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Interactive comment on "Water Scarcity under Various Socio-economic Pathways and its Potential Effects on Food Production in the Yellow River Basin" *by* Y. Yin et al.

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Responses to the Reviewer 1 We truly thank the anonymous reviewer for their constructive comments and suggestions for improving our work. We have addressed all the comments in our revised manuscript. The point-by-point responses to the comments are provided below.

Some general comments:

- Question 1: Although this paper has been excellently prepared as a scientific report, as far as I have observed, the contents are lacking originality and poorly supported by local facts. First, the authors used the WaSSI index. The water scarcity assessment

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using WaSSI has been established two decades ago by Raskin et al. (1997), Vorosmarty et al. (2000), and Alcamo et al. (2003). Second, the authors used only the output of global hydrological models and highly conceptualized techniques devised for global assessments in this study. I would like to suggest the authors to thoroughly revisit the settings and validate the results of ISI-MIP before using them for local applications. Due to the aforementioned shortcomings, the results and discussion presented in this draft paper are general and not much different from the earlier global water scarcity assessments by Schewe et al. (2014).

- Answer: Thank you for the comments and suggestions. WaSSI is a simple and useful index which considers regional trends in both water supply and demand. Since it was established decades ago, it has been widely used as a metric of water supply stress in many references. So we argue that WaSSI is a proper index to be used. As the water scarcity in Yellow River is largely affected by the changes in both water demand and supply sides, we argue that WaSSI is a proper index to be used. This study differs from Schewe et al. (2014) in several important aspects. Firstly, this study assessed water scarcity at sub-basin scale and considered the water flow regulation rule implemented by the local river administration which set limit on water withdrawals for each sub-basin. In contrast, the global study of Schewe et al. (2014) does not consider the regulation rule and cannot assess the effects of water regulation on water stress. Secondly, this study assessed the water stress with the ratio of human water appropriation (RHWA) ranging from 50% to 90% in the Yellow River, which is much higher than the criterion of 40% reduction in discharge that is widely used in the global studies. This localized setting of RHWA enables a more realistic assessment of water scarcity than the global assessment. Thirdly, we have proposed a simple method to correct model simulated water supply. The corrected simulations were evaluated by comparing the ISI-MIP model results against the streamflow observations (see responses to Question 2). Lastly, we further assessed the impacts of water scarcity on agricultural production which was absent in Schewe et al. (2014). As one of the major food production regions in China, the area of cultivated land in the Yellow River basin accounted for 13.3% of the national totals in the year of 2000. Assessing the potential impacts of water scarcity on agricultural production under a changing environment could help shape adaptation approaches. In the revised version, we have clarified the objective and scientific significance of this study in the introduction section.

- Question 2: Line 114: “six global gridded hydrological models”: The performance of these models should be validated. In the present form, the authors only showed the mean annual runoff at Lanzhou, Longmen, Sanmenxia, Huayuankou in Supplemental Table S4 without any detailed discussion. At least the reproducibility of monthly river discharge and its inter-annual discharge of MPI-HM and PCR-GLOBWB is approximately half and double of observation in the Yellow River. The rational of adopting these models in this study must be also clearly described.

- Answer: Thanks for the constructive comments. The global models are usually not calibrated against streamflow observations, and thus often exhibit considerable biases in monthly discharge simulations. However, a recent study showed that the sensitivity of the global models to climate variability is generally comparable to that of the regional models which are calibrated (Hattermann et al., 2016). It suggests the model results, after correction for bias, may be used to assess climate change impacts on water supply. We have proposed a simple method to correct model simulated water supply. The corrected simulations were evaluated with the ISI-MIP models by comparing the model results against the streamflow observations. The results show that the bias-corrected water supply can reproduce well the reference conditions. We have clarified this issue in the revision.

Reference: Hattermann, F. F., Krysanova, V., Gosling, S., Dankers, R., Daggupati, P., Donnelly, C., Flörke, M., Huang, S., Motovilov, Y., Buda, S., Yang, T., Müller, C.,Leng, G., Tang, Q., Portmann, F. T., Hagemann, S., Gerten, D., Wada, Y., Masaki, Y., Alemayehu, T., Satoh, Y., and Samaniego, L., 2016. Cross-scale intercomparison of climate change impacts simulated by regional and global hydrological models in eleven large river basins. Climatic Change, accept.

