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Hydrology and Earth System Sciences
Discussions

Interactive comment on "An improved method for calculating regional crop water footprint based on hydrological process analysis" *by* Xiao-Bo Luan et al.

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<Manuscript number: HESS-2018-125> Dear Editors and Reviewers: Thank you for your letter and for the reviewers' comments concerning our manuscript "An improved method for calculating regional crop water footprint based on hydrological process analysis". We appreciate your comments and constructive suggestions very much, and they were valuable for improving the quality of our manuscript. We have revised the manuscript in detail according to the editor and reviewers' comments. We hope that these modifications, based on your suggestions and the reviewers' comments, will raise the quality of our manuscript to meet the publication standards of Hydrology and

Earth System Sciences. The revised portions are marked in red in the paper. The main corrections in the paper and the responses to the reviewer's comments are as follows:

Anonymous Referee #1

In this manuscript the authors enhance the Water Footprint method to a regional scale. For that purpose, the water losses in the irrigation water distribution system are included into the WF (blue water). A procedure for the quantification of water losses in the canal system is introduced. The topic addressed in this manuscript is relevant and has certain novelty for the water footprint assessment. Nevertheless, several minor and major aspects need to be improved. The overall calculation approach needs to be checked, since some calculation steps are contradictory to the common water footprint method. The grammar is very poor throughout the whole paper and has to be improved. Response: Thank you for your recognition of the innovation of the paper. In the revised manuscript, we describe the difference of the calculation method of water footprint between this study and the traditional method, as well as the innovation of this study. At the same time, we improve the language of the thesis (The paper was edited by Elsevier Language Editing Services).

General comments: 1. Comment: Water loss from the canal system and application on the fields is calculated as water consumption. This is not correct, because leached water recharges the local groundwater aquifers and, thus, contributes to the water availability. In that term, it is not consumed. Therefore, water consumption equals the actual evapotranspiration (for the agricultural production), while water losses (leaching from the fields) is subtracted from the water used for the irrigation. Therefore, I do not understand why you calculate it as water footprint. I can understand if you state that water is recharged in another aquifer, however the groundwater aquifers are connected. Please consider that issue with the water losses and the spatial aspect of water losses. The second scenario is not plausible, because, as stated later on in this paper, 75% of the water input comes from the irrigation, that is why this is not a red-fed agriculture and stopping all irrigation will lead to a total yield loss. Therefore, this scenario cannot exist in reality. If you want to develop a scenario, please consider, for example, deficit irrigation. Nevertheless, I do not see the necessity of the second scenario for your paper. The methodology for calculating WF on the field level (so, for the rain-fed agriculture) already exists and is broadly applied. Therefore, there is no novelty in your approach concerning that aspect. Furthermore, the results of the second scenario are missing in the section Results. Response: During the agricultural production process, especially in irrigated agriculture, the use of water by crops has undergone the following processes: first, water is diverted from the water source (river, lake or groundwater) and then transported to the field through irrigation canals or water pipelines, where crops are irrigated through various irrigation methods. In the process of water diversion, part of the water will be lost, one is the evaporation and leakage in the canal or pipeline, the other is the evapotranspiration, runoff and leakage in the field irrigation. These losses are paid to make sure the crop production. In this study, the loss of irrigation water in the course of water transportation was included in the calculation of the water footprint of crop production. The water lost in the process of irrigation water transportation is contained in the local planned water intake, which leads to the local water diversion being higher than the actual net irrigation amount of the crop. At the same time, the water distribution facility needs to be built during the transportation process, which consumes a large amount of labor, capital and technology. Therefore, from the perspective of agricultural water management, the loss of irrigation water should also be included in the calculation of the water footprint of crop production. In addition, although the water lost in the canal system and the field leakage can be redeveloped and utilized, it also needs to consume a large number of labor, capital and technology. Meanwhile, the redeveloped water can be considered as an additional source of new irrigation water, and local water use plans need to be adjusted, which can also affect local water resources management. Therefore, for agricultural production, the water consumption in crop production is calculated based on the crop water consumption, and the above-mentioned loss of crop-related water is calculated, which is conducive to the local water management department to allocate and

manage the regional water resources. In this study, the Scenario 2 was set to calculate the consumption of green water. In this study area (HID), because of less rainfall, the effective precipitation formed by precipitation is all used for crop growth. Therefore, the consumption of green water for crops is equal to the effective precipitation, which means that green water is reflected by calculating the effective precipitation stored in soil by SWAT model. We modified the formula, as follows: (6) Where Wg is the green water consumption during the crop growth period (m3), PRECIPs2 is the precipitation during the crop growth period in Scenario 2 (m3), SUPQs2 is the surface runoff during the crop growth period in Scenario 2 (m3), LATQs2 is the soil lateral flow during the crop growth period in Scenario 2 (m3).

