The Response to Comments on Manuscript

"**Evolution of the human-water relationships in Heihe River basin in the past 2,000 years**"

Submission Reference: hess-2014-560

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Dear Reviewer.

We would like to sincerely thank and acknowledge your efforts for spending your valuable time reviewing our manuscript. We are pleased to resubmit for publication the revised version of hess-2014-560 “Evolution of the human–water relationships in Heihe River basin in the past 2000 years”. We appreciate your constructive comments and criticisms. We have addressed your concerns and provided our response (in red) to your comments (in black) as below. Over the past few weeks and the revision process, we have also improved the paper for clarity. We have also provided two version of the manuscript: one with all changes using the “Track Changes” function in Microsoft Word; and the other one is not highlighted but with the same content.

Thank you and regards,

Dr. Yongping Wei

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Responses to major comments of Reviewer #1:

1. Comment: The estimation of E is not clear to me. Is E estimated by equation (2) or (3) for the basin or for cultivated oases and natural oases separately? Is w=3.5 for all the historical periods? Should the value of w be different between cultivated oases and natural oases? Should w even change with time depending on the type and intensity of crops?

E is estimated by equation (2) and (3) for the basin. There are two equations because of different emphasis on E_0 and P, respectively. Throughout the paper w=3.5 for all the historical periods.

We totally agree that the value of w will vary among different land use types and could change with time depending on the type and intensity of crops. However, due to the lack of historical documents or data for natural oases (forest and grassland) in this region, it is impossible for us to characterize w for the natural oases in the historical periods. In addition, in equations (2) and (3), when w is larger than 3, the impact of changes in w on E is likely to be small, especially in this arid region where E_0/P is large, and the available water for evapotranspiration becomes the determining factor (Zhang et al., 2001; Zhang et al., 2004). Therefore, we consider that using w=3.5 for all the historical periods is reasonable. However, we have discussed this issue as a limitation of this manuscript in the Discussions and Conclusions section; see line 41 page 5 to line 6 page 6 and lines 30-36 page 14.

2. Comment: Water supply is computed as the summation of local precipitation and irrigation (or groundwater ET). Is irrigation water pumped from groundwater or surface water withdrawal?

Irrigation water was obtained by surface water withdrawal from upstream reaches in historical periods. It has been both pumped from groundwater and diverted from surface water since the establishment of New China in 1949 as the surface water resource was insufficient for the rapid development of agriculture. The development of pumping and drilling technology during this period also facilitated this change. We have improved the description of irrigation in the revised manuscript to clarify this, see lines 25-29 page 6.

3. Comment: Is a portion of local precipitation recharged to the groundwater? If not, the groundwater is fully replenished by the precipitation recharge at the upstream (mountain).

Yes, a very small part of local precipitation recharges the groundwater in extremely wet years in the mid and lower stream reaches of our study area. We agree that most of the groundwater is replenished by the precipitation recharge in the upper catchment (mountains).

4. Comment: Line 15 page 1061: change to ", e.g., water"

We agree. We have made this change in our revised manuscript, see line 43 page 1.

5. Comment: Lines 1-3 page 1062: There are some recently published papers which are for explanatory and predictive purpose, e.g., "A prototype framework for models of sociohydrology: identification of key feedback loops and parameterisation approach" by Elshafei et al. (2014 HESS)

Thanks for introducing to us this very useful reference to improve the quality of our manuscript. We have read it and referenced it in our revised manuscript, see lines 11-14 page 2.

6. Comment: Lines 24-25 page 1062: some information is repeated at lines 4-9.

We agree. We have deleted the repeated information in our revised manuscript, see lines 35-36 page 2.

7. Comment: Line 15 page 1064: "Budyko and Miller, 1974;" Double check this.

We agree. We have doubled check it and changed it in our revised manuscript, see line 5 page 4 and line 19 page 15.

8. Comment: Line 20 page 1064: change to "respectively; " Similar changes are applicable for other locations.

We agree. We have made this suggested change throughout our revised manuscript, see line 10 page 4.

9. Comment: Line 16 page 1066: correct "Fu (1981) fFor details,"

We agree. We have made this suggested change in our revised manuscript, see line 26 page 5.

10. Comment: Line 24 page 1066: change "PET" to "E0" or define PET.

We agree. We have changed "PET" to "E_0" in our revised manuscript.

11. Comment: Lines 24 page 1066 – line 1 page 1067: E0 is assumed to be the same between the historical period and the instrumental period. This assumption needs to be justified or the uncertainty on estimated E due to this assumption needs to be discussed.

Thanks for the point raised. We have added some sentences to discuss the uncertainty of estimated E in our revised manuscript, see lines 30-41 page 5 and lines 30-34 page 14.

12. Comment: Line 15 page 1067: since "I" has been used for irrigation in Equation (5), you can use "J" to replace "I" in equation (5).

Thanks for the point raised. We have made the suggested change, see lines 8-11 page 6.

13. Comment: Line 2 page 1074: "m3/year"? Check the unit in Table 2 too.

We agree. We have changed "m^3" to "m^3/year" in our revised manuscript.

14. Comment: Lines 10-11 page 1076: The period from 2000-2010 is short. I am not sure whether it has already reached a new equilibrium stage. Natural oasis may continue to increase from Figure 5.

Thanks for the points raised. We have developed in-depth discussion on the equilibrium stage in our manuscript and changed “a new equilibrium stage” to “a new state”, see lines 11- 18 page 8 and lines 22-23 page 13.

15. Comment: Line 13 page 1077: Are predictions of its possible future dynamics discussed? How to predict future dynamics?

