Cover letter

Dear professor Murugesu Sivapalan:

We greatly appreciate you and the reviewers for taking time to review this manuscript and provide us with constructive and valuable comments. We have addressed all comments from reviewers and the manuscript has been much improved. Our changes are marked in Blue in the revised manuscript. And our responses to the reviewers are detailed in this response-to-reviewers document submitted with the revised manuscript.

Looking forward to hearing from you.

Sincerely,

Dr. Dedi Liu
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Reviewer 1

This study addresses the phenomenon that the water, energy, and food crises that human society is facing are highly interconnected issues, and their evolutions would further stimulate human response actions, which would in turn (re)shape the evolution trajectories of the FEW systems. In doing so, the authors develop a holistic sociohydrologic model, which not only mimics the water, energy, and food systems but the related human components (e.g., population, GDP, industry, agriculture) are also incorporated endogenously. Overall, the work is interesting and represents a very important direction for extending the scope of sociohydrology, which has been discussed particularly by Di Baldassarre et, al, Sociohydrology: Scientific Challenges in Addressing the Sustainable Development Goals https://doi.org/10.1029/2018WR023901. In this sense, I think this manuscript is a valuable contribution to the scientific progress within the scope of sociohydrology. However, I do have some concerns and suggestions that need to be addressed, which are listed below.

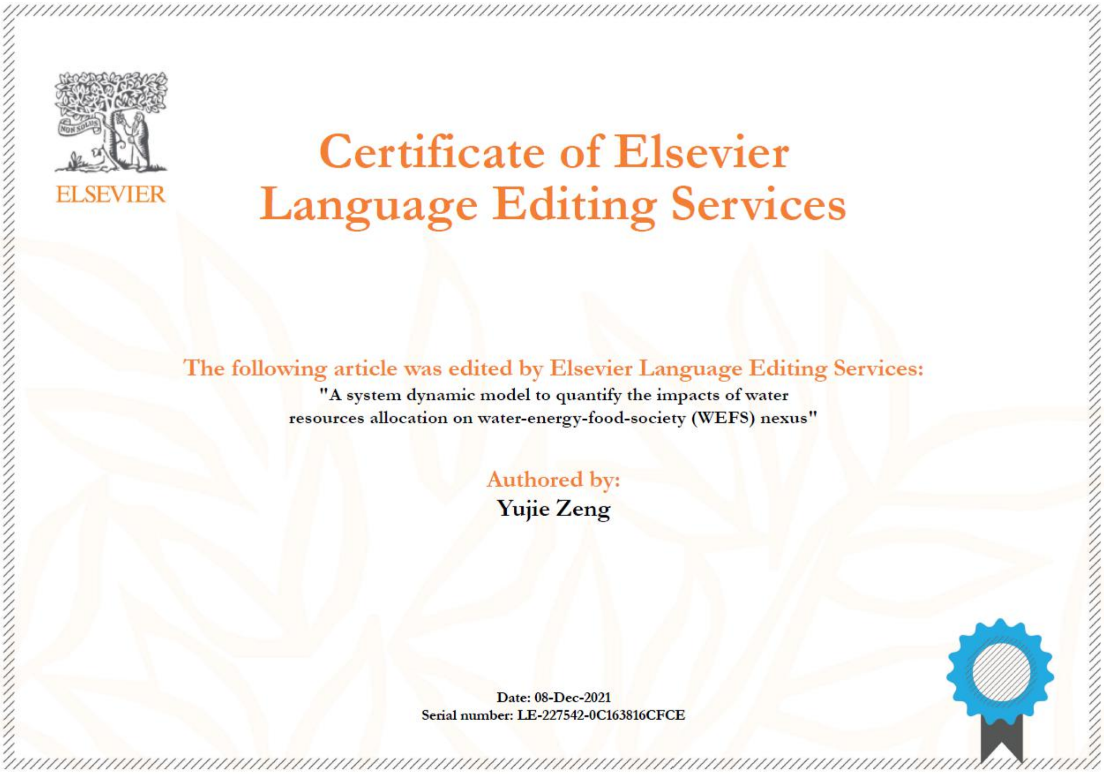
Thank you very much for your positive feedback and valuable comments on our paper. We have thoroughly revised the paper based on the comments. We believe the current comments have greatly helped improve the quality of the paper. Here are the responses to your comments:

We have carefully read the valuable paper in the comments "Sociohydrology: Scientific Challenges in Addressing the Sustainable Development Goals" and cited it in line 82.

