Revision Notes (hess-2019-359)

Responses to the comments of Reviewer #1:

The study principally simulated soil hydrology and crop irrigation water productivity with recently developed regional temporal-spatial hydrological model in the arid district. These results attributes mainly to the dynamic-management of local agricultural water resources distribution and crop cropping system under changing climate environment, e.g. salinity, groundwater depth. The paper is well written and organized with novel idea and new findings. The model's simulation results are reasonable. Suggest accept after addressing these comments:

Response: We are appreciating to the reviewer for the useful comments and suggestions to the paper. According to your comments, we have made further efforts to make the paper acceptable for publication. We make a large number of revisions based on the comments to make the paper easier to read. We believe that the quality of this paper has been fundamentally improved after that.

Below are the corresponding responses to the reviewer's eight detailed comments. We cited first the comment, which is followed by our response and often by a section how the text will be revised in the manuscript. The text in blue are changes and additions in the original text. For clarity we do not show the removed text in the blue content.

Comment1: The title is too long and needs revision. Suggest: A novel regional irrigation water productivity model coupling soil hydrology and salinity dynamics in arid regions, China

Response: Thanks very much for this useful comment. We rewrote the title to "A novel regional irrigation water productivity model coupling irrigation-drainage driven soil hydrology and salinity dynamics, and shallow groundwater movement in arid regions, China".

Comment2: L39-40 in Abstract, how about the simulation agreement of validation and calibration plots?

Response: Thanks very much for this useful comment. We added the detailed model simulation performance in the revised manuscript as "The model reasonably well simulated soil moisture and salinity, as well as groundwater table depths and salinity. Overestimations of groundwater discharge were detected in calibration and validation due to the assumption of well-operated condition of drainage ditches, and regional evapotranspiration (ET) were reasonably estimated while ET in uncultivated area was slightly underestimated in RIWP model".

Comment3: Provide details on model's calibration procedure before L345 as subtitle 2.3.2.

Response: Thanks very much for this useful comment and suggestion. We added the detailed procedures of model's calibration and validation procedures in the revised manuscript as subtitle 2.3.3 as following:

2.3.3 Model calibration and validation

To comprehensively evaluate the accuracy and reliability of the model, the data in years 2010-2013 and in years 2006-2009 was respectively used as calibration and validation dataset. The daily measured soil moisture content of crop root zone (θ), electrical conductivity of soil water (EC), groundwater table depth (h_g) and groundwater salinity, were calibrated with measured data from the 22 soil water and salt observation sites and 55 groundwater observation sites (Fig. 5), which were mentioned in section 2.3.1. The RIWP simulated regional ET for each HRU was calibrated by the remote sensing based ET images obtained once per 8 days. The regional drainage processes was calibrated by the monthly groundwater drainage data from main ditches, in which the simulated drainage of each main ditch was the sum of drainage of its controlling HRUs.

We revised the name of subtitle 2.3.2 to "Parameterization of distributed RIWP model".

Comment4: Crop growth is closely with ET? What are the model simulation performances of cash crops growth (biomass, LAI, phonology) and grain yield in the calibration and validation systems in the section of 3.1.

Response: Yes. The crop ET module embedded in the regional RIWP model is based on FAO Irrigation & Drainage 56 ($ET_m = K_c * ET_0; ET_0 = \frac{0.408\Delta(R_n-G)+900\gamma u_2\frac{(e_s-e_a)}{T+273}}{\Delta+\gamma(1+0.34u_2)}$) and the equation developed by Pereira et al. (2007) ($\frac{ET_{a\ ws}}{ET_m} = K_{sc} = K_{ss}K_{sw} = \left[1-\frac{b}{100*k_y}(EC_e-EC_{et})\right]\frac{TAW_{salt}-D_r}{(1-p_{cor})TAW_{salt}}$) to estimate crop actual ET under water stress and/or saline condition. Actual ET is affected by the soil water and salt content in the crop current root zone, and due to the crop root growth during the growing season the crop root zone is changing with time. We applied an empirical equation to quantify the crop root depth change with time in our ET module. In one hand, ET is affected by the soil water and salt content in the root zone, on the other hand, ET will affect the soil water and salt content in the root zone due to its role of water balance component. Thus, crop growth is closely connected to ET in our study. We did not include the estimation of biomass such as LAI, crop height in the ET and yield estimation module in our study. Also, as crop yield is actually affected by the crop actual ET during the growing season, we used the model of Stewart et al. (1977) ($\frac{Y_a}{Y_m} = \prod_{j=1}^{n=4}\left(1 - k_y\left(\frac{ET_{aj}}{ET_{mj}}\right)\right)$) to calculate crop yield in our study, in which crop ET and yield has a positive correlation. However, due to the lack of yield data, we only calibrated regional ET and made validation, and the model simulation indicated a reasonable performance of regional ET.

Comment5: Each section of the three Results and Discussion is needed for greater improvement especially in global sensitivity analysis and irrigation water productivity. Provide more explanations regarding the cause of simulation results, except for comparison with similar previous study results.

