<u>Responses to Peer Reviewers</u>

<u>Reviewer #5</u>

Major comments

In this discussion paper, the authors applied the SWAT model to the Heihe River in China. They conducted four hydrological simulations with different settings and com-pared the results. The settings are different in terms of land use (1986 and 2005), climate (1986 and 2005) and expansion of irrigated area (provisional). They reported and discussed the differences in the green and blue water among simulations.

This study tried to address the consequence of water use, land use, and climatic change to hydrological cycle in a semi-arid basin, but as far as I observed, it is halfway. First, the authors showed only the outputs of their model without validation. At least the results for two base years (1986 and 2005) should be intensively compared with observation.

Authors' response:

We have validated model simulation results with observation data: two hydrological stations in upstream (see our previous published paper in HESS) and one station in mid-stream (new results that are not covered in the previous version). The validation results (Fig. 3, see in Page 7 in this Response Letter)) will be shown in the revised manuscript.

Second, the authors mainly argued two points in this paper: (a) land use change alters simulated runoff (because the curve number is different) and (b) irrigation water withdrawal decreases river flow that reaches the terminal lake. Both of there marks are too general. More concrete, quantitative, and novel findings should be reported here.

Authors' response:

Agree! Following the advice, we will provide more concrete, quantitative and novel findings in the revised manuscript. We have added more tables (e.g. Table 2, Table A1; see in Page 5 and in this Response Letter)) and more figures (Fig. 3, Fig.A3; see in Page 7 and 8 in this Response Letter)) to help quantify and interpret the results.

Additionally, the authors repeatedly stressed that the major hydrological change in the Heihe River basin was due to the expansion in urban area, although the area for "town" and "village" accounts for only approximately 0.2% of the total basin area. I was hardly convinced that it explains the change.

Authors' response:

This is a very important question. Urban area is not large in the basin, but it is very decisive for blue water flow generation. Furthermore, because the resolution of land use data is 1 km^2, we may miss smaller village, small town and mining areas. To make the simulations more accurately for the revised paper, we will identify towns and villages in the SWAT model based on sub-basin level (i.e. three classes of residential areas; high, middle and low intensive). Only the intensively populated areas were referred to in Figure 4 of our paper (Wang et al., 2007). The green and blue water flow changes were occurring in the midstream of the Heihe river basin, where most of the cities and human activities of the river basin are located, and the irrigation expansion also occurred there. Besides urbanization, irrigation expansion also contributed to the simulated green and blue water flow changes. The total discharge of the Heihe river basin is 3.3 billion m^3 (Li et al., 2009), and the land use changes in the midstream area have changed by nearly 6% the blue water flow in the entire river basin. There are also other types of land cover changes, but they did not influence the green and blue water flow significantly.

The authors have succeeded in setting up their model. It would be nice that their simulation results will be well validated for various periods with different land use, irrigation, and climate conditions utilizing local hydro-meteorological observations. I hope that some of the interactions between human activities and hydrological phenomena would be clearly explained by this model.

Authors' response:

Agree! We accept the advice and will validate the model results for various periods. We have taken the reviewer's advice, and provided additional validation of the model results by comparing them with observations for the Zhengyi Canyon in midstream, where high intensive human activities occur. The validation results are satisfying as shown in Fig. 3 (see Page 7 in this Response Letter), which will be added to the revised manuscript. We will explain the interactions between human activities and hydrological phenomena in revised manuscript.

Minor comments

Page 9483, line 19 "This study is ...": I think this paragraphs should be moved to Introduction.

Authors' response:

Agree! We will move it to introduction.

Page 9485, line 6 "concurrent increase": Possibly, it should be "concurrent decrease".

Authors' response:

Agree! We will modify it as your suggestion.

Page 9486, line 10 "where precipitation has decreased significantly": I'm a little bit confused because the authors sometimes mix up climatic variability and trend. For a trend analysis, I think the period is too short (25 years) and the statistical significance is too low (Figure 8 shows that the trend of precipitation is statistically significant for only two stations).

Authors' response:

Agree! We will definite the scale of climate variability and extent the trend analysis period to more than 30 year (1975 to 2010) (Fig.9, see in Page 9 in this Response Letter)). Because the trend analysis period is too short, this has influenced the results, we will analyze this again by longer test period.

Page 9488, line 3 "The results imply that land use change towards urbanization has led to a major shift from green to blue water flow in the study area, while irrigation expansion had resulted in a shift from blue to green water flow.": I think the remark is too general. I would like to see some more concrete, quantitative, and novel findings.

