

## ***Interactive comment on “Evolution of Vegetation System in Heihe River Basin in the last 2000 years” by Shoubo Li et al.***

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We would like to thank the reviewer for the positive feedback on our manuscript and we are grateful for the valuable critical comments which could further improve the manuscript. Listed below is our response to each comment. Full details of the revisions will be provided in the revised manuscript.

Referee #1's General comment This study aims to understand the evolution of vegetation system in Heihe River Basin over the past 2000 years, by reconstructing the spatiotemporal distribution of natural vegetation and crop vegetation from those previous study results and Landsat images. Because of the challenging problems in the human-environment interaction in this region, long-term change in vegetation system in the study area should be much appreciated. This research has made some advance-

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ment in the evolution of vegetation system with long-term scale, by synthesizing remote sensing data and results from previous researches. It will promote the understanding of the ecosystem health in the region and how to achieve a sustainable management in the Heihe River Basin. Overall, this is a solid and well documented contribution that can be accepted after some moderate revisions.

Response: We appreciate the reviewer's positive general comment on this study. We will revise the manuscript according to the reviewer's specific comments. The response to these comments is given as follows:

Referee #1's Specific comments 1) Spelling and grammar should be improved in general. Sometimes the sentence construct is not concise enough. e.g. Page 1, line 15-17.

Response: Thanks for the comment. We will go through the manuscript to improve the sentences where the construct is not concise enough.

In specific to the example provided (Page 1, line 15-17), we have revised the sentence as below: "The area and biomass of the vegetation before 1987 were reconstructed based on the relationships between vegetation and climatic and hydrological variables developed with instrumental data in the last 30 years."

In addition, after addressing all the comments, the manuscript will be edited by a native English-speaking expert to improve the English expressions of the whole manuscript.

2) P2, Lines22, there were some references about the historical landscape changes about this research area, and please cite these literatures, for example, "Nian, Y. Y., X. Li, and J. Zhou. 2017.'Landscape changes of the Ejin Delta in the Heihe River Basin in Northwest China from 1930 to 2010.' International Journal of Remote Sensing 38 (2): 537-57. doi: 10.1080/01431161.2016.1268732".

Response: Thanks for the comments and the suggested references. We will add these references to the list and include their major findings in the introduction section.

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3) Page 2, line 38. Please add the newly published papers about the historical landscapes or cultivated area, especially in river basin scale. e.g. Xie et al., 2016. Assessing the evolution of oases in arid regions by reconstructing their historic spatio-temporal distribution: a case study of the Heihe River Basin, China. *Frontiers of Earth Science*; Hu and Li, 2014. Spatial distribution of an ancient agricultural oasis in Juyan, northwestern China. *Frontiers of Earth Science*, 8(3): 338-350.

Response: We agreed and will add these papers to the Reference section and include their major findings in the Introduction section.

4) P3, Line20, the moving and semi moving dunes should be revised as the words of the mobile dune and semi-mobile dune.

Response: We agreed. We will correct the "moving and semi moving dunes" to "mobile dune and semi-mobile dune" as suggested.

5) P3, Line21-22, when did these percent happen? please give more descriptions.

Response: Thanks for the comment. The percentage was calculated based on the land use and land cover data of the HRB in 2011. The LULC data were collected from the WestDC database. To clarify the point, we will include the necessary information in the revised manuscript.

6) P4, Figures1, please mark the name of the meteorological stations.

Response: We agreed. We will update Figure 1 with meteorological stations labelled with station names.

7) P5, Line8, the Juyan Lake started to retain water again in 2002, please make sure this is correct or maybe you shall cite other reference about the lake restore.

Response: Thanks for the comment. We checked published references and the Lake was reported to retain water again since 2002. We will cite references to confirm this point.

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8) P5, Line22, please use a table to list the data sources about Landsat iamges (path/row).

Response: We agreed. We will provide a table in the revised manuscript listing the images used in the analysis. Information including imaging dates, data quality (e.g. Cloud coverage, signal noise) will be detailed in the table.

9) P5, Line25, please delete the words of "during late summer and early autumn", and retain the words of "from June to October".

Response: Agreed. We will revise the sentence accordingly.

10) Yingluoxia Station is a key point to divide the upstream, midstream and downstream, but it is hard to identify the position of this station. Please change the symbol and color in the Figrue1. Furthermore, Heihe River Basin is your study area, so I would suggest to draw out the upstream area in figure 1 as well.

Response: We agreed. We will further modify Figure 1 by adding upstream area of the Heihe River Basin and changing the symbol and color of Yingluoxia Station.

11) Page 5, line 17. The study area has a long history and many human activities took place during different periods. The ancient study periods given in this manuscript is incomplete. First, historical documents support evidence that there are human activities in the Heihe River Basin in Sui Dynasty, and this should be included. Also, you can combine those two dynasties in Sui and Tang Dynasties. Second, there were prosperous human activities performed in the study area more than 150 years during Xixia Dynasty. I think the history of the Heihe River Basin should include the Xixia Dynasty. It is incomplete to ignore the above two important historical periods for HRB. Recommend to refer to some papers to get the information about the human activities developed in the downstream of the Heihe River Basin during the Xixia Dynasty. e.g., Hu and Li, 2014. Spatial distribution of ancient agricultural oasis in Juyan, northwestern China).