2. Comment: Regarding the term ET, it would be good to distinguish between the potential and actual ET. I would appreciate if you specify it in the text. Response: Thank you for your comment. We have modified the description in the revised manuscript as your suggestion. The modified parts are as follows: The first is the crop water requirement method. This method simulates the actual evapotranspiration (ET) of crops under optimal conditions with the potential ET calculated by the Penman-Monteith Equation (Allen et al., 1998). (Page 4, line 74, 75.) The green water consumption is the smaller value of total crop actual ET and effective precipitation. The blue water consumption is obtained through the difference between the total crops actual ET and effective precipitation. (Page 4, line 76-79.) These methods can simulate actual ET throughout the crop growing period according to the soil water balance under optimal or suboptimal conditions. (Page 5, line 96.) The green water consumption is equal to the total actual ET minus blue water. (Page 5, line 99.)

3. Comment: I would appreciate if you also address the importance of efficiency of the water distribution systems in the Discussion Response: Thank you for your suggestion. We have added the importance of efficiency of the water distribution systems in the Discussion section. The modified parts are as follows: Page 24, line 445-452. 4.4 The influence on efficiency of irrigation system The efficiency of irrigation system is

affected by the way of water transportation, the condition of canal system, the irrigation technology and so on. Therefore, the water use efficiency of the regional irrigation system can be improved by changing the water delivery method (from the channel to the pipeline) and the irrigation method (such as dropper, sprinkler and other advanced irrigation technologies). For the study area, the results show that more than half of the water resources were lost during the process of canal water transport and irrigation. Therefore, the use of anti-seepage measures to reduce the leakage of canal systems, while the use of advanced irrigation technology to reduce the amount of irrigation water is conducive to reduce the water footprint of crop production of the region.

4. Comment: Please improve the grammar throughout the whole paper. Your sentences are sometimes built in a strange way and are difficult to understand. I recommend to ask a native speaker to review the paper. Response: Thank you for your suggestion. We have carefully revised the language of the paper and invited native speaker to polish the manuscript (The paper was edited by Elsevier Language Editing Services).

Specific comments and technical corrections: 1. Comment: L21: effectively managing -> effectively manage. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 2, line 21. With the shortage of water resources, assessing the water use efficiency is crucial to effectively manage agricultural water resources.

2. Comment: L22: It is not correct to state that WF is a new method; it is used in the scientific community since decades. I would recommend deleting this statement. Abstract: please address that you are quantifying the WF in terms of blue and green water, because there are other methods, for example impact assessment using the AWARE, WSI and WAVE models, but also the grey water footprint. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 2, line 22. The water footprint is an improved index for water use evaluation, and it can reflect the quantity and types of

water usage during crop growth. This study aims to establish a method for calculating the region-scale water footprint of crop production based on hydrological processes, and the water footprint is quantified in terms of blue and green water.

3. Comment: L26: do you mean with the term “underground water”? Groundwater use? Please use another term. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 2, line 26. This method analyzes the water-use process during the growth of crops, which includes irrigation, precipitation, groundwater, evapotranspiration, and drainage, and it ensures a more credible evaluation of water use.

4. Comment: L34: further -> further away. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 2, line 35. The spatial distribution pattern of the green, blue and total water footprint for the three crops demonstrated that higher values occurred in the eastern part of the HID, which had more precipitation and was further away from the irrigating gate.

5. Comment: L44: to ensuring -> to ensure. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 3, line 45. In China, 63% of all water is used for agricultural production each year, and the area of irrigated farmland is 39.6% of the total arable land. Irrigation is the key to ensure agricultural production (NBSC, 2016).

6. Comment: L54: utilization of crop production -> for crop production. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 3, line 55. Strengthening agricultural water management and improving water use efficiency are significant aspects of handling water scarcity, and a reasonable evaluation of the water resource for crop production is the premise for developing an agricultural water management plan and implementing water saving measures.

7. Comment: L57: What do you mean with “reduce the negative impact of the reduction of available agricultural water”? Please check and correct this sentence. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The modified parts are as follows: Page 3, line 57. Therefore, how to precisely evaluate the effective utilization ratio of current agricultural water use, improve the utilization efficiency, and reduce the negative impact of the reduction of available agricultural water on agricultural production, is an important issue that all countries need to address globally, this is also of vital importance for ensuring food production and reducing the pressure on water resources.

