Responses to Peer Reviewers

Reviewer #2

General comments

Overall, the manuscript is clearly written, however the novel scientific contribution is not clear. The methodology is based on a traditional model-based scenario approach, which is by no means novel. The dataset and selected model (SWAT) are also not unique.

Authors' response:

One novelty of the paper is the analysis of green-blue water transformation under climate variability and human activities. This novelty will be explicitly mentioned in the revised manuscript. Based on our best knowledge, green-blue water transformation has been poorly studied in the literature, but strong human interventions to the natural hydrological processes have led to such transformation in many river basins all over the world. However, in recent years, most of water transformation studies are focused on precipitation and local precipitation exchange (Smith et al, 2003), precipitation and evaporation exchange (Joachim et al, 1999; Xu et al., 2013) and surface water and ground water exchange (Marios et al., 2000). However, the research of green and blue water flows transformation is still in need of further study. Therefore, we will revise the manuscript title to "Green-blue water transformation due to human activities and climate variability: a case study of the Heihe River Basin in Northwest China", and emphasize this novel topic in the revised introduction section. We agree the data and model are not unique, but applying a scenario approach to study green-blue water transformation is to our best knowledge the first attempt, methodologically suited to address this research question.

It is not clear to what extent the results reflect only the model parameter sensitivity and to what extent are the simulated causal relations 'real'.

Authors' response:

In our research, we used the parameter set calibrated and validated against monthly river discharges for two upstream stations (Zhamushike station and Yingluo canyon) in our previous study (Zang et al., 2012), and this setting was used here as well. More than 85% of the annual discharge in the Heihe River flows through these two hydrological stations. Furthermore, we had used the SUFI-2 method in the SWAT-CUP interface (Abbaspour et al., 2007) for parameter optimization. In this method, all uncertainties (parameter, conceptual model, input, etc.) are mapped onto the parameter ranges, which are calibrated to bracket most of the measured data in the 95% prediction uncertainty (Abbaspour et al., 2007). The calibration and validation performed with SWAT at the two hydrological stations was satisfactory, as indicated by high values of E_{ns} and R^2. The E_{ns} values at both Zhamushike and Yingluo canyon are above 0.87, and the R^2 values are greater than 0.90 (Zang et al., 2012). The most sensitive parameters with their best parameter intervals and best parameter values eventually used in this study are shown by Zang et al., (2012). Furthermore, we have compared green water simulation results with observed data in 2007, the results showed that green water simulation is similar to observed data, the relative change error are between -10% -12% (Zang and Liu, 2013). This information will be briefly summarized in the revision.

The paper reads like a case study, but I missed a closer look and deeper assessment of the coupled climate-human interaction which will bring some more understanding of the linkage between hydrologic and socio-economic processes and their controls.

Authors' response:

In our paper, we not only analyze the spatial and temporal distribution of the green and blue water flows under natural climate variations without considering human activities, but also build scenarios to simulate green-blue water transformation by explicitly considering different human activities, e.g. land use and irrigation. Our paper provides a case study to understand how humans have changed to hydrology of a specific study region relative to effects of climatic variation, for a previously unstudied topic (green-blue water transformation).

In our research, we use different land use change scenarios and irrigation scenarios to assess green and blue water flow variability, to which hydrological variation in the Heihe river basin is particularly sensitive, at least in midstream areas (Xiao et al., 2011). The urbanization can increase blue water flow, but decrease green water flow; the irrigation can increase green water flow, and decrease blue water flow. We are aware (and will highlight in the revised paper) that we study only the influence of humans on water flows, and not the feedback of these changes to humans. We still hope that this is sufficient to be considered as a relevant study for the Special Issue, as it also contains papers that do not study these two-way interactions or co-evolutions.

Specific comments

1) Abstract: Please consider to use mm instead of m^3. Please indicate also the temporal dimension (yearly, daily, etc).

Authors' response:

We thank reviewers' suggestion. We will use mm and m^3 simultaneously in the revised version, and indicate the temporal dimension.

2) Introduction:"With global warming, extreme weather events are now occurring more frequently, ... (Vorosmarty et al., 2000, 2010, ...)". The sentence reads like the cited references confirming increased frequency of extreme events, which is likely not the case. Please consider to revise.

