Response to Reviewer 2

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<tr><th colspan="3">Response to Reviewer 2</th></tr>
<tr><td>No.</td><td>Comment</td><td>Response</td></tr>
<tr><td>R2C1</td><td>This manuscript enhanced the capability of a global hydrological model named H08in simulating two perennial bioenergy crops, Miscanthus and switchgrass. The results were validated against site-level and country-level observed crop yields. The enhanced model is applied to simulate the impact of irrigation on crop water consumption and water use efficiency compared to rainfed condition. This study makes contribution to study the impact of large-scale deployment of bioenergy crops on water resources. However, I have some major comments as listed below.</td><td>Deer Reviewer, thank you very much for taking time to carefully read our manuscript. We are pleased to see your agreement on the contributions of this paper. Your valuable comments enabled us to clarify a number of points that we previously unaware of, and we hope that we have increased the quality of the manuscript substantially. We have revised the paper by trying to incorporate all relevant comments and remarks. We have also tried to respond to all the comments meticulously as you may see below. Please find our responses to each comment below.</td></tr>
<tr><td>R2C2</td><td>Model validation: This study only validates the simulated yield results against observations for Miscanthus and switchgrass. While the main contribution/innovation of this study is on hydrological applications, this study didn’t validate any variables for the water cycle, including evapotranspiration, runoff, and irrigation. With-out such validations, I feel difficult to be convinced for the reliability of the simulated results for crop water consumption and WUE.</td><td>Thank you for noting this issue. As you mentioned, we validated the simulated yield because our primary goal in this study was to improve the simulation of bioenergy crop yield in the H08 global hydrological model. Note that variables related to the water cycle, such as river discharge, terrestrial water storage, and water withdrawal have been thoroughly validated in a series of previous studies (Hanasaki et al., 2008a, 2008b, 2018). Here, we noted this has not been explicitly described in the manuscript, we therefore added it on lines 60–62. To address this question as well as possible, we compared our simulation of irrigation water consumption/withdrawal (on-going study) with previous reports (as shown in the table below), and found that our simulation is well within the range of existing reports. Because WUE is calculated using yield and water consumption, we believe that our estimates of WUE is also reasonable.
<table>
<tr><th>Studies</th><th>Irrigation water consumption/withdrawal [km^3 yr^{-1}]</th></tr>
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		<table><tr><td>**Beringer et al. (2011)**</td><td>1481~3880**</td></tr><tr><td>**Bonsch et al. (2016)**</td><td>3350***</td></tr><tr><td>**Yamagata et al. (2018)**</td><td>1910**</td></tr><tr><td>**Heck et al. (2018)**</td><td>> 2334**</td></tr><tr><td>**Jan et al. (2018)**</td><td>3000~9000**</td></tr><tr><td>**Stenzel et al. (2019)**</td><td>587~2946**</td></tr><tr><td>**Our study**</td><td>2187**/3929***</td></tr><tr><td colspan="2">**Note: ** refers to water consumption; *** refers to water withdrawal**</td></tr></table>
R2C3	Study innovation: The Introduction didn't well motivate the study and present the novelty/uniqueness of this study. For example, the argument "However, it is noted that the model performance for the simulated bioenergy crop yield was not validated at all." is a little bit difficult to be taken as an innovation of this study. And almost all the parameter values were directly taken from Trybula et al. 2015, which makes me wonder what are the main differences/improvements of this current study compared to Trybula et al. 2015? Given the difference between H08 used in this study and SWAT used in Trybula et al. 2015, can the authors justify the applicability of directly using SWAT's parameter values?	This is a good point. Let us further explain the uniqueness of our study here. Currently, only few models, such as LPJml, H08, and CLM5 include global implementations of both bioenergy and schemes for irrigation, river routing or water withdrawal. This limitation severely restricts the application of models to address possible global bioenergy–water tradeoffs or synergies in the future. Moreover, these three models have some limitations. First, in LPJml, *Miscanthus* and switchgrass are not distinguished and instead a general C4 grass is used to parameterize both species. Separate parametrization of these two bioenergy crops could enhance the bioenergy simulation, as they show major differences in plant characteristics and crop yield. Second, CLM5 has been successfully modified and validated for separate simulation of *Miscanthus* and switchgrass based on observations at the University of Illinois Energy Farm (Cheng et al., 2020), but global validation or application remain untested. Third, H08 has two weakness: 1) the original model produces apparent overestimations or underestimations, and 2) the original assumptions of potential heat units are unrealistic. Our study addressed these gaps and issues through systematic