8. Comment: L58: Globally -> globally. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 3, line 59. Therefore, how to precisely evaluate the effective utilization ratio of current agricultural water use, improve the utilization efficiency, and reduce the negative impact of the reduction of available agricultural water on agricultural production, is an important issue that all countries need to address globally, this is also of vital importance for ensuring food production and reducing the pressure on water resources.

9. Comment: L62: Please address and explain here the terms green, blue and grey water instead of the term “types of resources”. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The modified parts are as follows: Page 4, line 63. It reflects the amount of water, the green, blue and grey water that are consumed (Hoekstra, 2011).

10. Comment: L72: This data is not necessarily provided by USDA, it is available in other sources. Of course, you used this data source for your case study, but here it is better to delete the reference to the USDA. Response: Thank you for your comments. We have modified this reference in the revised manuscript as suggested. The modified parts are as follows: Page 4, line 76. This method simulates the evapotranspiration (ET) of crops under optimal conditions with the ET calculated by the Penman-Monteith

Equation (Allen et al., 1998) and the effective precipitation calculation method refer to Doll and Siebert (2002). Reference: Doll, P., Siebert, S. (2002). Global modeling of irrigation water requirements. Water Resources Research, 38(4):1037-1048.

11. Comment: L76: Please indicate, that the WF is calculated per kg or ton of crop. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The modified parts are as follows: Page 4, line 79. Finally, when combined with crop yields, the crop blue and green water footprint (m3/t) can be calculated.

12. Comment: L68-81 – please insert the equations for the calculation of green and blue WF. Response: Thank you for your comments. We have added the equations in the revised manuscript as suggested. The equation (2) is the crop water requirement method, the equation (3) is the irrigation schedule method. The modified parts are as follows: Page 5, line 83-95. These two methods formulas are as follow, the equation (2) is the crop water requirement method, and the equation (3) is the irrigation schedule method. (1) (2) (3) where CWUgreen is the green component in crop water use, CWUblue is the blue component in crop water use, ETgreen is the green water evapotranspired, ETblue is the blue water evapotranspired, Y is the crop yield, ETc is the crop evapotranspiration, Peff is the eïňĂective rainfall, Kc is the crop coefficient, ET0 is the reference evapotranspiration, IRRt is the total net irrigation, IRRa is the actual irrigation requirement, ETa is the adjusted crop evapotranspiration, Ks is the soil water stress coefficient, describes the eïňĂect of water stress on crop transpiration, For soil water limiting conditions, Ks < 1; when there is no soil water stress, Ks = 1. These equations are based on CROPWAT model.

13. Comment: L80 – Please explain the terms net irrigation water and the actual irrigation water requirement. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The Net irrigation water is the amount of water actually irrigated to the field. The net irrigation water requirement is the actual irrigation amount needed in the field. The modified parts are

as follows: Page 5, line 97, 98. The blue water consumption is the smaller value of net irrigation water and the net irrigation water requirement.

14. Comment: L89: I agree that the existing methods do not consider the water losses in canals, but the water leached from the fields (if I correctly understand the term “drainage water”) is actually considered. Therefore, please revise this statement. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The modified parts are as follows: Page 6, line 105-107. These methods calculated the field-scale water footprint with net irrigation water considered as irrigation water, and without considering water loss during transport, which definitely serve for crop growth.

15. Comment: L95: The term “irrigation quota” is not clear. Do you mean the irrigation demand? Please add the definition and probably also use another term throughout the whole paper. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The irrigation quota is the irrigation demand. The modified parts are as follows: Page 6, line 114. Second, the irrigation data in these methods are simulation values and not based on the actual irrigation time and irrigation quota (the amount of water demanded for crop irrigation);

16. Comment: L96: I would not define it as incorrect, rather not complete. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The modified parts are as follows: Page 6, line 115. Therefore, these data cannot reflect the real situation of the local water usage due to the incomplete simulation data.

17. Comment: L97: that is not true, precipitation and irrigation water are distinguished, that is why it is possible to distinguish between the green and blue water. The irrigation water is calculated as the amount of water to meet the part of the crop water requirement, which cannot be fulfilled by the precipitation. Concerning the groundwater, you are correct: surface water and groundwater are evaluated together for the blue water

calculation. Response: Thank you for your comments. This description is indeed inaccurate. According to your suggestion, we have deleted this sentence. The modified parts are as follows: Page 6, line 116, 117. The traditional method does not completely analyse the water footprint components of water resources in the process of water diversion, water transfer, irrigation and drainage.