Authors' response:

Agree! We will analyze our results carefully again, and will give more concrete, quantitative and novel findings.

Table 1: What are the basin total blue and green water flows?

Authors' response:

Total blue and green water flows of the entire basin are 23.2 billion m^3.

Table 2: The area for "town" and "village" is around 400 km^2, which is 0.2% of total 0.24 million km^2 (page 9481, line 12). I think urban area is quite minor in this basin, hence the change could be negligible.

Authors' response:

This is a very important question. Urban area is not large in the basin, but it is very decisive for blue water flow generation. Furthermore, because the resolution of land use data is 1 km^2, we may miss smaller village, small town and mining areas. To make the simulations more accurately for the revised paper, we will identify towns and villages in the SWAT model based on sub-basin level (i.e. three classes of residential areas; high, middle and low intensive). Only the intensively populated areas were referred to in Figure 4 of our paper (Wang et al., 2007). Furthermore, the urban distribution has significant spatial difference (Fig.

A3), and the green and blue water flow variation also have significant spatial difference (Table 2). The green and blue water flow changes were occurring in the midstream of the Heihe river basin, where most of the cities and human activities of the river basin are located, and the irrigation expansion also occurred there. Besides urbanization, irrigation expansion also contributed to the simulated green and blue water flow changes. The total discharge of the Heihe river basin is 3.3 billion m^3 (Li et al., 2009), and the land use changes in the midstream area have changed by nearly 6% the blue water flow in the entire river basin. There are also other types of land cover changes, but they did not influence the green and blue water flow significantly.

Reference:

Li, H., Zhang, Y., Vaze, J., Wang, B.: Separating effects of vegetation change and climate variability using hydrological modelling and sensitivity-based approaches. Journal of Hydrology, 420, 403-418, 2012.

Wang, L. C.: The town development process history and driving mechanism of Heihe river basin, PhD thesis of cold and arid regions environment and engineering research institute, CAS, 2007.

Li, Z.: Runoff simulation in the upper reaches of Heihe River Basin and uncertainty anakysis in hydrological modeling, Degree of Doctor of Engineering of Beijing Normal University , 5-21, 2009.

Table A1 Irrigation scenarios sets information in SWAT model

Parameters	**Upstream**	**Midstream**	**Downstream**
IRRSC	1	1	3
IRRNO	32	30	5
IRRNO,cont	32	30	5
FLOWMIN	50	70	
DIVMAX	90	100	
DIVMAX,cont	1	1	
FLOWFR	0.5	0.7	
DDRAIN	100	100	100
TDRAIN	36	36	36
GDRAIN	48	48	48

Note:IRRSC: irrigation code. The options are: 0, no irrigation; 1, divert water from reach; 2, divert water from reservoir; 3, divert water from shallow aquifer; 4, divert water from deep aquifer; 5, divert water from unlimited source outside watershed. IRRNO: irrigation source location. IRRNO, cont: the definition of this variable depends on the setting of IRRSC; IRRSC=1, IRRNO is the number of the reach that water is moved from; IRRSC=2, IRRNO is the number of the reservoir that water is moved from; IRRSC=3 or 4; IRRNO is the number of the sub-basin that water is removed from; IRRSC=0 or 5; this variable is not used; Required if 1≤IRRSC≤4. FLOWMIN, minimum in-stream flow for irrigation diversions (m^3/s). DIVMAX, maximum daily irrigation diversion from reach (mm). DIVMAX,cont, it is may be set when IRRSC=1. FLOWFR, fraction of available flow that is allowed to be applied to the HRU. DDRAIN, depth to subsurface drain (mm). TDRAIN, time title drain soil to filed capacity (hours). GDRAIN, drain tile lag time (hours).

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.