		parameter calibration using the best available data. We have rephrased the introduction and provided further details on lines 30–50. About the second question, the work of Trybula et al. (2015) is the first report of updating the SWAT for bioenergy crop simulation based on field observations. It provides a valuable reference for our study, as the crop module in H08 is similar to that of SWAT. Therefore, in our model enhancement process, the crop parameters related to leaf area development (potential heat unit, optimum temperature, maximum leaf area index, and two complex numbers; see details in Table 1) were based on their field observations (Trybula et al., 2015). For other important parameters, such as radiation use efficiency (be), maximum leaf area index (blai), base temperature (Tb), maximum daily accumulation of temperature (Hunmax), and minimum temperature for planting (TSAW), we conducted systematic calibration based on the ranges reported for that parameter in previous studies (see Table 3). The results demonstrated that the finalized parameter scheme is applicable to global simulation of bioenergy yield. It is possible to use SWAT's parameter because the crop module structure of H08 is similar to that of SWAT.
R2C4	Model description: This study only describes the crop module in H08 without much descriptions for the hydrological module in the model, especially given the important role of hydrological processes in this study. In addition, many indices and simulations (e.g., using new meteorological dataset) were not well described in the methods section, such as how WUE is calculated, how irrigation works, and how many	Based on your suggestion, we have largely revised the methods section, as follows. First, we added the model structure to Fig. 1. The relevant hydrological processes are descripted on lines 62–69: "The six sub-modules (land surface hydrology, river routing, crop growth, reservoir operation, environmental flow requirements, and anthropogenic water withdrawal) are coupled in a unique way (Fig. 1a). The land surface module

	simulations were conducted in total and their respective purposes.	can simulate the main water cycle components, such as evapotranspiration and runoff. The former is used in the crop module, and the latter is used in the river routing and environmental flow modules. The agricultural water demand simulated by the crop module and the streamflow simulated by the river routing and reservoir operation modules finally enter into the withdrawal module. Note that the crop module is independent, except for the water stress calculations, which require evapotranspiration and potential evapotranspiration inputs from the land surface hydrology module." Second, we added a description of the additional S14FD meteorological data on lines 164–166. "Another meteorological dataset for the period 1979–2013 in S14FD (Iizumi et al. 2017) with the same spatial resolution was also used to check the stability of results to input meteorological data." Third, we added the equations used for yield calculation on lines 79–123. Fourth, we described the calculation of WUE on lines 195–201. Fifth, we added a description on irrigation in lines 77–78. Sixth, we modified the simulation setting descriptions on lines 187–193. Sine these additions are quite long, we have not included them here; please see details in the specific lines noted above.
R2C5	Paper organization: The main context is missing many important information (e.g., sensitivity test results, model descriptions, equations). Many important information and results were given in the SI rather than directly presented in the main context. The methods section is missing descriptions for the simulations conducted in this study and many new simulations came out suddenly in	Thank you. We have reorganized the paper, as follows. First, we added a schematic figure to show the submodules of H08 as Fig. 1a. The corresponding text is on lines 62–69. Second, we added the equations used for yield calculation of the crop module on lines 79–123. Third, we described the sensitivity analysis in Section 2.7 and the result are presented in Table S5.

