

We would like to thank Referee Prof. HHG Savenije for his interest in this topic and for the valuable comments to improve our manuscript. Based on the comments some recalculations have been performed. Our point-by-point response to the comments is given in the following:

General comments from referee

In this paper, the authors analyzed output from the GSFLOW model in the middle and lower Heihe River Basin (HRB), and investigated the division between green and blue water and their interaction in different ecosystems. There are quite a number of models that have been applied to the HRB, among which the GSFLOW model, which has been crosschecked with multi-source datasets.

Comment 1

Figures 3 and 6 provide a clear representation of the water balance of the middle and lower HRB and in different ecosystems. However, I am not sure if Figure 6 fully represents reality. It is assumed that all the precipitation that does not runoff goes through the soil moisture stock. I doubt this. Apparently it is assumed that this water is transported through the root zone, and evaporated by transpiration. This cannot be true. Judging by the very low precipitation (about 170 mm/a), I would expect most of the precipitation on the lower Heihe to be partitioned into interception. In forested areas, the preferential infiltration may be substantial, but in forests interception is also substantial. On the desert, the infiltration is probably zero. Also on farmland and grassland, most of the precipitation will be captured by (leaf and ground) interception. I think the authors should make an effort to identify the partitioning of ET in Transpiration, Interception and Soil Evaporation.

Author's response

Thanks for the comments. Indeed, we would like to use Figure 3 and Figure 6 to represent clearly the water balance, especially reveal the exchanges between blue and green water.

In Figure 6, the green arrow which is marked as the "Soil Moisture Recharge" is actually the part that consists of soil moisture recharge and interception. We are very sorry for this mistake which causing confusion here. We thank you for pointing it out. We have now corrected it. Since the interception, transpiration and soil evaporation are all accounted as the green water, thus we combined them together in this study as the evapotranspiration that represents the total green water flux.

We totally agree that the ET partition is important, especially for the moisture cycling. As different evaporation components plays different role in the hydrological cycle (van der Ent et al., 2014). However, it is out of the scope of this work. In this study, we focused on more the water resources assessment rather than the hydrological cycle. Therefore, we are more interested in the green and blue water flowing and the interconnection between them rather than the partition of hydrological fluxes. To provide a clear representation of the movement of green and blue water without making the results unnecessary complex. We combined some fluxes on purpose, e.g. the surface runoff and subsurface runoff are combined as runoff. Even though the surface runoff and subsurface runoff has different mechanism on the perspective of hydrological processes. They play similar roles in green and blue water flow chart on the perspective of water resources assessment. Interception, transpiration and soil evaporation are originally combined on the same purpose as runoff.

However, we still believe that the separation of canopy interception is necessary and could help improving the description of green and blue water flow regimes. As the canopy interception actually does not go in the soil and will directly evaporate back to the atmosphere from leaves. We have extracted the variable of canopy interception and updated the manuscript and the figures. The updated figure is shown in the following. We also inserted the following content in the manuscript “Eventhough interception is accounted as green water, it is still separated from total evaporation. As it is directly evaporate back to the atmosphere from leaves and does not go into the soil. The interception for farmland, forest, grassland and desert are 47.5 mm/year, 30.8 mm/year, 41.5 mm/year and 0.6 mm/year, respectively. The irrigation is not intercepted due to the reason that flood and furrow irrigation are still the main irrigation modes in HRB during our research period (Zhou et al., 2015). There is also interception in desert area, since some regions are covered by desert vegetation that is considered in our model.”

Currently, the model used in this study has only the module for canopy interception simulation. Therefore, the floor interception is not considered during the simulation. Also, in the model, the soil evaporation and transpiration are not separated inherently limited by the model structure. However, it will not affect the results of the green water flow regime, as they are all accounted as green water and play similar roles on the perspective of flow regime analysis. Furthermore, the irrigation is not intercepted due to the reason that flood and furrow irrigation are still the main irrigation modes in HRB during our research period (Zhou et al., 2015).