Response: Thanks very much for this comment and suggestion. We have made further explanations of the cause of the simulation results in each section of the three Results and Discussion. In section 3.1 Model performance, we added "Besides, the cumulative ETRS was taken by the 8 times of daily ET on satellite acquisition date, thus using the non-representative ETRS above the average daily value may also result in the underestimation of ET_{IWP}." and "In the uncultivated area (Fig.7a), simulated groundwater table level presented a slower and more flat decreasing trend than measured value. By assuming a completely non-vegetation coverage condition of uncultivated area while it is not actually the case, estimated groundwater evapotranspiration driven by capillarity will become smaller than its actual value, in which small vegetation will transpires amounts of water from soil and soil moisture is relatively low thus groundwater evapotranspiration is higher." in the revised manuscript. In section 3.2 Global sensitivity analysis, we added "Due to the high sensitivity of IWP, groundwater table depth and salinity to the specific yield, it is highly recommended to use spatially variable values of specific yield rather than a constant one as a model input if it is available, which could greatly enhance the evaluation accuracy of the RIWP model. Also, it is indicated that the permeability coefficient of unconfined aquifers (K) did not significantly affect the IWP, groundwater table depth and salinity. Due to the lack of measurement data in our study, we adopted a unified K value for the whole study area, which also make the model simulations reasonable for their insensitive to this parameter." in the revised manuscript. In section 3.3 Regional irrigation water productivity, we added "Note that these IWP values were based on the simulated water balance and crop yields of individual HRU, which may deviate to a certain extent from the real values. It can still represent the utilization of water resources at the regional scale." and "As we can see in Fig. 9, the simulated IWP values for three crops were lower in the south, west, north and north-west of the JFID than in the other regions. The south of the JFID is the main canal for water diversion, which provide higher irrigation quota than other regions, in which results in a lower IWP. For the west of JFID, it is mainly uncultivated area, thus the IWP is lower than other regions. In the north-west of the JFID, main drainage ditch received the drainage water with high saline content from four sub-main ditches and drained all the way to the north of JFID. Ditch seepage water with high salinity resulted in the severe soil salinization in the north and north-west of JFID, which will restrict the crop growth and lower the IWP." in the revised manuscript.

Comment 6: L705, what are the measured values? Detail on figure title.

Response: Sorry about not describing the parameter value ranges in Table 3. These are the possible parameter value ranges of this study area, which referred to the local measurements, survey data and relevant research papers. We revised the Table title to "Table 3. The collected possible parameter variation ranges and calibrated values of the parameters describing soil hydraulic characteristics (K_e, S_y, K) and irrigation and drainage system (η_{lc}, η_{fc}, γ_d, A, m). "in the revised manuscript. We added a note below the Table 3 to explain the source of the possible parameter value ranges in the revised manuscript as following:

Note: The parameter value ranges were collected from local measurements, survey data and relevant research results. Soil texture of canal bed was silty sandy loam for 0-1 and 2-3 m depth below the ground, and sandy loam for 1-2 m. For silty sandy loam soil, the bulk density and saturated soil water conductivity are 502.3 mm d-1 and 1.42gcm-3, respectively. For sandy loam soil, the bulk density and saturated soil water conductivity are 1.49g cm-3 and 592.6 mm d-1, respectively. There were fine sand and sandy soil in the phreatic layer. And corresponding adjustment was made to the figure title in L698-699 of the revised manuscript.

Comment7: Each section of L704 provide details on soil particle size, bulk density, saturated water conductivity in table 3.

Response: Sorry about the unclear expression of the soil texture and its hydraulic characteristics in Table 3. We have provided details about the soil particle size, bulk density and saturated water conductivity for canal bed and the phreatic layer in the note below Table 3 in the revised manuscript as "Soil texture of canal bed was silty sandy loam for 0-1 and 2-3 m depth below the ground, and sandy loam for 1-2 m. For silty sandy loam soil, the bulk density and saturated soil water conductivity are 502.3 mm d-1 and 1.42gcm^{-3}, respectively. For sandy loam soil, the bulk density and saturated soil water conductivity are 1.49g cm-3 and 592.6 mm d-1, respectively. There were mainly fine sand and sandy soil in the phreatic layer."

Comment8: Figure 10, there was no obvious difference in irrigation water productivity in groundwater 0-1 and 1-2 m? If not, provide the corresponding results between these groundwater levels

Response: Thanks very much for this comment. Yes, there was no obvious difference in irrigation water productivity between groundwater table depth in the range of 0-1 and 1-2m. When groundwater table level is shallower (0-1m), more groundwater evapotranspiration could contribute to crop water use, which will increase the irrigation water productivity. On the other hand, due to the high groundwater salinity bigger soluble salt content will go into the crop root zone, which enhance the salt stress on crop water use and thus decrease the irrigation water productivity. Similar, deeper groundwater table level will contribute less groundwater evapotranspiration but also less salt content to root zone for crop water use. In this way, the irrigation water productivity under the 0-1 m groundwater table depth was not obviously different from that under the 1-2 m groundwater table depth.