	the Results sections. It will be necessary to reorganize the paper and move some important information from SI to the main context.	Fourth, we rephrased the simulation setting description in Section 2.5 and added a summary table (Table S1). Fifth, we added meteorological data (S14FD) in Section 2.3. Sixth, we moved the original Fig. S5 and Fig. S7 to the main text (see Fig. 5 and Fig. 7, respectively, in the revised manuscript) and added corresponding text to Section 3.2 and 3.4.
R2C6	Limitation in discussion: the current results and discussions are quite limited. For example, quantitative evaluations for model improvements were missing. What are the improvements of the enhanced H08 compared to its old version which uses C4 grass to characterize switchgrass and Miscanthus? One of the most important features of switchgrass and Miscanthus is their perennial features and longer growing seasons, but this study didn't have any discussions on this kind of perspectives.	Thank you for this very good suggestion. The enhanced model strongly reduced the yield bias for both *Miscanthus* and switchgrass. Also, as noted in previous reports (Cheng et al., 2020), *Miscanthus* and switchgrass have longer growing seasons than maize. Here, we compared our results with reported growing season days. We added a discussion of these differences, as follows (lines 354–357): "Compared with the original H08, our enhanced model markedly decreased the mean bias (from –52% to –9% for *Miscanthus*, from 25% to –7% for switchgrass). Moreover, the growing seasons for *Miscanthus* (145–165) and switchgrass (101–114) during the period 2009–2011 at the Water Quality Field Station of the Purdue University Agronomy Center are consistent with the values of 140 and 120 reported in Trybula et al. (2015)."
R2C7	Lines 31-36: Actually, CLM5 also has the irrigation scheme and river routing and CLM5 also includes both bioenergy crops and the water cycle.	We have added CLM5, as follows (lines 30–32): "However, among these models, only a few, such as LPJml, H08, and CLM5 include the global implementation of schemes for irrigation, river routing or water withdrawal."
R2C8	Line 34: typo, should be "bioenergy and the water cycle"	Thank you. We have corrected the typo.
R2C9	Line 61: I am curious does it mean H08 can only simulate hydrological processes and crop growth as a 0.5 degree and at a daily scale? How about other spatial and temporal	You are correct. For global standard simulation (default setting), hydrological processes and crop growth can presently be simulated only at the 0.5-degree and daily.

	resolutions? Can H08 simulate GPP and LAI? If so, how about the simulation results for GPP and LAI?	Regional versions have higher spatial resolution (5 arc-minutes) (Hanasaki et al., 2020). As the land surface hydrological model of H08 is the first generation that based on the bucket model (Manabe et al., 1969), GPP and LAI are not estimated in the land surface model. This is different from the LPJmL and CLM5, which are a dynamic vegetation model and a latest generation land surface vegetation model, respectively, and they do simulate GPP and LAI. In the crop module of H08, it calculates the yield and LAI. LAI is coded as a medium variable in the process of yield calculation but is not an output item in current model version. Since our primary goal here is the improvement and validation of bioenergy crop yield, please let us retain current model version. We will consider your comment and modify the code in future model development.
R2C10	Lines 61-64: What are the six sub-modules? It will be great if the authors can add more descriptions for the H08 model (e.g., calculations/illustrations for the hydraulic processes), as not every reader is familiar with H08.	We have added a description of the six submodules after the term on lines 60-62. We have also added a schematic diagram showing the connections among submodules as Fig. 1a. We have included the equations related to the yield simulation in the crop module on lines 80–120. A full description of the H08 model would require thousands of words, and is available elsewhere (Hanasaki et al., 2008a, 2008b, 2018).
R2C11	Line 75: what is single-irrigated and double-irrigated mean?	Single-irrigated indicates that the irrigated land is used only for one crop per year, while double-irrigated refers to irrigated land planted with two crops per year.
R2C12	Line 85: what is “substantially” mean? Can you quantify the changes?	Here, substantially represents a large difference between the modified (1830 °C for *Miscanthus*, and 1400 °C for switchgrass) and original (9999 °C for both *Miscanthus* and switchgrass) potential heat units.
R2C13	Section 2.2: Can you change some descriptions into equations? For example,	We added the equations related to the yield calculation on lines 79–123. Water