Author’s changes in manuscript

We have change all the term of “evapotranspiration” that may cause confusion in the manuscript to “total evaporation” and stated in Page 7, Line 20 “The total evaporation consists of interception and evapotranspiration.”

Page 10, Line 17.

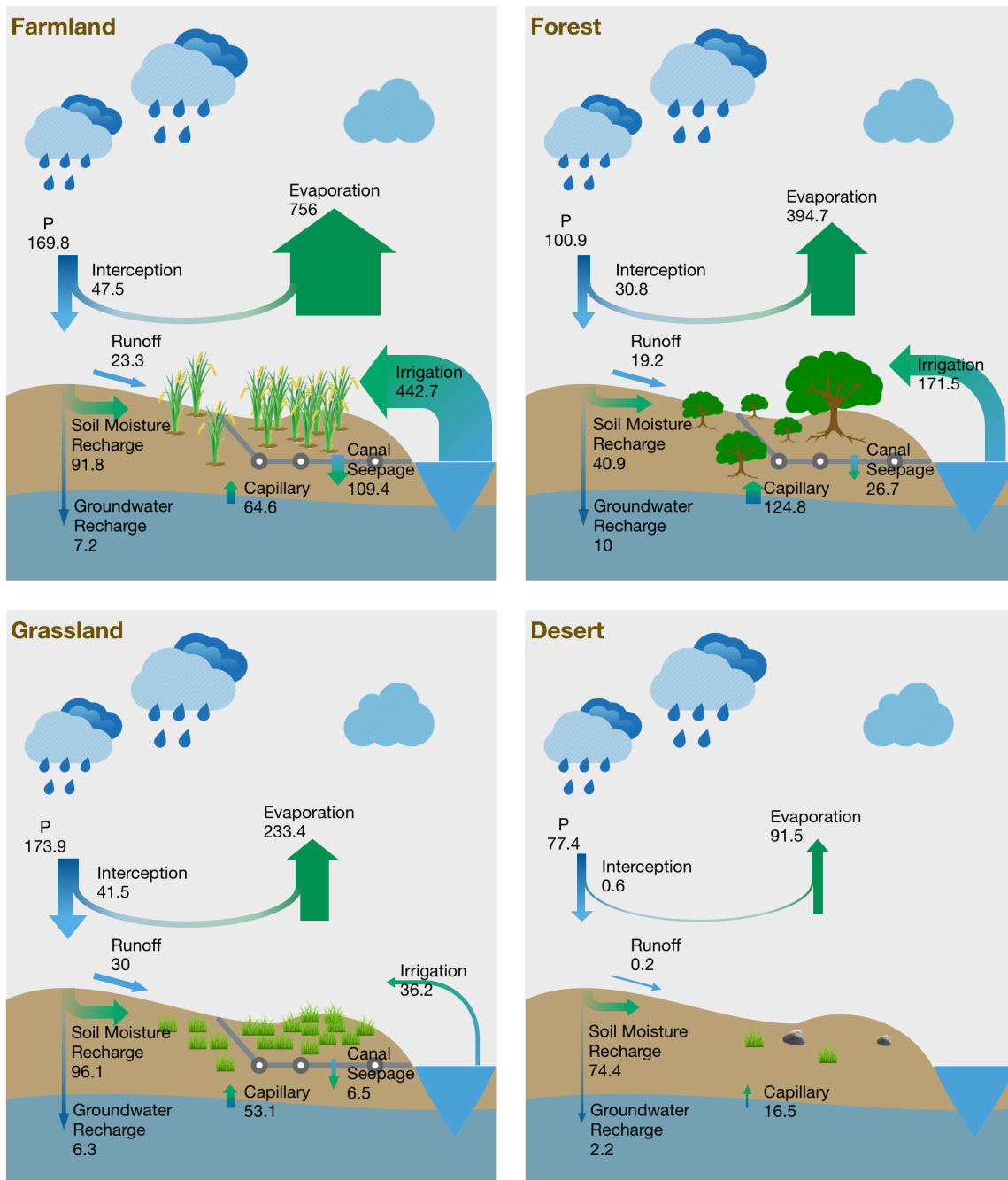
We have inserted the following sentences before “The GWC for farmland ...”.