18. Comment: L99-101: it is not clear how it is different from the other limitations you mentioned above. Response: Thank you for your comments. We have modified this sentence in the revised manuscript as suggested. The modified parts are as follows: Page 6, line 118, 119. The method that Sun et al. (2013b) used also had these limitations which mentioned above.

19. Comment: L106-107 – this a repetition. Response: Thank you for your comments. According to your suggestion, we have deleted this sentence.

20. Comment: L109 – 115 – the sentences are too long and difficult to understand. Please rewrite this section. Response: Thank you for your comments. We have modified these sentences in the revised manuscript as suggested. The modified parts are as follows: Page 7, line 126-133. This method simulated the hydrological cycle of the region based on a physical hydrological model (SWAT). Based on the method, this study analyzed the water input and output during crop production, and calculated the water consumption in crop growth, field drainage and water loss during canal water transport. Combined with crop yields, the water footprint of crop production at the regional scale was quantified. This method will provide comprehensive information for the analysis of water consumption during crop production process and improve the spatial resolution of the regional distribution of water footprint of crop production.

21. Comment: L121-122: Since it has monsoon climate, the annual average values for precipitation and ET do not provide any valuable data. Consider providing average values for the dry season and monsoon season. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The

modified parts are as follows: Page 7, line 139-141. The average monthly precipitation is 37.5 mm (May to September), 3.4 mm (October to next year April), and the average monthly potential evaporation is 290.6 mm (April to September), 77.2 mm (October to next year March).

22. Comment: Fig 1: Please use another word for the areas (Dengkou etc), e.g. districts in the legend, because the term "country" is misleading. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The Hetao Irrigation District mainly consists of 5 counties, namely, Dengkou, Hangjinhouqi, Linhe, Wuyuan, and Wulateqianqi. The modified parts are as follows: Page 8, line 147.

Fig. 1. Location of the Hetao Irrigation District (HID) in China

23. Comment: L125: Could you please explain more the differences between canals and ditches? Response: Thank you for your comments. The canal is the engineering measure that the water is transported from the water source to the field. The drainage ditch is the engineering measure to guide the surplus water from the field into the river or lake.

24. Comment: L170-172: I do not see a benefit of writing the formulas 2, 3 and 4 into the text. I recommend deleting them. Response: Thank you for your comments. According to your suggestion, we have deleted these formulas (R2, NSE, and PBIAS).

25. Comment: L175-176: The explanation of the R2 is not needed, since it is a very common parameter in statistics. Response: Thank you for your comments. According to your suggestion, we have deleted the explanation of the R2.

26. Comment: L166-189: This section includes information on the uncertainty analysis, which is a bit confusing. It distracts the reader from the actual content of the paper. It will be better to put this data into the supplementary material and only mention that the results are satisfactory. Response: Thank you for your comments. According to your

suggestion, we have put this data into the supplementary material.

27. Comment: L203: What exactly do you mean with the term "irrigation water in the fields"? Surface water from the irrigation channels? Please use another term, otherwise it is not clear what you mean. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 11, line 201. In scenario 1 (S1), crop water consumption was derived from precipitation and irrigation water (irrigation systems and irrigation quotas are based on local irrigation methods), i.e., the actual situation of crop water use.

28. Comment: L205: I do not understand how this scenario should work in reality. If the fields are irrigated, this means, that there is not enough precipitation to meet the crop water requirement. That would mean that in your scenario 2 the crops do not have enough water. So, do you also consider the yield loss? Because you cannot get the same yield under such different conditions. Response: In this study, the Scenario 2 was set to calculate the consumption of green water. In this study area (HID), because of less rainfall, the effective precipitation formed by precipitation is all used for crop growth. Therefore, the consumption of green water for crops is equal to the effective precipitation, which means that green water is reflected by calculating the effective precipitation stored in soil by SWAT model. We modified the formula, as follows:

Where Wg is the green water consumption during the crop growth period (m3), PRECIPs2 is the precipitation during the crop growth period in Scenario 2 (m3), SUPQs2 is the surface runoff during the crop growth period in Scenario 2 (m3), LATQs2 is the soil lateral flow during the crop growth period in Scenario 2 (m3).