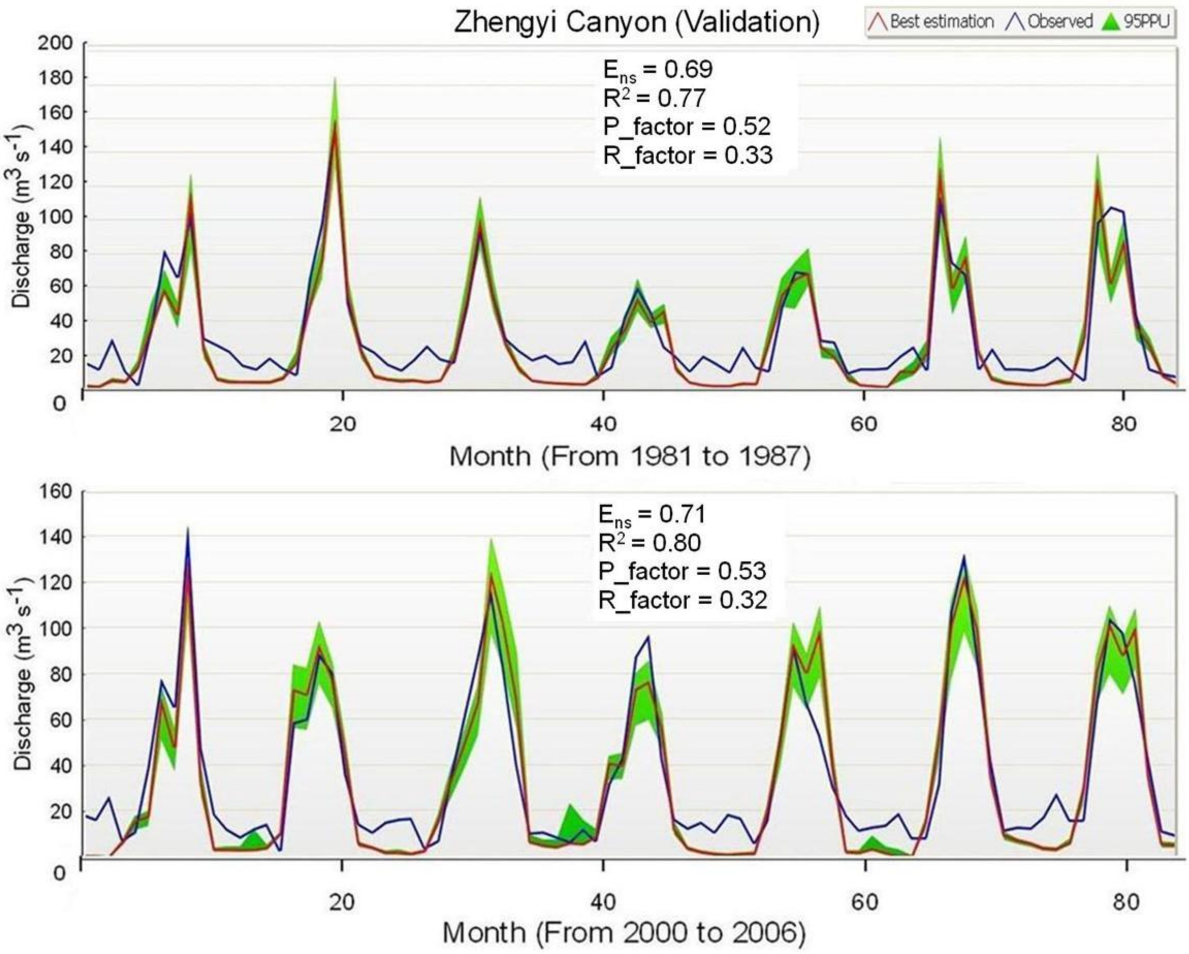

Fig. 3. The validation of SWAT model with previous parameters in Zhengyi Canyon

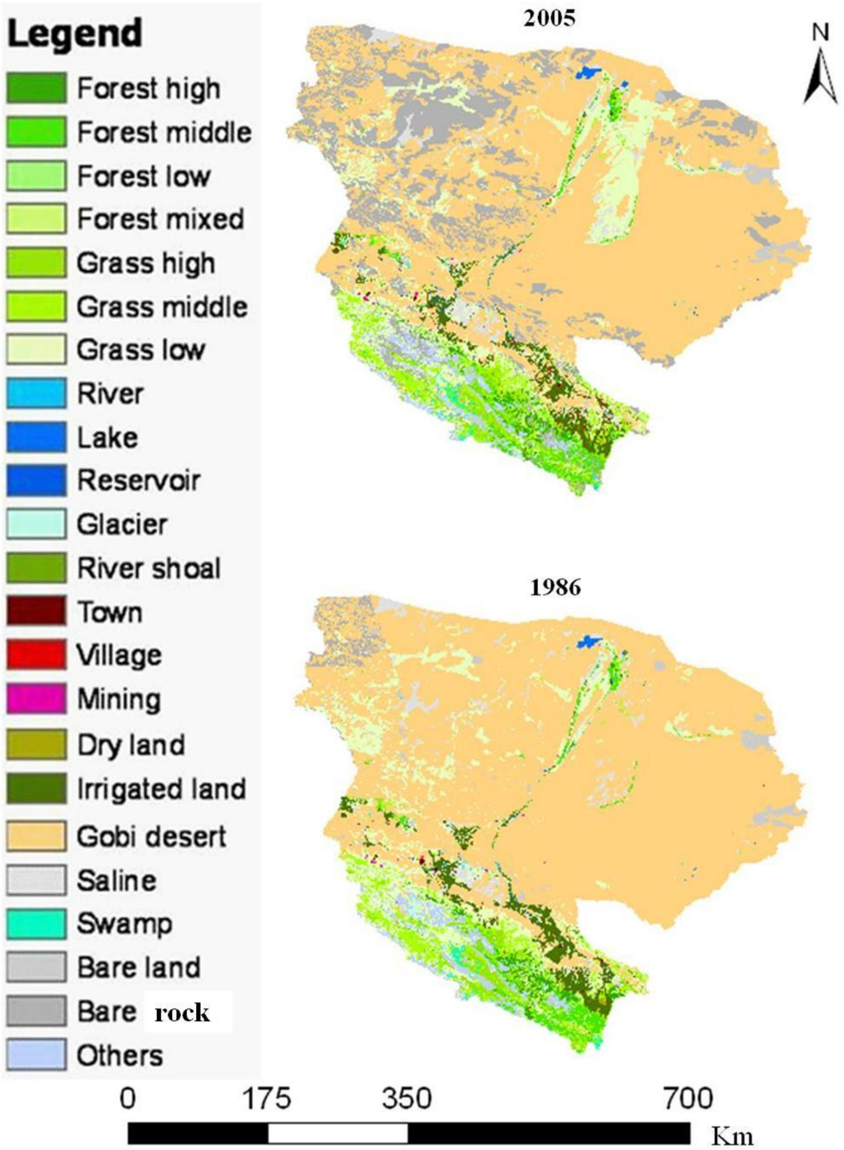

Fig. A3. Land use map in the Heihe river basin in 1986 and 2005