	how did you calculate the output item for water consumption and WUE? If they are already in the supplementary materials, it will be great if you can move some key equations to the main context. What is the bug in the original code?	consumption is calculated as actual evapotranspiration. The bug is related to the improper use of ".eq." in place of ".ge." As this bug is too trivial to report, we have removed it from text.
R2C14	Section 2.5: How is irrigation calculated in H08, such as the irrigated area and irrigated amount?	Our intention was to determine the general effects of irrigation on bioenergy crop yield and the variations among different climate zones. Therefore, we assumed a whole grid is irrigated for bioenergy crop production. The irrigation water amount in H08 is defined as the supply of water other than precipitation to maintain soil moisture above 75% of field capacity during the cropping period.
R2C15	Line 23 under section 2.5: since 1944 simulations were conducted, can you give more results for the ensemble runs rather than just present the one with lowest RMSE? For example, what are the uncertainty ranges for the calibrations? What are the sensitivity results for all the calibrated parameters? Here the authors only mentioned the most sensitive parameter names in line 20 but no results were given to support it.	We have added a new figure (Fig. 3) to illustrate the performance of the enhanced model after calibration, which shows good agreement with the observations. We have also added a new figure (Fig. S1) showing the variations of root mean square error (RMSE) and corresponding correlation coefficient (R) values used for the calibration. The uncertainty range of each parameter is listed in Table 3. We also calculated the sensitivity and summarized the results in Table S5. Among the five parameters we calibrated, radiation use efficiency was the most sensitive parameter to the results, followed by base temperature. This finding is consistent with the sensitivity results reported by Trybula et al. (2015).
R2C16	Line 38 in section 3.1: change to "because only few sites were irrigated".	We have changed the text, as follows (line 216): "because only a few sites were irrigated"
R2C17	Line 38 in section 3.1: can you add reference after the "previous reports"?	We have rephrased the sentence and added a citation, as follows (line 217): "These values are similar to those of Trybula et al. (2015)."

R2C18	Line 50 in section 3.2: can the authors add more quantitative results and discuss the reasons/mechanisms for why the over- and under-estimations have been addressed in the enhanced H08? Actually Miscanthus is still underestimated in the enhanced H08, why?	We have quantified the bias and rephrased the text as follows (lines 231–233): "For *Miscanthus*, the bias of original model ranged from –84% to 80% with a mean of –52%, while the bias of the enhanced model ranged from –59% to 53% with a mean of –9%. For switchgrass, the bias for original model ranged from –78% to 338% with a mean of 25%, while the bias for the enhanced model ranged from –52% to 109% with a mean of –7%." One important reason for the improved bias is the adjustment of the potential heat unit based on the field observations from Trybula et al. (2015). This parameter adjustment would change the crop leaf area development and also the aboveground biomass accumulation. As for switchgrass, another important reason is the decrease of radiation use efficiency, which can largely address the overestimation. Note that site-specific yield simulation and validation of traditional crops is a major challenge for global models (Müller et al., 2017), notwithstanding the bioenergy crop, which are being added to existing global models. For example, underestimation or overestimation have also been reported in other global models like LPJml and ORCHIDEE that including the bioenergy crops. We added a new figure (Fig.3) of the calibrated results. It illustrates very good performance. Fig. 4 shows the validation of the model. Although it shows much better performance than the original simulation, it also shows a tendency toward underestimation. However, if we separately analyze each site, as shown in Fig. 5, most yield estimates were similar to or within the observed yield ranges. Therefore, our simulation appears to be reasonable at the global scale.

R2C19	Line 58 in section 3.2: what are sites 1, 2, and 10? Can you refer to more specific names or descriptions for those sites, as these site numbers are not quite meaningful?	We have modified the text, as follows (lines 240–242): "We also investigated the performance under the irrigated condition (shown in Fig. 6). We used the reported observed yields for ten sites globally (Table S3). We found that the simulated yields were within or close to the observed yields for five sites located in China, the UK, and France (see Table S3)"
R2C20	Line 59 in section 3.2: again, adding irrigation scheme in H08 in the methods section will be helpful.	We have added a description of the irrigation scheme on lines 77–78: "Irrigation in H08 is defined as the supply of water other than precipitation to maintain soil moisture above 75% of field capacity during the cropping period."
R2C21	Line 64 in section 3.2: the two results were similar, but what are the implications? What are the differences between the two meteorological datasets? Also, it makes me wonder how many simulations or how many kinds of simulations were conducted in this study? This new simulation with additional meteorological dataset never mentioned in the methods section. I will suggest the author add a new table or at least a new paragraph in the methods section to better illustrate the simulations conducted in this study, including their names, descriptions, differences, purposes, etc.	We apologize for the unclear description. Let us further clarify the text here First, we aimed to test the stability of the modelling results by varying the meteorological inputs. The results indicated that our simulation is quite stable. The S14FD dataset is reported to be more accurate than WFDEI for representing the observed temperature and precipitation extremes in recent decades (1961–2000 and 1979–2008) (Iizumi et al., 2017). Second, four types of simulations were conducted, and we have added a new table (Table S1) and rephrased the text to describe the simulations as follows (lines 187–193): "After calibration, four different kinds of simulation were run with different purposes. The first simulation was conducted using the original model without irrigation to investigate its performance. The second simulation was conducted using the enhanced model without irrigation to investigate its performance under rainfed condition. The third simulation was conducted using the enhanced model with irrigation to investigate its performance under irrigated condition. These three simulations