1. The text and grammar should be revised throughout. There are many places (too many to be listed) where the language is unclear and misleading.

1 Response:

Thanks for your supportive suggestion. We have carefully improved the writing quality in the revised manuscript.



ELSEVIER

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The following article was edited by Elsevier Language Editing Services:

"A system dynamic model to quantify the impacts of water resources allocation on water-energy-food-society (WEFS) nexus"

Authored by:

Yujie Zeng

Date: 08-Dec-2021

Serial number: LE-227542-0C163816CFCE

2. I suggest the authors give a more detailed description of figure 1. This figure is very important for understanding the overall feedback relationships between the model variables. Currently, I am not very clear about the feedback relationships.

2 Response:

Thanks for your supportive suggestion. We agree with your opinion. We have given more details for the description about the primary feedback loop driven by environmental awareness in Figure 1. Description for connection between water system and energy system as well as food system will be improved in line 130~136 "The water demands and available water resources are further inputted into the water resources allocation model to determine the water supply and water shortage for every water use sector in each operational zone. The water supply for socioeconomic water use sectors and agricultural water shortage rates as outputs from the water system module are taken as the inputs of the energy system module and food system module to determine the energy consumption and food production, respectively."

Descriptions for feedback driven by environment awareness have been added in line 144~148. As environmental awareness accumulates over its critical value, negative feedback on socioeconomic sectors (i.e., population, GDP, and crop area) will be triggered to constrain the increases in water demand, and further energy consumption, and food production to sustain the WEFS nexus.

3. I have some concerns about equations (2)-(5). First, this seems not the Malthus growth model. In the Malthus growth model, the right side of equations 2-5 should be N, G, A, and WQ, respectively, instead of N0, etc. please check if it is a typo. Second, there is an exponential term which the authors call the technology effect, dampening the growth rate of the state variables. This is not very convincing. I believe that technology development would contribute to water conservation activities and thus reduce water use quota, but I do not understand why it would have a negative effect on GDP, population and crop area, this is somewhat counter-intuitive. Third, equation (5). Why is there a negative sign in front of WQ? From table 2, rqwu is already a negative value (i.e., -0.02). If you intend to indicate that the water use quota is decreasing over time, one negative sign needs to be removed. In addition, in this case, the exponential term would dampen the decreasing rate of water use quota. This might not be reasonable, because technology development is always supposed to accelerate the decreasing of water use quota instead of dampening it. Fourth, there is a term representing the effect of GDP on water use quota in equation (5). I assume the rationale is that GDP development would prompt the advancement of water-saving technology. But the effect of technology has already been considered by the exponential term. I think perhaps the equation (5) is over-complex. Fifth, line 155, the authors claim that this study considers municipal and rural water consumption, industrial water consumption and agricultural water consumption, so I think there should be a distinction of water use quota for each of these types of water use. However, there seems no distinction between the different types of water use in equation (5).

3.1 Response to the first comment:

Thanks for your supportive suggestion. We have added the original Malthusian growth equation in these equations. And the forms of equations for population, GDP and crop area have been corrected in equation (2)-(4) and interpreted in line 171~178. As the growth rate in the original Malthusian growth model is adopted as a constant, socioeconomic factors will reach infinity in a long-time evolution. Therefore, we assume that population, GDP, and crop area increase with decreasing rates over time, based on previous studies (He et al., 2017; Lin et al., 2016). And feedback functions, as well as environmental capacities of socioeconomic variables, are adopted to constrain the infinite evolution of these socioeconomic variables through equations (2)–(4) (Feng et al., 2016; Hritonenko and Yatsenko, 1999).

$$\begin{cases} \dfrac{dN_t}{dt} = r_{P,t} * N_t \\ r_{P,t} = \begin{cases} r_{P,0} * (1 + \kappa_P * \exp(-\varphi_P t)) + f_1(E) & N_t \le N_{cap} \\ \mathrm{Min}(0, r_{P,0} * (1 + \kappa_P * \exp(-\varphi_P t)) + f_1(E)) & N_t > N_{cap} \end{cases} \end{cases} \quad (2)$$

$$\begin{cases} \dfrac{dG_t}{dt} = r_{G,t} * G_t \\ r_{G,t} = \begin{cases} r_{G,0} * (1 + \kappa_G * \exp(-\varphi_G t)) + f_2(E) & G_t \le G_{cap} \\ \mathrm{Min}(0, r_{G,0} * (1 + \kappa_G * \exp(-\varphi_G t)) + f_2(E)) & G_t > G_{cap} \end{cases} \end{cases} \quad (3)$$