29. Comment: Equations 5-9 – please check the formatting. Eq.5 – this equation is obvious, you can describe it in the text (total WF is the sum of the green and blue WF), but you don't need an equation for that. Eq. 6- please provide more explanation. It is not clear why the groundwater, which raises to the soil plow layer, is included into the green WF calculation. Eq.7: Qd – same as for the water loss in the canal – this is not a

loss because the water recharges the GW aquifer, so actually the equation should be Qf-Qd. Again, including Qg into the water consumption is not clear. Response: Thank you for your comments. We have modified these formulas in the revised manuscript as suggested. In this study, the field discharge (Qd) flow out of the Hetao irrigation district, those water could not been used again, so, the field discharge (Qd) is a part of blue water consumption. The modified parts are as follows: Page 12, 13, line 209-226. (5) (6) (7) (8) (9) (10) where WF is the water footprint of crop production (m3/t), WFg is the green footprint (m3/t), WFb is the blue water footprint (m3/t), Wg is the green water consumption during the crop growth period (m3), Wb is the blue water consumption during the crop growth period (m3), Y is the crop yield (t), PRECIPs2 is the precipitation during the crop growth period in Scenario 2 (m3), SUPQs2 is the surface runoff during the crop growth period in Scenario 2 (m3), LATQs2 is the soil lateral flow during the crop growth period in Scenario 2 (m3), Qc is the amount of water loss in the canal system (m3), Qf is the actual ET of field irrigation water (m3), Qd is the field discharge (m3), It,s1 is the amount of total irrigation water diversion in Scenario 1 (m3), and If,s1 is the actual amount of water irrigated in the field in Scenario 1 (m3). ks1 is the effective utilization coefficient of canal water in Scenario 1 (Obtained from the local Water resources management department), ETs1 is the crop actual ET during the crop growth period in Scenario 1 (m3), WYLDs1 is the total amount of water leaving the HRU in Scenario 1 (m3). The data of parameters PRECIPs2, SUPQs2, LATQs2, It,s1, ETs1, WYLDs1 were obtained from the SWAT model.

30. Comment: Fig4 – please include explanation of Acronyms and indices into the name of the table. Could you also show the part A and part B on the figure? Response: Thank you for your comments. We have added explanation of acronyms and indices in the revised manuscript as suggested. The figure of Part A and Part B are the intermediate process of the calculation process. We input the data of Part A and Part B into ArcGIS to obtain figure a and figure b, then add the two pictures to obtain the figure of final result, which is Figure 6(Canal water loss). Because the two figures are intermediate process figure, it could not been displayed in the paper. The modified

parts are as follows: Page 15, 16, line 272-280.

Fig. 4. Model for calculation of water loss in canal system Note: Sjn is the area of each sections in the jth main canal, Wjn is the water loss per unit area of the section of the jth main canal in Part A, Qji is the actual amount of water loss per unit area of the i section of the jth main canal, Sj is the area controlled by the jth main canal, kj is the coefficient of the water distribution from the general main canal to the jth main canal, Qj is the water loss per unit area of the jth main canal in Part B, kgc is the water conveyance efficiency of the general main canal, kmc is the water conveyance efficiency of the main canal, j is the number of the main canal, i is the number of the equidistance sections in the jth main canal.

31. Comment: Eq. 10-15 – check formatting of the numeration of the equations. It is difficult to follow the equations. It would help to understand, if you split them into calculation for the part A and part B and include the explanations of the indices directly after each equation. More description of the whole calculation path is needed to follow the calculation procedure. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 13-15, line 228-271 Water transfer loss is a kind of water loss in the process of channel water delivery, and it is an important part of blue water consumption in crop production. For a piece of cultivated land, the water loss during the process of the crop production includes the loss of water from the water source to the field flowing through the canal system. In the Hetao Irrigation District, irrigation canal is composed of seven grades (general main canal, main canal, sub-main canal, branch canals, lateral canals, field canals, and sub-lateral canals). Because of the complex distribution of canal system and the lack of hydrological data in irrigation districts (the lack of effective utilization coefficient of canal water below the main canal). Therefore, in calculating the water loss of canal system during crop production process, we generalized Hetao Irrigation District into a model similar to the histogram (Fig. 4). We divide the total water loss of canal system into two parts. Part A is the loss of the main canal and canal,