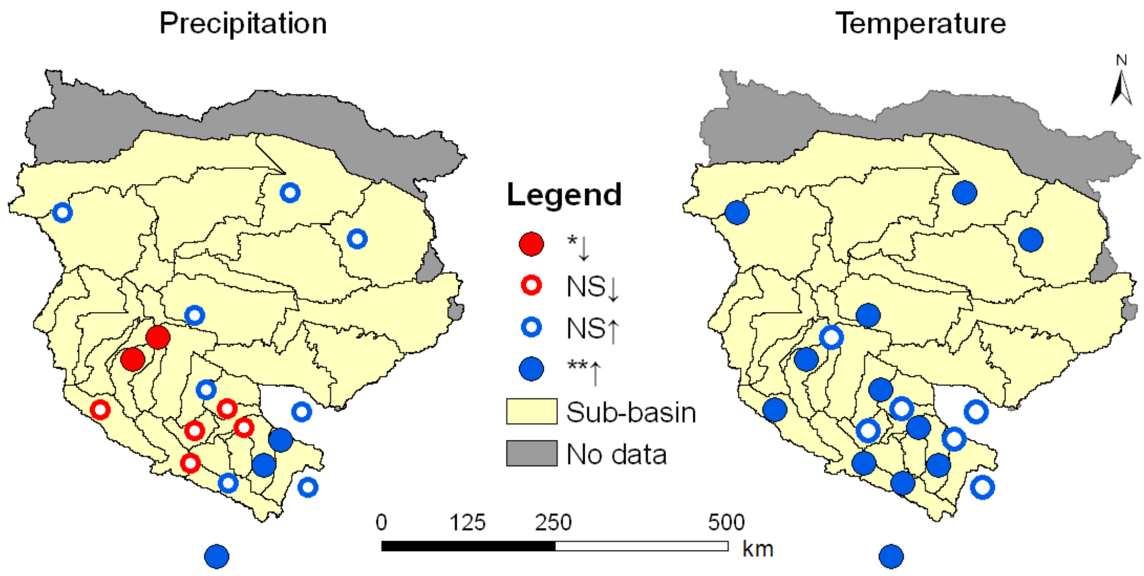

Fig. 9. The variability of precipitation and temperature in the Heihe river basin from 1975 to 2010. ↑ indicates increasing trend; ↓ decreasing trend, ** significant at $p < 0.01$; * significant at $p < 0.05$; NS, not significant.