$$\begin{cases} \dfrac{dCA_t}{dt} = r_{CA,t} * CA_t \\ r_{CA,t} = \begin{cases} r_{CA,0} * (1 + \kappa_{CA} * \exp(-\varphi_{CA} t)) + f_3(E, FA) & CA_t \le CA_{cap} \\ \mathrm{Min}(0, r_{CA,0} * (1 + \kappa_{CA} * \exp(-\varphi_{CA} t)) + f_3(E, FA)) & CA_t > CA_{cap} \end{cases} \end{cases} \quad (4)$$

where N_t, G_t, and CA_t are the population, GDP, and crop area in the t-th year, respectively; N_{cap}, G_{cap}, and CA_{cap} denote the environmental capacities of population, GDP, and crop area, respectively; $r_{P,0}$, $r_{G,0}$, and $r_{CA,0}$ represent the growth rates of population, GDP, and crop area in the baseline year, respectively, which are observed from historical data; $r_{P,t}$, $r_{G,t}$, and $r_{CA,t}$ are the growth rates of population, GDP, and crop area in the t-th year, respectively; κ_P*exp(-$\varphi_P t$), κ_G*exp(-$\varphi_G t$), and κ_{CA}*exp(-$\varphi_{CA} t$) are used to depict the impacts of technological development on the evolution of population, GDP, and crop area, respectively; E is environmental awareness; FA is food shortage awareness; and f_1, f_2, and f_3 represent the feedback functions.

3.2 Response to the second comment:

Thanks for your supportive suggestion. Taking equation (3) as an example. The exponential term (e.g., exp(-$\varphi_G t$)) is used to depict the impacts of technology development on GDP evolution, and further determine the growth rate of GDP. GDP is assumed to increase but with a decreasing rate, as the difficulty for increasing GDP is increasing as time goes (He et al., 2017; Lin et al., 2016), which can be fitly accounted by the exponential term (i.e., exp(-$\varphi_G t$) is non-negative and decrease over time, keeping GDP increasing with a decreasing rate).

3.3 Response to the third comment:

Thanks for your supportive comment. We have taken your valuable suggestion removed the negative sign in equation (5) for water use quota simulation. The exponential term would dampen the decreasing rate of water use quota (rather than water use quota) as '3.2 Response' discussed, as the difficulty of saving water by the advances in technology is increasing over time. We have given more details for water use quota simulation in line 193~196. Water use quotas are also assumed to decrease with the technological development owing to the expansion economy (Blanke et al., 2007; Hsiao et al., 2007). As the difficulties in saving water by technological advancement are increasing, the changing rate of water use quota is decreasing in equation (5) (Feng et al., 2019).

$$\begin{cases} \frac{dWQ_{i,j}^{t}}{dt} = WQ_{i,j}^{t} * r_{qwu,t} \\ r_{qwu,t} = r_{qwu,0}(1 - \kappa_{qwu} * \exp(-\varphi_{qwu} t)) \end{cases} \quad (5)$$

where $WQ_{i,j}^{t}$ denotes the water use quota of the j-th water user in the i-th operational zone in the t-th year; $r_{qwu,0}$ and $r_{qwu,t}$ are the growth rates of water use quotas in the baseline year and t-th year, respectively; and κ_{qwu}*exp(-$\varphi_{qwu}t$) is used to depict the water-saving effect of technological development on the evolution of water use quota.

3.4 Response to the fourth comment:

Thanks for your supportive suggestion. We have taken this valuable suggestion and removed the feedback driven by the changing rate of GDP as is shown in Figure 1. The model has been re-built and the results have been updated.

3.5 Response to the fifth comment:

Thanks for your supportive suggestion. We have considered the different types of water use in each operational zone for water quota use simulation. We have improved equation (5) for water use quota by adding subscripts to show the distinctions between the different types of water use in different operational zones.

4. The description of the water resources allocation in section 2.1.2 is too simple. I cannot understand the rationale behind equations 6 and 7. Especially, reservoir operation is an important focus of this study, I suggest the authors give some more

detailed descriptions of the water resources allocation processes. Currently, it is difficult to see how the water shortage rate is calculated in equation 7.

4 Response:

Thanks for your supportive comment. We have taken your valuable suggestion. More details for Interactive River-Aquifer Simulation (IRAS) water resources allocation model have been added.