Authors' response:

Agree. We will revise it.

3) Introduction. The topic of human and climate impacts on water resources is really wide, resulting a huge number of publications. Please consider to present the context for your research in a closer way, in order to clearly show/distinguish, what is already published, what is missing and what is new and novel here. In the present state, the introduction is very general.

Authors' response:

Agree! We will revise the introduction to cite papers that are more appropriate to our analysis and study region.

4) The SWAT model. Please be more specific in parts, which are relevant to the topic-evapotranspiration and runoff. How is the climate and human impacts parametrised and linked together? Is there some dynamical link between human and climate interactions on the water balance? How stable/sensitive are the parameters in time?

Authors' response:

The model is designed in a way that climate and land cover influence the evapotranspiration and runoff. Precipitation and temperature change will influence the quantity of green and blue water flow generation; human land cover changes will change the runoff and evapotranspiration. In our research, the SWAT model parameters were not changed over the simulation period, but the input information certainly reflects changes over time. We did not consider the dynamical links between human and climate interactions on water balance, and the influence of human and climate on water balance is examined independently. We will clarify these shortcomings in the revision.

5) p.7, l. 25: Is the Nash-Sutcliffe efficiency based on daily values?

Authors' response:

We used Nash-Sutcliffe efficiency based on monthly value. We will clarify this.

6) Results, p.9, l.11-15: From Fig.4 and Table 2, it is not clear how much is the surface runoff accelerating and what categories (in Table 2) are taken as urban land use class. Please clarify and justify the interpretations made. For readers, which are not familiar with geographical and climate variability within the region, it is difficult to understand the differences and causing factors. Please consider to add some more detailed explanations about the causing processes.

Authors' response:

Agree. The Figure 4 and Table 3 just offer parts of information for land use change and irrigation districts distribution (i.e. not containing cropland in downstream and the model sets information for small village and towns), more information will be offered in the revised manuscript. We will also add more detailed explanations of the causal processes. From 1986 to 2005, the urban area and mining land use have increased by 47% and 21%, respectively (Table 3). The characteristic of these types of land cover is hardened ground, which decreases infiltration and actual evapotranspiration generation time, accelerating surface runoff production. From 1986 to 2005, the irrigation district of the Heihe river basin has also increased by 27% (Table 3). In an earlier study, irrigation expansion was shown to require a large amount of water from rivers and groundwater (Wang et al., 2003). This has likely led to a decrease in discharge of river and aquifers, i.e. of the blue water flow. According to our simulation results (Table 1), at the river basin level, land use change has resulted in an increase of blue water flow by 206 million m^3 and a concurrent increase in green water flow by the same amount. This information will be added to the revised paper, as well as some maps illustrating the land use changes (Fig. A3, see in Page 8 in this Response Letter) and some connections (http://westdc.westgis.ac.cn/).

7) Table 1: Please use values in mm.

Authors' response:

We thank reviewers' suggestion. We will use mm and m^3 simultaneously in the revised version. We have added Table 2 (see in Page 7 in this Response Letter) where the unit of mm is used.

8) Figure 8. (mean annual precipitation and air temperature change)?

Authors' response:

Yes, it is referred to annual means, will be clarified.

9) Green and blue water. The reason for this terminology is not clear. Why not evapotranspiration and runoff?

Authors' response:

First of all, blue water flows include surface runoff, lateral flow and groundwater recharge; green water flow is evapotranspiration. Hence, blue water flow is more than runoff alone.
The conventional water-resource planning and management focus is on liquid water, or blue water. It served the needs of engineers who were involved in water supply and infrastructure projects quite well. However, the blue water that has dominated the water perceptions in the past only represents one-third of the real freshwater resource, the rainfall over the continents. Most rain flows back to the atmosphere as a vapor flow, dominated by consumptive water use by the vegetation. We therefore need to incorporate a second form of water resource, the rainfall that naturally infiltrates into the soil and that is on its way back to the atmosphere.
We will add the reasons for using the terminology of green and blue water in the revised paper.

Reference:

Smith,R., Jiang,Q., Ma,T., et al.: Orographic precipitation and air mass transformation: An Alpine example, Q. J. R. Meteorol. Soc., 129, 433-454, 2003, doi: 10.1256/qj.01.212.