Inserted sentences “Eventhough interception is accounted as green water, it is still separated from total evaporation. As it is directly evaporate back to the atmosphere from leaves and does not go into the soil. The interception for farmland, forest, grassland and desert are 47.5 mm/year, 30.8 mm/year, 41.5 mm/year and 0.6 mm/year, respectively. The irrigation is not intercepted due to the reason that flood and furrow irrigation are still the main irrigation modes in HRB during our research period (Zhou et al., 2015). There is also interception in desert area, since some regions are covered by desert vegetation that is considered in our model.”

Minor Comments

I think that the last paragraph of the conclusion would be better placed in the discussion section.

I think that one publication on the Heihe is missing, which is the paper by Gao et al. (2014), which studied the runoff of the Upper Heihe river basin and providing the input to the middle HRB, see: Gao, H., Hrachowitz, M., Fenicia, F., Gharari, S., and Savenije, H. H. G.: Testing the realism of a topography-driven model (flex-topo) in the nested catchments of the upper heihe, china, *Hydrology and Earth System Sciences*, 18, 1895-1915, 10.5194/hess-18-1895-2014, 2014.



updated Figure 6. Explicit green and blue water assessment for different ecosystems at an annual scale. The data is summed up from all the pixels that from a certain ecosystem and then converted into equivalent water thickness. The unit is mm/year for all of these four plots. Blue arrows indicate the blue water flows and green arrows stands for green water flows. Arrows with a gradient transition from blue to green stands for the transformation of blue water to green water. The size of the arrow reflects the magnitude of water flows.

Answer

Thank you for the suggestion. We have moved the last paragraph of the conclusions into the end of discussion section. '

Thank you for the nice paper which is related to the runoff generation in Upper Heihe river basin that providing streamflow for middle and lower HRB. We have cited the suggested relevant paper in our work in Page 8, Line 15.

Author's changes in manuscript

Page 13, Line 19.

The complete paragraph "However, for this study there are a few shortcomings. First, ..." has been deleted.

Page 12, Line 18.

A paragraph is inserted after the sentence "... that aims to balance the water use between human and nature."

Inserted paragraph "However, for this study there are a few shortcomings. First, the current work omitted the industry and domestic water uses due to the lack of data. Even though it did not much influence the interactions between green and blue water, the calculation of water consumption for human is slightly affected thus causing a small impact on the investigation of water consumption dynamics between human and nature. Second, the results are simulated with one model. Although the model has been calibrated and validated in several previous studies in the same region (Li et al., 2017, 2018, Tian et al., 2015a, 2015b), simulations may be constrained by the fundamental assumption and approaches used in this model. Third, this study is only a fundamental investigation on water resources. It shows the natural ecosystems may take a higher pressure when the water competition between human and nature increases, which provides implications for water management under the changing environment. Further research is needed in the future to quantify the potential risk each grid cell or different ecosystems may take. Thus, the hotspot area that may suffer higher risk on water use can be identified. This would make the research more practical and meaningful."

Page 8, Line 15.

A paper is cited here in the end of the sentence. "... additional water from upstream (upper HRB) is also crucial for the ecosystems in this region (Gao et al., 2014)."

Some small corrections:

page 5 line8, do you mean by "grids"

We are not sure if the question is "what do you mean by grids?", If so, the answer would be: "grids here is more or less like the pixels, in this study it represents the hydrologic response units (HRU) in the model"

page 5 line18, what is improved in the GSFLOW model?

One of the key improvement is the explicit consideration of irrigation, water diversion and groundwater pumping (Page 5, Line 4 in the manuscript).

page 8 line 3, "Which means...", please merge the two sentences.