and Part B is the loss of the remaining canal system (the water loss of the sub-main canal and its sub-channels at all levels). The calculation of water loss in part A is as follows: first, the water loss of each section is calculated by dividing the main canal into equal distances (10 km). Then the water transfer loss of each section of the canal is allocated to each field downstream [Equation 10], thereby obtaining the water transfer loss in the crop production process on the field block. Therefore, the actual water loss caused by irrigation in a field is the sum of the water loss of the transfer canal and the canal in the upstream. We assign the actual water loss of the field by irrigation (Qji, formula 11) to the midpoint of the each section, and use Kriging interpolation in ArcGIS to obtain the water loss distribution map of the figure a (Part A). Due to the lack of the effective utilization coefficient of canal water and the distribution map of the canals at all levels and below, the calculation process of the water loss in Part B is as follows: the remaining canal loss in each irrigation canal is divided by the main canal irrigation and the unit area loss of the canal control area is obtained. Then, the amount of water loss per unit area within the control range of each main canal in the irrigation area (Qj, formula 15) is obtained, and the data is brought into ArcGIS for the water loss distribution map of figure b (Part B). Finally, the figure a and the figure b are superimposed and calculated in the ArcGIS using the map algebra module of the spatial analysis tool to obtain the water loss distribution map of the canal system in HID.The formulas are as follows: (11) (12) (13) (14) (15) (16) where Qji is the actual amount of water loss per unit area of the i section of the jth main canal in Part A(m3/ha), Wjn is the water loss per unit area of the section of the jth main canal in Part A (m3/ha), j is the number of the main canal, i is the number of the equidistance sections in the jth main canal, n is the total number of the sections in the jth main canal, m is the total number of the main canals, WA is the amount of water loss in Part A (m3), kj is the coefficient of the water distribution from the general main canal to the jth main canal, Sjn is the area of each sections in the jth main canal (ha), It,s1 is the amount of total irrigation water diversion in Scenario 1(m3), kgc is the water conveyance efficiency of the general main canal, kmc is the water conveyance efficiency of the main canal, Sj is the area controlled by

the jth main canal (ha), Qj is the water loss per unit area of the jth main canal in Part B (m3/ha), WB is the amount of water loss in Part B (m3), and Qc is the amount of water loss in the canal system (m3).

32. Comment: L253: Do you mean “sections”? Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 15, line 264. i is the number of the equidistance sections of the jth main canal.

33. Comment: L255: Qn is the actual amount.... Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 15, line 262. Qji is the actual amount of water loss per unit area of the ith section of the jth main canal in Part A (m3/ha).

34. Comment: L270: I do not understand for which parameters these rates are. Precipitation, irrigation on field and canal loss? Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 16, line 289-293. Precipitation and irrigation are the water input items in the process of crop production, and the canal water loss, field actual ET and field drainage are the water output items. For water input, precipitation and irrigation accounted for 25.1% and 74.9%, respectively. For water output, channel water loss, field actual ET and field drainage accounted for 47.9%, 41.8% and 10.3%, respectively.

35. Comment: L290: Since you didn’t consider the groundwater irrigation, please indicate here, that the blue WF includes only the surface water irrigation. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 17, line 313. Blue water is the surface water used for crop growth in this study.

36. Comment: L299-300: I do not see this correlation in your results. Actually, there is rather more field discharge by larger ET, if I understand your figures correctly. Please

check this data. It is also interesting whether there are same irrigation techniques applied on the whole study area. Because water loss on the field depends on the irrigation method applied. Please address this aspect. Response: For the field, actual ET and drainage are the mainly water output items. So the ET increase will lead to the decrease of the field drainage when the amount of water in the field soil is certain. In this study, due to the large area of irrigation areas, and farmland were planted by a large number of farmers, its irrigation time, irrigation water will have some differences. In order to reduce the complexity of the study, irrigation time and irrigation water were set to the same parameters in the entire Hetao irrigation district in the SWAT model.

37. Comment: L302: This sentence is a repetition, please delete. Response: Thank you for your comments. We have deleted this sentence in the revised manuscript as suggested.

38. Comment: L322-325 and L310-311: These statements are obvious, because these three crops have different crop water requirement. Please consider deleting these sentences. Response: Thank you for your comments. We have deleted these sentences in the revised manuscript as suggested.

39. Comment: L345: Do you mean "water footprints on the regional scale and field scale"? Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 20, line 365. The region scale and field-scale methods for calculating crop production water footprints

40. Comment: L346: Method for. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 20, line 366. In this paper, the calculation method for calculating crop production water footprints is divided into the field scale and region scale.

41. Comment: L350-353: I understand what you want to say, but this sentence is misleading, because you firstly states, that the studies are on national, regional etc scale,

but then says that the studies are on the field scale. Please change the rephrase to make it more understandable. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 4, line 69-73. Many scholars have quantified various levels of crop production water footprints, such as a global level (Mekonnen and Hoekstra, 2011), a national level, such as Europe (Vanham and Bidoglio, 2013) and China (Zhao, 2009), and a regional level, such as Beijing (Sun, 2013a), Cremona province (Bocchiola, 2015) and Hetao (Luan et al., 2018).