Joachim, G., Andri, B., and Herbert, L.: Spatially distributed hydrotope-based modelling of evapotranspiration and runoff in mountainous basins, Hydrol. Process. 13, 2751-2768, 1999.

Marios, S.: Interactions between groundwater and surface water: the state of the science, Hydrogeology Journal, 10:52–67, 2002, DOI 10.1007/s10040-001-0170-8.

Xu, Y., Ding, Y. H., and Zhao, Z. C.: A Scenario of Seasonal Climate Change of the 21st Century in Northwest China, Climatic and Environmental Research, 8, 19-26, 2003.

Zang, C. F., Liu, J. G., and Vander, V. M.: Assessment of spatial and temporal patterns of green and blue water flow under natural conditions in inland river basins in Northwest China, Hydrology Earth System Sciences, 16, 2859-2870, 2012.

Abbaspour, K. C.: User Manual for SWAT-CUP, SWAT Calibration and Uncertainty Analysis Programs, Swiss Federal Institute of Aquatic Science and Technology, Eawag, Duebendorf, Switzerland, 93pp, 2007.

Wang, G. X., Cheng, G. D., and Du, M. Y.: The impacts of human activity on hydrological processes in the arid zones of the Hexi Corridor, northwest China, in the past 50 years. Water Resources Systems-Water variability and Global Change (Proceedings of symposium HS02a held during IUGG2003 al Sapporo. July 2003), IAHS Publ. no. 280, 93-103, 2003.

Xiao, S. C., Xiao, H. L., Li, Y., and Yang, Y.: Water Issues and Integrated Water Resource Management in Heihe River Basin in Recent 50 Years, Journal of Desert Research, 31, 529-535, 2011.

Zang, C. F., and Liu, J.: Trend analysis for the flows of green and blue water in the Heihe River basin, northwestern China, Journal of Hydrology, 502, 27-36, 2013.

Table 2 Variability of green/blue water flows among difference scenarios (Units: mm)

Sub-basins number	GB (S_B-S_A)	GB (S_C-S_B)	GB (S_D-S_C)	GB (S_D-S_A)	B (S_B-S_A)	B (S_C-S_B)	B (S_D-S_C)	B (S_D-S_A)	G (S_B-S_A)	G (S_C-S_B)	G (S_D-S_C)	G (S_D-S_A)
1	4	-1	0	3	0	1	0	1	3	-2	0	1
2	6	0	0	6	0	0	0	0	6	0	0	6
3	4	-1	0	3	0	1	0	1	3	-2	0	1
4	7	0	0	7	3	-3	-2	-2	5	2	3	10
5	6	0	0	6	0	1	1	2	6	-1	0	5
6	5	0	0	5	0	-1	0	-1	5	1	-1	5
7	5	0	0	5	0	-1	0	-1	5	1	-1	5
8	7	0	0	7	3	-3	-2	-2	4	3	3	10
9	6	0	0	6	2	0	1	3	3	0	-1	2
10	2	0	0	2	0	0	0	0	2	0	0	2
11	-10	1	0	-9	-5	2	0	-3	-6	0	0	-6
12	-10	0	0	-10	-4	1	-4	-7	-7	0	0	-7
13	-10	2	0	-8	-7	2	0	-5	-2	-1	0	-3
14	-10	1	0	-9	-8	5	-1	-4	-2	-4	6	0
15	-7	0	0	-7	-7	1	-8	-14	0	3	4	7
16	-7	0	0	-7	-8	0	0	-8	1	0	0	1
17	4	1	0	5	2	3	0	5	2	-2	0	0
18	1	0	0	1	0	9	-1	8	2	-9	4	-3
19	-10	1	0	-9	-8	2	-5	-11	-2	-2	10	6
20	1	0	0	1	0	9	-1	8	1	-9	4	-4
21	1	0	0	1	-2	1	0	-1	2	0	0	2
22	-1	0	0	-1	-2	0	0	-2	1	0	0	1
23	-1	0	0	-1	-4	1	0	-3	4	-2	0	2
24	-16	0	0	-16	-19	-5	-6	-30	2	6	7	15
25	-10	1	0	-9	-4	2	0	-2	-6	-1	0	-7
26	0	-1	-2	-3	-9	-9	-4	-22	8	9	8	25
27	20	1	0	21	2	11	0	13	18	-10	0	8
28	-3	0	0	-3	-3	10	-2	5	0	-10	4	-6
29	-11	0	0	-11	-2	6	-9	-5	-9	-6	7	-8
30	41	0	0	41	14	20	0	34	27	-21	0	6
31	1	0	0	1	0	0	0	0	1	0	0	1
32	51	0	0	51	29	-7	-13	9	21	8	9	38