Temporal resolutions for IRAS model has been added in line 207~210. IRAS model runs on a yearly loop. The year is divided into user-defined time step, and each time step is broken into user-defined sub-time step, base on which water resources allocation conducts.

Detailed descriptions for water shortage estimation has been added in line 216~225. "The water shortage at the demand node should first be determined based on its water demand and total water supply. The total water supply comprises natural water inflow (i.e., local water availability) and water supply from reservoir. In each sub-time step (except the first), the average natural water inflow in the previous *sts*-1 sub-time steps is estimated as the extrapolated natural water inflow in the remaining sub-time steps using equation (6). The water shortage can then be determined by deducting the demand reduction, total real-time water inflow, and extrapolated natural water inflow from water demand using equation (7). The total water shortage rate can then be determined using equation (8)."

Details for water supply have been added in line 235~241 "The water shortage at the demand node requires water release from the corresponding reservoir nodes according to their hydrological connections. The amount of water released from the reservoir depends on the water availability for demand-driven reservoirs and operational rules for supply-driven reservoirs, respectively. The water release for the supply-driven reservoir is linearly interpolated based on Figure 2 and equations (9)–(15). Additional details on the IRAS model can be found in Matrosov et al. (2011)."

$$WE_{i,j}^{sts} = \left(\sum_{1}^{sts-1} WTSup_{i,j}^{sts} - \sum_{1}^{sts-1} WRSup_{i,j}^{sts}\right) * \frac{(Tsts - sts + 1)}{(sts - 1)} \tag{6}$$

$$WS_{i,j}^{sts} = \frac{WD_{i,j}^{ts}(1 - f_{red}) - \sum_{1}^{sts} WTSup_{in}^{sts} - WE_{i,j}^{sts}}{Tsts - sts + 1} \tag{7}$$

$$WSR_{i,j}^{t} = \frac{\sum_{ts}\sum_{sts} WS_{i,j}^{sts}}{\sum_{ts} WD_{i,j}^{ts}} \quad (8)$$

where *ts* is the current time step; *Tsts* denotes the total number of the sub-time steps; *sts* is the current sub-time step; $WE_{i,j}^{sts}$ represents the extrapolated natural water inflow for the *j*-th water use sector in the *i*-th operational zone; $WTSup_{i,j}^{sts}$ is the total water supply; $WRSup_{i,j}^{sts}$ is the water supply from reservoir; $WD_{i,j}^{ts}$ is the water demand; f_{red} is the demand reduction factor; $WS_{i,j}^{st}$ is the water shortage; and $WSR_{i,j}^{t}$ is the water shortage rate in the *t*-th year.

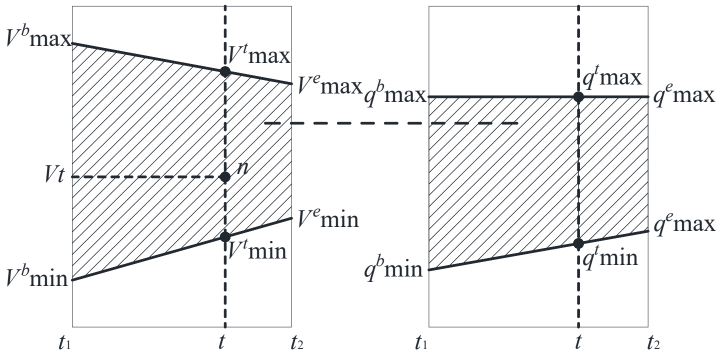


Figure 2. Water release rule for supply-driven reservoir.