		were conducted at a daily scale with annual meteorological data from WFDEI for the period 1979–2016. The last simulation was conducted using identical model settings to the third one, except using different meteorological data from S14FD for the period 1979–2013. Note that irrigation in this study means uniform unconstrained irrigation."
R2C22	Section 3.3: can you add those correlation and significant level values in Figure 5 as well?	Thank you. We have added the corresponding correlations and significance values.
R2C23	Line 10 in section 3.4: grammar error for the sentence	Thank you for letting us know about this issue. This section now reads as follows (line 307): "indicating that irrigated yield was more than double the rainfed yield." We have revised the whole manuscript further, and have employed the professional English proofreading service from Textcheck (http://www.textcheck.com/en/text/page/index).
R2C24	Line 55-58 in section 3.6: again, how is the current results compared to old H08 which uses C4 grass to represent Miscanthus and switchgrass?	In response to the Reviewer's previous comment (R2C6), we have added the following discussions (lines 354–357): "Compared with the original H08, our enhanced model markedly decreased the mean bias (from –52% to –9% for *Miscanthus*, from 25% to –7% for switchgrass). Moreover, the growing seasons for *Miscanthus* (145–165) and switchgrass (101–114) during the period 2009–2011 at the Water Quality Field Station of the Purdue University Agronomy Center are consistent with the values of 140 and 120 reported in Trybula et al. (2015)."
R2C25	Line 63-65 in section 3.6: I doubt the argument that the enhanced H08 is the only model that can simultaneously simulate Miscanthus and switchgrass with consideration of water management, as CLM5 also has this capability.	We apologize. We have added CLM5 to the introduction and modified this sentence, as follows (lines 362–364): "In summary, our enhanced model provides a new tool that can simultaneously simulate

		Miscanthus and switchgrass with consideration of water management"
R2C26	Tables 1 and 2: could you add the long name or descriptions for these parameters? What is "step" mean in Table 2?	This is a good point. We have added a new table (Table 1) to describe the parameters, and their full names and descriptions can be found there. The term "step" refers to the increment of the parameter within the range of our calibration. We have changed the term "step" to "increment".
R2C27	Figure 1: could you add a flow chart or schematic figure for the hydrological processes in H08 or the overall model structure?	We have added a schematic diagram to show the structure and connection of the submodules as Fig. 1b.
R2C28	Figure 3: can the authors decrease the maximum magnitudes for figure b and d, like to be 40, since no data exceeds 40 and right now most of the points are centered to a very small range? And can the authors add a third axis (e.g., different colors) to distinguish the locations/climate zones for the points?	Thank you for this useful suggestion. We have modified the maximum value of the axis as you suggested. Since we had used red and blue colors to distinguish *Miscanthus* and switchgrass, we used different shapes (see the legend for Fig. 4) to identify the climate zone of each point.
R2C29	Figure 6: it will be helpful to add a title name in the figure, e.g., (a) Rainfed Miscanthus.	This is a good point. We have added a title name in the upper right conner of the figure. For details, please see Fig. 9.
R2C30	Figure 7: it may be helpful to move Figure S6 to the main context and combined with Figure 2 to better illustrate the methods section. But the authors can decide after revise the methods section.	Thank you for this useful suggestion. We have moved Fig. S6 to the main text and combined it with Fig. 2 to better illustrate the method. By doing this, we now include both climate zone and site location in Fig. 2.

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