Note: GB is total green and blue water flows; B is blue water flow; G is green water flow; S_A is scenario A; S_B is scenario B; S_C is scenario C; S_D is scenario D. S_j-S_i is difference between scenario j and i.

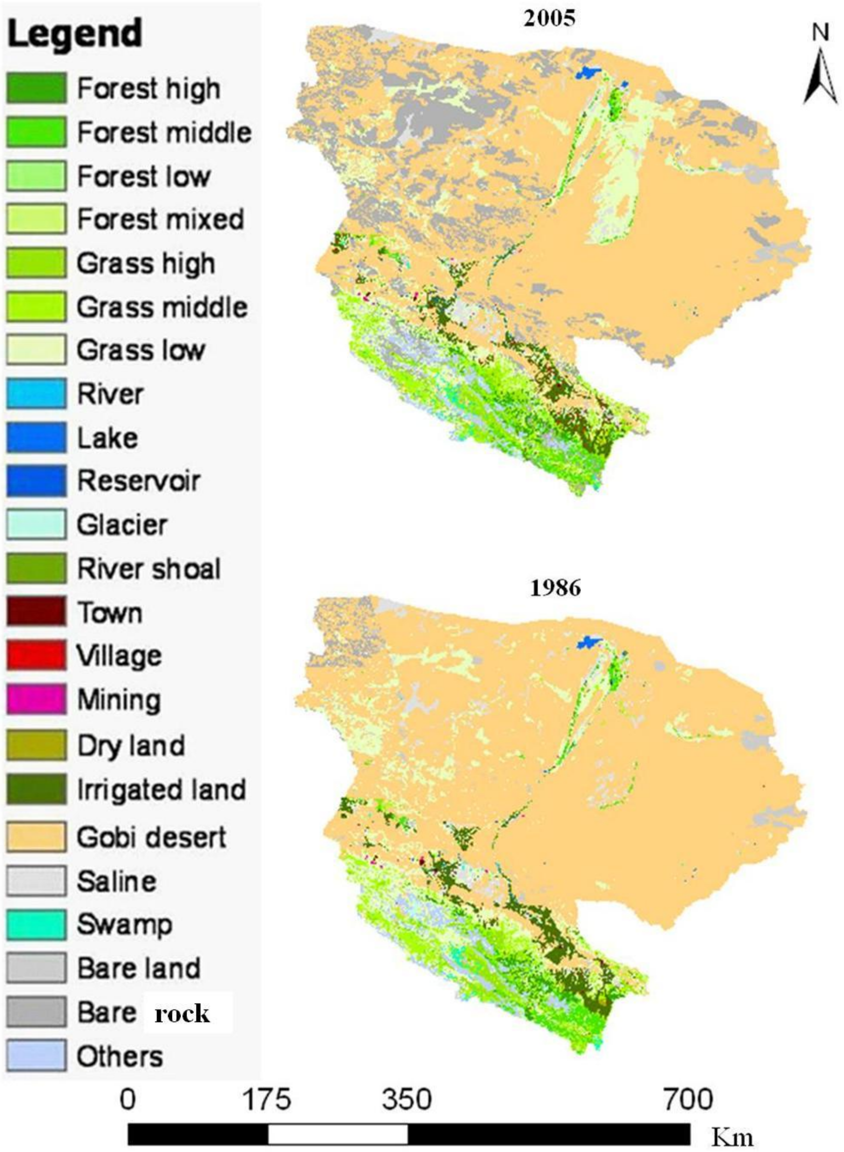

Fig. A3. Land use map in the Heihe river basin in 1986 and 2005