei River catchment.)



Meteorological station (Caliration) : 1. Minxian; 2. Yuzhong; 3. Huajialing; 4. Maiji; 5. Guyuan; 6.Kongtong; 7. Longxian 8. Taibai; 9. Fengxiang; 10. Huanxian; 11. Yanchi; 12. Changwu; 13. Wuqi; 14. Qindu; 15. Jingbian;16. Luochuan; 17. Pucheng; 18. Shangxian; 19. Huashan; 20. Yanchang

Meteorological station (Validation) : 1. Xiji; 2. Dingbian; 3. Xifeng; 4. Yongshou; 5. Wugong; 6.Yaoxian

Hydrological station (Caliration) : 1. Wushan; 2. Qin'an; 3. Linjiacun; 4. Hongde; 5. Yangjiaping; 6.Yuluoping; 7. Qingyang 8. Jiaqiao; 9. Wuqi; 10. Zhangjiashan; 11. Xianyang; 12. Liujiahe; 13. Jiaokou; 14. Huaxian; 15. Zhuangtou

Hydrological station (Validation) : 1. Beidao; 2. Jingchuan; 3. Weijiabao; 4. Banqiao; 5. Jingcun; 6.Lintong; 7. Huangling

RC 3: Several times in the results the authors have long lists of results that would be better presented in tables. It's very hard to follow long lists of results, especially for people who are less familiar with the study area.

AR 3: Thanks for your comment. We have added two tables (Table 2 and Table 3) to describe the total trend of discharge and sediment load in each sub-catchments from 6000 BCE to AD 1850, following your suggestions.

Table 2 The total difference of mean annual discharge in each sub-catchment from 6000 BCE to AD 1850

Mainstream of Wei River		Jing River		Beiluo River	
Wushan	-13.2%	Hongde	-37.3%	Wuqi	-33.1%
Qin'an	-26.7%	Jiaqiao	-20.2%	Liujiahe	-29.6%
Linjiacun	-20.7%	Qinyang	-37.3%	Jiaokou	-39.9%
Xianyang	-31.1%	Yuluoping	-44.7%	Zhuangtou	-50.4%
Huaxian	-35.1%	Yangjiaping	-22.7%		
Outlet	-21.8%	Zhangjiashan	-47.2%		

Table 3 The total difference of mean annual sediment load in each sub-catchment from 6000 BCE to AD 1850

Mainstream of Wei River		Jing River		Beiluo River	
Wushan	+2519.9%	Hongde	+1275.3%	Wuqi	+1397.6%
Qin'an	+920.8%	Jiaqiao	+3100.4%	Liujiahe	+2407.5%
Linjiacun	+1687.5%	Qinyang	+1007.0%	Jiaokou	+1953.4%
Xianyang	+1506.7%	Yuluoping	+1282.1%	Zhuangtou	+1278.1%
Huaxian	+3126.9%	Yangjiaping	+1396.5%		
Outlet	+906.8%	Zhangjiashan	+1411.1%		

RC 4: I'm concerned that the humidity is set to modern levels but we know that various times in the Holocene had very different humidity levels based on loess vs soil accumulation on the Chinese Loess Plateau. I wonder if this would then affect vegetation and erosion.

AR 4: Thanks for your comments and suggestions. Just as you mentioned, the humidity varied in the Wei River catchment during the Holocene. However, we set the humidity same as modern levels, since the data was lacking. Changes of humidity do have an impact on the absolute values of the simulated discharge and sediment load. We have done sensitivity analysis for the variation of humidity in the Beiluo River, which is a tributary of the Wei River, in our previous simulation works (Chen et al., 2021). The results show that 6% change in relative humidity could lead to a <17% variation of discharge and a <23% variation of sediment load. However, we found the variation of relative humidity had a limited impacts on the relative results between different scenarios (Chen et al., 2021). Therefore, the comparisons between different scenarios are sufficiently accurate even though we set the relative humidity equal to the modern levels. We have added statements in the main text to explain the settings for the relative humidity in the Holocene simulations (line 240-243).

> (line 240-243) The humidity and the sunshine duration values are set equal to modern values, because a sensitivity analysis has shown that variation of these two parameters has a limited impact on the results (Chen et al., 2021).

RC 5: Why was a 90 m DEM resampled (with, I assume, interpolation, although the exact interpolation was not specified) when there are high quality 30 m DEMs now available? It seems like an additional level of uncertainty that could have been avoided.

AR 5: Thanks for your comment. We also tried to resample the 30 m DEM (NASA SRTM Version 3.0 Global 1 arc second dataset) to a resolution of 1000 m. However, we found there were more artefacts in the resampled DEM from 30 m than that from 90 m. The artefacts make the river network disrupted when we perform the simulations. In order to guarantee the success of our simulation works, we chose to use the NASA SRTM 90m DEM.

RC 6: The authors talk a lot about base layers and surface layers but never specify what they are using for base and surface layers. Is the base layer loess? If so, how is loess thickness set when loess is continuously being deposited? Regardless, it would be good to explicitly say what the base and surface layers are composed of.

AR 6: Thanks for your comment and suggestion. In our simulations, the Surface layer is composed of sediment produced by hillslope- and fluvial process. The Base layer is composed of bedrock, which we obtain from the geological map (Fig S4a). Therefore, for the area covered by loess, the Base layer is loess. We didn't consider the deposition of loess during our simulations. We have added statements about the materials of Base and Surface layers to make a clear description (line 259-264).