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- Question 3: Line 121: “The global irrigated and rainfed crop area data (MIRCA2000)”: The authors should focus on some of the key simulation settings of ISI-MIP and discuss their validity. For example, ISI-MIP fixed the irrigation and rainfed crop area throughout the 21st century. What is the recent trend in cropland area in this basin? What are the projections by the government and experts? Such local details should be included in this study.

- Answer: Thanks for the comments. The cropland area of the Yellow River basin in the 2000s (about 16 million ha estimated by the Ministry of Water Resources of the People’s Republic of China, 2013) is quite close to that during the period of 1998-2002 shown in MIRCA2000 (about 16.27 million ha). Although the cropland area may change due to local adaptation to the environmental change, the projection of land use change is beyond the scope of this study. The land use map (i.e. cropland area) is fixed throughout the 21st century in this study. However, the irrigation or rainfed crop area is not fixed. When water shortage occurred (agriculture water availability is not enough for irrigation), we assume the irrigation area would be converted into rainfed. In this way, we can assess the impact of water shortage on agriculture production. We have clarified this in the revised manuscript.

- Question 4: Line 167: “the ratio of human water appropriation (hereafter RHWA)”: First, the definition of this term is missing in the current form of text. The definition and background concept should be clearly stated. Second, the rational of the thresholds of 50%, 70%, 90% should be carefully discussed. It should be well noted that in many densely populated river basins, total water withdrawal may exceed the total river discharge since treated waste water in upstream is utilized in downstream. Even if the total water withdrawal exceeds the river discharge, water scarcity never occurs if waste water is properly treated and returned to the stream.

- Answer: Thanks for the comments. In this study, the ratio of human water appropriation (RHWA) describes the fraction of net water withdrawal (Yellow River Conservancy Commission of the Ministry of Water Resources (YRCC), 2013) and is defined as the annual net water withdrawal divided by the annual runoff. The net water withdrawal is defined as the total water withdrawal minus the water that returns back to the river channel. The threshold values of 50%, 70% and 90% are three different scenarios of human water appropriation. The net water withdrawals of the runoff were occupied 53% during 1980s (Zhang et al., 2004) and 72% presently (YRCC, 2013). If environmental flow requirements in the river basin have greater priority than human society during the period of the study, we assumed that the ratio of human consumptive water appropriation in the basin is 50%. Otherwise, we assumed that the ratio of human consumptive water appropriation in the basin is 90%. 70% is the medium-level scenario. We have added the relevant content in the revision.

Reference: YRCC (Yellow River Conservancy Commission of the Ministry of Water Resources), 2013. Comprehensive planning of Yellow River Basin (2012-2030). Zhengzhou: The Yellow River Water Conservancy Press (in Chinese) Zhang, H. M., Niu, Y. G., Wang, B. X., and Li, S. M., 2004. The Yellow River water resources problems and countermeasures. Hydrology, 24(4), 26-31 (in Chinese)

- Question 5: Line 181: “The GGCM estimated irrigation water demand”: First, the authors should provide the setting and assumptions of this simulation related to water use. What types of crops were planted in the basin in the simulations? Was the crop type varied during the simulations to adapt to warmer climate? Such settings are crucially sensitive to the results. Then carefully discuss whether such simulation conditions are valid for the study basin, and what should be noted in interpreting the results.

- Answer: Thanks for the comments. We have added a table (Table S2 in the Supplemental materials) to show the setting of the GGCM. All the GGCMs simulate wheat, maize, and soybean, and all but PEGASUS simulates rice. This study assessed the four crops only. The planting area of these four crops is more than 80% of total crop area in the Yellow River basin. The crop type is fixed during the simulation – no adaptation measures were considered. The main purpose of this study is to assess how water shortage would affect agricultural production if no adaptation measures were taken. We have added a brief discussion in the revision.

- Question 6: Line 195: “using the historical GDP per capita and industry water use per capita data”: Although the authors claimed that their industrial water model followed Alcamo et al. (2003) and Flörke et al. (2013) in line 187, there is a fundamental difference in explanatory variables (input data). In reality, the explanatory variables of Alcamo et al. and Flörke et al. were electricity production (a rough indicator of the magnitude of manufacturing output) or value added of industrial sectors respectively, not GDP. In general, industrial water grows much gently than GDP in long term (see Alcamo et al., 2003 and Flörke et al., 2013). Note that the usage of GDP might be one the reasons why the industrial water exploded in late 21st century in this study.