Thank you for the suggestion, we have modified the sentence as following.

original: "It is important to point out that the total green water consumption (12.41 billion m^3 /year) is 67% higher than the original green water storage (7.4 billion m^3 /year). Which means a large amount of additional water resources is needed for this region and transformed into green water resources to meet the consumption."

updated: "It is important to point out that the total green water consumption (12.41 billion m^3 /year) is 67% higher than the original green water storage (7.4 billion m^3 /year), implying that a large amount of additional water resources is needed for this region and transformed into green water resources to meet the consumption."

page 8 line 33, in some regions, ...

It has been modified.

original: "In some region, ..."

updated: "In some regions, ..."

page 9 line 4, "The blue water map is not shown here..."

It has been modified.

original: "The blue water map is not show here..."

updated: "The blue water map is not shown here..."

page 9 line 15, "which supports the ecosystems and bridges the gap between..."

It has been modified.

original: "which support the ecosystems and bridges the gaps between..."

updated: "which supports the ecosystems and bridges the gap between..."

page 9 line 29, "water availability is the main..."

It has been modified.

original: "water availability is main..."

updated: "water availability is the main..."

page 10 Section 3.3 what do you mean by "explicit"?

“explicit” here refers to a detailed and clear investigation on green and blue water. To avoid the confusion, we have updated the section 3.3 to “Green and blue water analysis for different ecosystems”

page 10 line 18, ”all the precipitation”, precipitation is uncountable.

It has been modified.

original: “... and nearly all the precipitations fall in desert are store in the soil rather than runoff.”

updated: “... and precipitations fall in desert are mainly stored in the soil rather than runoff.”

page 10 line 29. ”the forest also received 171.5 mm/year irrigated water...” this is very interesting conclusion. Please clarify how forest is irrigated. Is this really happening in the entire basin or only in urban and agricultural areas?

In our study, irrigation also happens in the forest area in the middle and lower HRB due to two reasons. First, Chinese government launched water use policy since the late 1990s to protect the environment in the middle and lower HRB, especially for conserving *populus euphratica*, a typical plant in HRB. (Sun et al., 2016; Zhang et al., 2015). Thus, a part of water in HRB will be used to irrigate the forest (Nian et al., 2014). Second, there are also forests located in the irrigation districts in middle HRB (Li et al., 2018). They received the irrigated water resources from the irrigation system.

We have insert this clarification of irrigation in forest into the manuscript in Page 10, Line 31 after the sentence “... of grassland compared to forest (see Section 2.1)”.

page 10 line 33. ”there are quite amount of water are ...” this sentence should be rephrased.

It has been modified.

original: “Moreover, because of the irrigation system, there are quite amount of water are leaked from the irrigation canal, i.e. the canal seepage.”

updated: “Moreover, there are quite amount of water are leaked from the irrigation canal, i.e. the canal seepage.”

page 13, line 7 it is better to say ”for the first time...interconnections in the HRB”.

Thank you for the suggestion. It has been changed accordingly.

original: “This study for the first time assesses the water resources by considering not only the blue and green water but also their interconnections.”

updated: “This study for the first time assesses the water resources by considering not only the blue and green water but also their interconnections in the HRB.”

page 13, line 10 ”beyond the water balance”. I am not quite convinced with this conclusion. It seems to be still in the framework of water balance.

Thank you for the comment. We agree with the referee and change the statement accordingly to “beyond the simple flow in and out framework.” The supportive information for this conclusion is followed.

In this work, in addition to analysis the flow of green and blue water in and out of the HRB, i.e. the simple flow in and out framework, we revealed the interconnection between the green and blue water. In our research domain, the received green and blue water and consumed green and blue water are not balanced. We investigated not only how much of green and blue water flow in and flow out of the domain, but also how green and blue water transformed between each other to match the imbalanced green and blue water flow regime.

References

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