42. Comment: L350-362: There is too much text explaining the methods. I recommend deleting Response: Thank you for your comments. We have inserted these sentences into the introduction in the revised manuscript as suggested in comment 43. The modified parts are as follows: Page 4, 5, line 73-83. The first is the crop water requirement method (Cao et al., 2014; Sun et al., 2013c). This method simulates the actual evapotranspiration (ET) of crops under optimal conditions with the potential ET calculated by the Penman-Monteith Equation (Allen et al., 1998) and the effective precipitation calculation refer to Doll and Siebert (2002). The green water consumption is the smaller value of total crop actual ET and effective precipitation. The blue water consumption is obtained through the difference between the total crops actual ET and effective precipitation. Finally, when combined with crop yields, the crop blue and green water footprint (m3/t) can be calculated. The second is the irrigation schedule method. This method is based on an empirical formula model such as the CROPWAT model (FAO, 2010; Mekonnen and Hoekstra, 2011) CropSyst (Bocchiola et al., 2013), the EPIC model (Williams et al., 1989; Shi et al., 2017), the GEPIC model (Liu et al., 2007), and the AQUACROP model (Pasquale et al., 2009; Chukalla, 2015; Zhuo, 2016).

43. Comment: L353-360 or insert them into the introduction and refer to it here. Response: Thank you for your comments. We have insert these sentences into the introduction in the revised manuscript as suggested The modified parts are as follows: Page 4, 5, line 69-83. Currently, based on two mainly methods proposed by Hoekstra

et al. (2011), many scholars have quantified various levels of crop production water footprints, such as a global level (Mekonnen and Hoekstra, 2011), a national level, such as Europe (Vanham and Bidoglio, 2013) and China (Zhao, 2009), and a regional level, such as Beijing (Sun, 2013a), Cremona province (Bocchiola, 2015) and Hetao (Luan et al., 2018). The is the crop water requirement method (Cao et al., 2014; Sun et al., 2013c). This method simulates the actual evapotranspiration (ET) of crops under optimal conditions with the potential ET calculated by the Penman-Monteith Equation (Allen et al., 1998) and the effective precipitation calculation refer to Doll and Siebert (2002). The green water consumption is the smaller value of total crop actual ET and effective precipitation. The blue water consumption is obtained through the difference between the total crops actual ET and effective precipitation. Finally, when combined with crop yields, the crop blue and green water footprint (m3/t) can be calculated. The second is the irrigation schedule method. This method is based on an empirical formula model such as the CROPWAT model (FAO, 2010; Mekonnen and Hoekstra, 2011) CropSyst (Bocchiola et al., 2013), the EPIC model (Williams et al., 1989; Shi et al., 2017), the GEPIC model (Liu et al., 2007), and the AQUACROP model (Pasquale et al., 2009; Chukalla, 2015; Zhuo, 2016).

44. Comment: L366-370 –This text is not needed, please delete it. Generally, I do not see the necessity of the section 4.1. It better fits for the introduction. Fig10: I did not find any reference to this figure in the text. Response: Thank you for your comments. We have deleted these sentences in the revised manuscript as suggested and have added the reference of Fig. 10. The modified parts are as follows: Page 20, 21, line 373,374. Fig. 10 is the calculation range of the regional scale and field scale method of crop production water footprint.

45. Comment: L379: What do you mean with applicable conditions? Response: Thank you for your comments. We have modified this description in the revised manuscript. The applicable condition is the calculation boundary of the two methods. The modified parts are as follows: Page 21, line 387-389. The calculation boundary of the two

methods of calculating water footprints are different, the calculation of the green water footprint is the same, whereas the calculations of the blue water footprint are different.

46. Comment: L383: what do you mean by stating that the rain-fed agriculture depends on groundwater? If it is rain-fed, it is not irrigated. Thus, groundwater is not used. If you mean the moisture, which is stored in the soil and used by the plants, it is the green water and not the blue water. Please revise this sentence. Response: Thank you for your comments. We have modified this description in the revised manuscript as suggested. The modified parts are as follows: Page 21, line 389-391. The rainfed agriculture depends on precipitation (green water), and the water consumption mainly includes actual ET.

47. Comment: L429-433: You state that the method you developed also applies for the rain-fed agriculture. This is correct, because then you just exclude the irrigation parameter from the SWAT model. Nevertheless, this is a commonly used method and I do not see any novelty of your method here. For this reason, I recommend to delete this section. Response: Thank you for your comments. We have deleted these sentences in the revised manuscript as suggested.