Thanks for the point raised. We did not mean that the future dynamics were predictable at this stage, rather that our findings can inform attempts towards this. We have changed, see lines 1-9 page 15.

16. Comment: Lines 15-18 page 1077: I think the claim is over stated. The manuscript can be shortened, but the “transition theory” needs more description and discussion.

Thanks for the point raised. We agree. We have rewritten this section and added more description and discussion on transition theory in our revised manuscript, see lines 11-18 page 8 and lines 1-9 page 15.

Additional references:

Zhang, L., Dawes, W., and Walker, G.: Response of mean annual evapotranspiration to vegetation changes at catchment scale. Water resources research, 37, 701-708, 2001.
Zhang, L., Hickel, K., Dawes, W., Chiew, F.H., Western, A., and Briggs, P.: A rational function approach for estimating mean annual evapotranspiration. Water resources research 40, W02502, doi:10.1029/2003WR002710, 2004.

Responses to major comments of Reviewer #2:

1. Comment: How the past 2000 years were divided into several different periods is not entirely clear. First, Table 1 provides vague timelines for the different dynasties; it would be much better if the authors provided start and end years to these periods. It would also help the reader understand whether these were successive contiguous periods. Second, it is mentioned in Section 2.3.1 that the authors used "precipitation in each historical period reconstructed by Ren et al. (2010)". Are Ren et al. (2010)'s historical periods the same as the seven dynastic periods chosen in this study? If not, how different are Ren et al.'s divisions of the historical period?

Thanks for this point. We have listed the start and end years of related dynasties in the past 2000 years in our revised manuscript. The reason why we selected seven periods, not seven whole dynasties, was because the data of reconstructed land use and land cover were only available during these periods (Xie, 2013; Xie et al., 2013). Ren et al. (2010) reconstructed a complete precipitation sequence spanning 2000 years with a resolution of 50 years, so the precipitation data for the seven chosen periods in this study were directly extracted from Ren et al. (2010). See lines 29-36 page 3.

2. Comment: In Section 2.3.3, three land use types are considered: cultivated oases, natural oases, and unused land. Equation 4 provides how the P (water supply) in the first two land use types was estimated, to be used in equations 2 and 3. However, for the unused land, was precipitation the only water supply considered? If yes, please state it explicitly; if not, please explain how water supply was calculated for unused land.

Yes. Precipitation is the only water considered for the unused land. We have stated this in our revised manuscript, see lines 30-30 page 6.

3. Comment: Sticking with Section 2.3.3, in equation 4, the groundwater irrigation I is kept constant at 500 mm throughout the entire historical period. This assumes that the types of crops cultivated in this basin did not change over 2000 years, and does not take into account the evolution in agricultural technology. Moreover, it directly contradicts the statements made in Section 3.6, such as "In the middle of the Qing Dynasty, the Hexi corridor was politically stable and free from wars and innovative farming and engineering methods were introduced, such as better seeds, new crops, and the steel farm implements".

We fully agree with your comment. We have investigated more historical documents on irrigation development in this region. According to Wang' (2003) research on the development history of water conservancy facilities in Heihe River basin, the main crop varieties, water conservancy facilities, irrigation method and farming conditions almost remained constant from the Han dynasty to the early modern period, so the irrigation was set at 500 mm for the whole historical period. However, it was increased from 500 to 650 mm when the cropping pattern evolved from single wheat to wheat and maize after the 1980s (Wang et al., 2005; Shi et al., 2011), and this is discussed as a limitation of this manuscript in Section Discussions and Conclusions, see lines 12-29 page 6, lines 30-38 page 12 and lines 30-37 page 14.

4. Comment: I think Section 4 of the paper needs to include a paragraph or two on the limitations/assumptions/caveats of the methods used. Historical reconstruction of annual

water fluxes over such a long period will most definitely involve huge uncertainties and assumptions (one example pointed out in my point 3 above). These need to be mentioned and discussed in this section.

Thanks for this point. We agree. Several points on key limitations/ assumptions/ caveats of the methods have been raised above and we have used those, plus a careful consideration of other limitations to develop a more detailed discussion of these in an additional paragraph in our revised manuscript, see lines 30-48 page 14.

5. Comment: What is k in Figure 6? I did not find any explanation in the article text.

Thanks for this point. *k* is the change rate of the factors and it was estimated by dividing the difference between the values at the start and end of the period to the years of the period. We have explained it in lines 25-27 page 8 of the Method Section.

Additional references:

Xie, Y.: Dataset of cultivated oasis distribution in the Heihe River Basin during the historical period. Heihe Plan Science Data Center, DOI: 10.3972/heihe.092.2013.db, 2013.
Xie, Y., Wang, X., Wang, G., and Yu, L.: Cultivated land distribution simulation based on grid in middle reaches of Heihe River basin in the historical periods, Advances in Earth Science, 28, 71-78, 2013.
Ren, Z., Lu, Y., and Yang, D.: Drought and flood disasters and rebuilding of precipitation sequence in Heihe River basin in the past 2000 years, Journal of Arid Land Resource and Environment, 24, 91-95, 2010.
Shi, M., Wang, L., and Wang, X.: A study on changes and driving factors of agricultural water supply and demand in Zhangye after Wwater reallocation of the Heihe River, Resources Science, 33, 1489-1497, 2011.
Wang, G., Yang, L., Chen, L., and Jumpei, K.: Impacts of land use changes on groundwater resources in the Heihe River basin, Acta Geogr. Sin., 60, 456–466, 2005.
Wang, Y.: The development history of water conservancy facilities in Heihe River basin, Gansu Nationalities Press, Lanzhou, 2003.