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Response: We agreed. The current six dynasties were selected according to the availability of vegetation maps for historic periods (Lu et al., 2015). We will include Sui by considering Sui and Tang as a single period as Sui-Tang. The situation was similar for the Xixia Dynasty and it could be combined into Yuan Dynasty. We will refer to the datasets and add the data for Sui and Xixia into the analysis in the revised manuscript.

12) Page 6, line 9-14. In the method part of 2.3.1, you use the MODIS NDVI profile 2013 to calibrate the Landsat NDVIs to obtain annual maximum NDVI. Why do you chose the year of 2013, but not other years?

Response: The reason why the year of 2013 was chosen is because 2013 is the final year we have Landsat images and it was naturally selected for this analysis. In addition, we made an assumption that vegetation growth would follow a similar phenology cycle in each year. Thus, data from different years would not cause significant differences in final results.

13) P 6, Figures 2, the equation in the figure should be separated from the figure.

Response: Agreed, the equation in the figure will be separated from the figure.

14) Page 7, line 14-24. Please clarify when did you use the model established by Zhao to calculate the biomass based on NDVI.

Response: We will clarify the period when we used the model established by Zhao to calculate the biomass based on NDVI and add details on how we calculated natural vegetation biomass and crops biomass of the study area

15) P7, Lines 20 and Line 21, Please list the reference "Zhao et al. 2006 and Zhao et al. 2010" in your references list.

Response: Thanks. We will add the reference to the reference list.

16) Page 8-9, line 39-line 1. In the section of 3.1, the reconstructed natural and crop vegetation distribution after 1987 were interpreted from Landsat images. How to dis-

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tinguish the natural and crop vegetation from Landsat images? And how about the accuracy? Please clarify the methods you used accordingly.

Response: The methods we used to distinguish natural and crop vegetation were provided in section 2.3.2. In brief, two rounds of threshold analysis were applied: the first threshold was used to mask out non-vegetation pixels; the second threshold was used to separate natural vegetation from crop vegetation. The threshold values were chose mainly based on analyzing the NDVI histogram distribution characteristics. The derived results were first compared to the corresponding Landsat images to check their accuracy in each year. In addition, the results in 2000 and 2011 were verified with existing land use maps (2000, 2011) obtained from the WestDC database. The calculated kappa coefficients (k) were 0.7206 and 0.6731 for 2000 and 2011, respectively.

17) P10, from your results and Figure3, how to interpret (forcing mechanism) the vegetation change in the west river of the lower reaches of the Heihe River from Yuan Dynasty to Ming Dynasty, also how to interpret the vegetation change in the Gurina area from RC to 1987.

Response: Thanks for the valuable comments. Among the reconstructed climatic and hydrological records in the study area, the variables which presented substantial changes were the annual average temperature and streamflow. The temperature kept decreasing from the early Yuan Dynasty to the end of the Ming Dynasty (Tang et al., 2017) while streamflow kept increasing (Sakai et al, 2012). Therefore, more streamflow and reduced evaporation possibly made more water available for local vegetation growth for this period. This could be the reason for the expansion of natural vegetation along the West River.

The vegetation change in the Gurina Area could be the results of different methods applied for previous dynasties and for recent years. For the reconstructions studies in historical periods, the effort was concentrated along the river channels while vegetation in remote areas was much less emphasized. Whereas in recent years with remotely

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sensed data used, vegetation in remote area could be identified much more easily and with higher precision. We will add this analysis in Discussion Section as the limitations of our methods in the revised manuscript.

18) Page14, line 17-19. You divided the natural and crop vegetation development in the study area into three stages. Why the period of the Republic of China (RC) is included into the Pre-development stage? Because the results of the pre-development stage was conducted from the previous studies, while that of the Republic of China (RC) is interpreted from Landsat imageries. Meanwhile, I think there were some common features of the ancient periods from the Han Dynasty to the Qing Dynasty, exclusive the period of Republic of China (RC). So, so it could be better to category RC period as as a rapid development period.

Response: Thanks for the comment. As revealed with the trend of natural and crop vegetation areas, RC could be recognized either as the end of a period with low coverage, or as the start of a period with rapid vegetation expansions. We agree when considering the common features of RC, it is more appropriate to categorize it as a rapid development period. We will revise the manuscript accordingly.

19) I think the discussion will be more convincing if the authors can further discuss the relationships between the climate change and human activities and the evolution of vegetation system. For example, how the climate influence the trend of vegetation changes can be analyzed according to the meteorological data or the previous studies. There is enough space to improve the discussion in the manuscript.

Response: Thanks for the comments. We will improve the discussion section in the revised manuscript by analyzing the relationships between the climate change and human activities and the evolution of vegetation system, adding the limitations of our research and implications for future research.

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