48. Comment: L456-457: You already stated in the L45, that blue water has the largest part of the total WF. Please delete this sentence. Response: Thank you for your comments. We have deleted these sentences in the revised manuscript as suggested.

Thank you for your helpful suggestion regarding our manuscript. We have revised the manuscript according to your comments carefully. We hope these modifications, based on your suggestions, will raise the quality of our manuscript to meet the publication standards of Hydrology and Earth System Sciences. We appreciate the editors and reviewers' work. Once again, thank you very much for your comments and suggestions.

Please also note the supplement to this comment:
https://www.hydrol-earth-syst-sci-discuss.net/hess-2018-125/hess-2018-125-AC1-

supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2018-125, 2018.

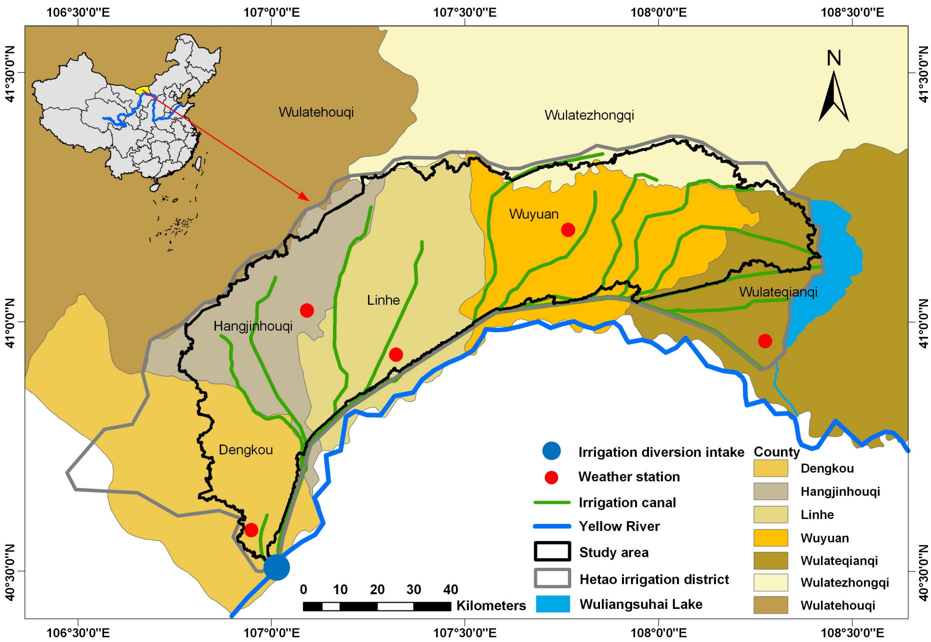

Fig. 1. Fig. 1. Location of the Hetao Irrigation District (HID) in China

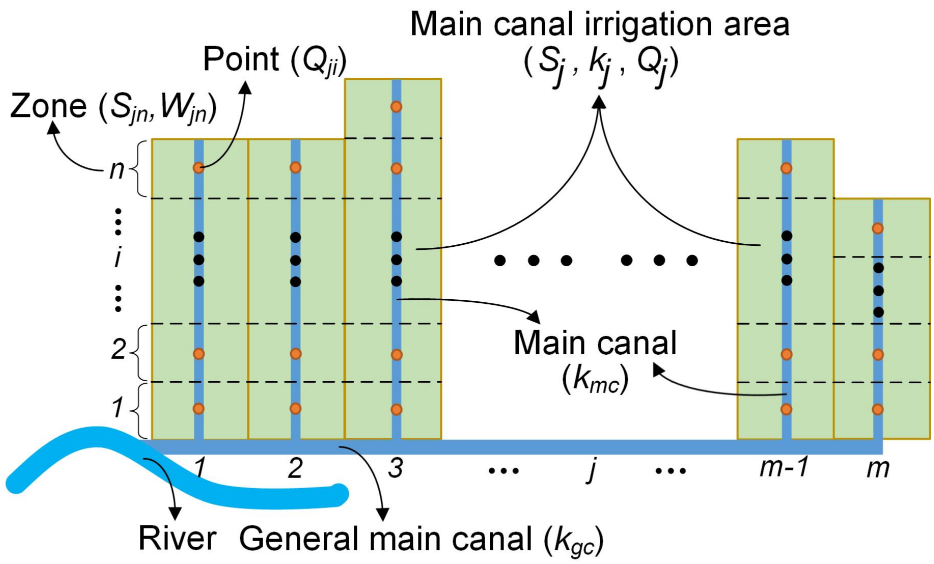

Fig. 2. Fig. 4. Model for calculation of water loss in canal system