> (line 259-264) There are two layers in the landscape evolution model, a Base layer and a Surface layer (Shobe et al., 2017). The Surface layer consists of loose material

and is above the Base layer, which is composed of basement (i.e. bedrock and loess in different areas). The Surface layer is composed of sediment produced by hillslope- and fluvial processes. The material of Base layer is set based on the rocky types, consisting of loess, sandstone, etc. (Fig S4a).

RC 7: What is the correction used for dams and irrigation channels? How do we know that is reasonable in the past?

AR 7: Thanks for your comment. We didn't consider the effect of dams and irrigation projects in our models. The human activities in our simulations are land use changes. In our calibration simulations (from 1996 to 2016), we first re-calculate the observed mean annual discharge and sediment load data collected from hydrological stations to the natural mean discharge and sediment load data, which are not affected by dams and irrigation systems. Then, we used the natural mean discharge and sediment load data to calibrate the parameters in our landscape model. Therefore, the results of Holocene simulations are the hydrologic and sediment processes without the effects of dams and irrigation systems. We have added some statement about these in the main text (line 285-288)

(line 285-288) Since our models don't consider the impacts of e.g. dams and irrigation systems, mean annual discharge and sediment load data measured at the stations are re-calculated into natural discharge and sediment load data by using the double-mass curves method (DMCs).

RC 8: All the web resources the authors list (mostly data sources) should be properly cited rather than just webpages listed in the text.

AR 8: Thanks for your suggestion. We have replaced the webpages with appropriate citations in the main text.

RC 9: In the discussion, I wasn't convinced by the argument that climate change is less important than human activity. It needs more explanation.

AR 9: Thanks for your comments and suggestions. Because the comparisons between Normal and WCC scenarios showed that the changes of climate variations would cause a significant **decrease** for both mean annual discharge and sediment yield after 1000 BCE (Fig. 5), we attributed the predicted significant **increase** of sediment thickness and sediment yield mainly to the large increase of land use rather than climate change. The contributions of climate change to the mean annual discharge and sediment yield do have some increases after 1000 BCE (Fig. 5). We think they are signals indicating the change of sensitivity of the fluvial catchment to climate change as a result of increasing ALCC. We have added some new statements in the main text to make a clearer explanation line (461-465).

(line 461-465) Since the comparisons between Normal and WCC scenarios showed the changes of climate variations would cause a significant decrease for both mean annual discharge and sediment yield after 1000 BCE (Fig. 5), the increments of sediment thickness and sediment yield should be a consequence of the large increase of the land use around the 1000 BCE.

RC 10: Likewise, I didn't understand the argument about the multiple thresholds of sensitivity to change. This seems interesting but was not well enough explained.

AR 10: Thanks for your comment. In Section 5.1, we first calculated the changes in the sensitivity of discharge and sediment yield to climate change. We used the abrupt changes of sensitivity as the marker of the regime shift in the Wei River catchment. Then, we attributed the abrupt change of sensitivity to the shift of the geographic center of land use change from the northwest to the southeast of the Wei River catchment, which made a switch of natural vegetation from grass to forest. The runoff in grassland is more sensitive to climate change than runoff in cropland, whereas runoff in forest is less sensitive than runoff in cropland. The switch of natural vegetation from grass to forest would make the sensitivity to climate change from decrease to increase. In Section 5.2, we present a correlation between the spatial distribution of sediment accumulation and the distribution of archaeological sites during the mid-Holocene (Fig.

6). Based on this correlation, we put forward the possibility that the shift of the geographic center of land use change, which causes the change of sensitivity of the Wei River catchment to climate change, could be a result of the increase of the areal extent of land use. Therefore, we showed that the change of sensitivity of the Wei River catchment to climate change, which indicates a regime shift of the fluvial system, would be caused by the increase of the areal extent of land use and also the exact changes of the kinds of vegetation (i.e from grass or forest to cropland). We have modified the statements in the Discussion to make the explanation clearer.

RC 11: It would be interesting to see this work connected to other human-land use work in China. There is such a rich literature on this topic, including from lake cores, simulations, and geochemistry. This paper would have a much bigger impact if it drew those connections more explicitly.

AR 11: Thanks for your comment and suggestion. We have compared our simulation works with other human-land use work in the Loess Plateau in the main text (line 465-476).

(line 465-476) This is in agreement with the evaluation of human-land use change accelerated soil erosion in the Loess Plateau recorded by colluvial components in Holocene loess–soil sequences (Huang et al., 2006), dike breaches (He et al., 2006), temporal changes of sedimentation rate from the Yellow River delta (Zhao et al., 2013) and previous modelling of the Beiluo River tributary of the Yellow River (Chen et al., 2021). The onset of the human-dominant soil erosion in our simulations (~1000 BCE) could be earlier than the inferences from the sedimentation rate records in Beilianchi lake (see the location in Fig. 1a; ~ AD 600; Zhang et al., 2019) and simulated soil erosion rate in the middle reaches of Yellow River (~ AD 1; Zhao et al., 2022a,b). These differences may be caused by the spatial variations of the development of agriculture in the Loess Plateau (Zhuang and Kidder, 2014; Yu et al., 2016).

RC 12: There are a few typos in figures and tables that need to be fixed. For example, table 1 has ages for Yangshao that don't overlap the time period for that row. Figure 5c has a typo in the title. In general, figures that have small text and a mix of red to green colors can be hard for many people to read.

AR 12: Thanks for your comment. All the typos in figures and tables have been corrected. The small text and a mix of red to green colors in figures also have been modified.