- Answer: Thanks for the comments. Unfortunately, it is still hard to get the electricity production projection or the value added of manufacturing sectors projection in the Yellow River basin or in China. Alternatively, the GDP projection data over the 21st century is readily available for different socio-economic scenarios. Also, we can obtain the share of manufacturing gross value added in total GDP over the 21st century for OECD and Non-OECD country from the UNEP GEO4 Driver Scenarios (Hughes, 2005). Given that China is a Non-OECD country, we could calculate the value added of manufacturing sector in the 21st century. Based on the industrial net water withdrawal and the calculated value added of manufacturing sector, we have reconstructed the industrial water model followed Flörke et al. (2013) in the revision.

Reference: Hughes, B. B., 2005. UNEP GEO4 diver scenarios (fifth draft). Josef Korbel School of International Studies, University of Denver, Colorado. Flörke, M., Kynast, E., Bärlund, I., Eisner, S., Wimmer, F., and Alcamo, J., 2013. Domestic and industrial water uses of the past 60 years as a mirror of socio-economic development: A global simulation study. Global Environment Change, 23, 144-156, doi: 10.1016/j.gloenvcha.2012.10.018

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- Question 7: Line 200: “In the domestic sector, TC was set as 1% per year”: SSP narrates substantially different view of the world (O’Neill et al., 2014). It is a bit odd to me that a same parameter was used for SSP1 (sustainable world) and SSP3 (unsuccessful fragmented world) in this study. For instance, Hanasaki et al. (2013) set different parameter for each SSP to make parameter and narrative scenario consistent.

- Answer: Agreed. We have revised the domestic water use estimates following Hanasaki et al. (2013).

- Question 8: Line 203: “ratio of water demand to water supply”: Define this term more precisely. The terms “water demand” and “water supply” are also unclear.

- Answer: Thanks for the comments. In this study, the WaSSI was defined as the ratio of annual water demand to annual water supply for a specific watershed. Annual water supply was defined as the total potential surface water available for withdraw from a watershed, and was equal to the annual runoff multiplied by RHWA (the ratio of human water appropriation). Annual water demand represents the sum of net water withdrawals for agricultural, domestic, and industrial uses.

- Question 9: Line 279: “the WaSSI for total water demand is large than 1 under each SSP, meaning that the water would be scare at the end of the 21st century”: Again, if the water withdrawn in upstream is properly treated upstream and returned to the stream, water scarcity doesn’t occur even if WaSSI exceeds one. Elaborate what are the key problems in the basin in reality, and what can be represented by the WaSSI index.

- Answer: In this study, the WaSSI represents water stress only with respect to net water withdrawals, which is defined as the total water withdrawal minus the water that returns back to the river channel, and measures whether water supplies are sufficient for all net withdrawal requirements within a watershed to be met concurrently. We have added those explanations in the section of Method of the revised manuscript.

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- Question 10: Line 265: “The water resource shortage is most serious under the conventional development scenario (SSP5)”: This is contradictory to the original narrative story line of SSP5 (O’Neill et al., 2014) which depicts a technology-oriented world with high capability of adaptation (humans would control negative consequences of environmental problems by technology). Water does “SSP” mean in this study? Is this mean that authors only took the projection of GDP and population from SSP database?

- Answer: Thanks for the comments. Each SSP contains a quantitative scenario and a qualitative scenario. The qualitative scenario includes the degree of technological change, overall environmental consciousness and so on. We agree that it is not reasonable to consider GDP and population only. We have taken into account of the effect of technological change and recalculated the water demands following Hanasaki et al. (2013) in the revision.

Reference: Hanasaki, N., Fujimori, S., Yamamoto, T., Yoshikawa, S., Masaki, Y., Hijioka, Y., Kainuma, M., Kanamori, Y., Masui, T., Takahashi, K., and Kanae, S., 2013. A global water scarcity assessment under Shared Socio-economic Pathways – Part 1: Water use. Hydrology and Earth System Sciences, 17, 2375-2391, doi:10.5194/hess-17-2375-2013

Some minor comments:

- Question 11: Line 66 “a grant figure”: What is this?

- Answer: Corrected.

- Question 12: Line 114: “H08”, “PRC-GLOBWB”: “H08” and “PRC-GLOBWB” respectively

- Answer: Revised.

- Question 13: Line 267: “meaning than water demand outstrip supply water”: Rephrase this part.

- Answer: Thanks for the comments. In the revision, we have replaced “meaning than water demand outstrip supply water” with “meaning that demand for water outstrips supply”.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-188/hess-2016-188-AC1-supplement.pdf

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