$$P_t = (t - t_1)/(t_2 - t_1) \quad (9)$$

$$V_{\max}^{t} = V_{\max}^{b} * (1 - P_t) + V_{\max}^{e} * P_t \quad (10)$$

$$V_{\min}^{t} = V_{\min}^{b} * (1 - P_t) + V_{\min}^{e} * P_t \quad (11)$$

$$q_{\max}^{t} = q_{\max}^{b} * (1 - P_t) + q_{\max}^{e} * P_t \quad (12)$$

$$q_{\min}^{t} = q_{\min}^{b} * (1 - P_t) + q_{\min}^{e} * P_t \quad (13)$$

$$P_v = (V^t - V_{\min}^{t})/(V_{\max}^{t} - V_{\min}^{t}) \quad (14)$$

$$q^t = q_{\min}^{t} * (1 - P_v) + q_{\max}^{t} * P_v \quad (15)$$

where t, t_1, and t_2 are the current time, initial time, and end time in the period, respectively; P_t denotes the ratio of current time length to period length; $V_{\max}^{t}$, $V_{\min}^{t}$, $V_{\max}^{b}$, $V_{\min}^{b}$, $V_{\max}^{e}$, and $V_{\min}^{e}$ represent the maximum and minimum storages at the current time, beginning, and ending of the period, respectively; $q_{\max}^{t}$, $q_{\min}^{t}$, $q_{\max}^{b}$, $q_{\min}^{b}$, $q_{\max}^{e}$, and $q_{\min}^{e}$ denote the maximum and minimum releases, respectively; P_v is the ratio of current storage; and q_t is the current release.

5. Equation 8 has the same problem as equation 5, please see comment (3).

5 Response:

Thanks for your supportive suggestion. We have improved equation (16) for energy use quota simulation as discussed in “3.3 Response”. The negative sign and feedback driven by changing rate of GDP have been removed.

$$\begin{cases} \dfrac{dEQ_{i,j}^{t}}{dt} = EQ_{i,j}^{t} * r_{e,t} \\ r_{e,t} = r_{e,0} * (1-\kappa_e \exp(-\varphi_e t)) \end{cases} \tag{16}$$

where $EQ_{i,j}^{t}$ is the energy use quotas of the j-th water user in the i-th operational zone in the t-th year; $r_{e,0}$ and $r_{e,t}$ denote the growth rates of energy use quotas in baseline year and the t-th year, respectively; κ_e*exp(-$\varphi_e t$) depicts the energy-saving effect of technological development

6. I am a bit confused about how energy consumption is defined in this study. In equation 9, energy consumption is calculated by multiplying water supply by energy use quota, so I assume that energy use quota is defined as the energy demand for supplying per unit of water. In this case, energy consumption in this study means the energy consumed by the water supply sectors only. However, in line 319, the authors introduce the energy consumption by the steel and petrochemical sectors. I think more clarifications are needed. In addition, would the situation of energy shortage have a negative effect on water supply? There is no energy considered in equations 2-7.

6 Response:

Thanks for your supportive comment. We have taken your valuable suggestion. We have re-built the WEFS nexus model by re-defining the energy consumption in Section 2.2 (i.e., line 258~263) and updated the results.

The energy system module focuses on the energy consumption during the water supply process for socioeconomic water users to further investigate the energy co-benefits of water resources allocation schemes (Zhao et al., 2020; Smith et al., 2016). Energy consumption for water heating and water end-use was not included in this study. Energy consumption is determined by the energy use quota and amount of water supply for the water use sectors (Smith et al., 2016).

Constant energy shortage can lead the increase of environmental awareness. Once the environmental awareness increases over its critical value, negative feedback on socioeconomic sectors will be triggered. The water demand will thus be decreased, and further water supply will be changed.

7. Equation 11. Similar to comment (3), technology development is supposed to benefit crop yield, but the exponential term here is dampening the crop yield.

7 Response:

Thanks for your supportive suggestion. We have improved equation (19) for crop yield simulation as discussed in "3.2 Response". The crop yield is assumed to increase with decreasing rate, as the difficulty of increasing crop yield is increasing over time.

$$\begin{cases} \dfrac{dCY_{i,j}^{t}}{dt} = CY_{i,j}^{t} * r_{pro,t} \\ r_{pro,t} = r_{pro,0} * (1 + \kappa_{pro} \exp(-\varphi_{pro} t)) \end{cases} \quad (19)$$

where $CY_{i,j}^{t}$ is the potential crop yields of the j-th crop in the i-th operational zone in the t-th year; $r_{pro,0}$ and $r_{pro,t}$ are the growth rates of crop yields in baseline year and the t-th year, respectively; $\kappa_{pro}*\exp(-\varphi_{pro}t)$ depicts the impacts of technological development on the evolution of crop yield

8. Environmental awareness put forward by van Emmerik et al. is intended to capture human sensitivity to environmental deterioration. In this study, the authors quantify environmental awareness by water shortage, food shortage and energy shortage (i.e., equation 14). I feel food shortage and energy shortage are more like social problems rather than environmental problems. It might be better if the authors change a name for this variable.

8 Response:

Thanks for your supportive suggestion. We agree with your opinion that "environmental awareness" describes societal perceptions of the environmental degradation within the prevailing value systems. This study is based on the concept of ”environmental awareness” proposed by Van Emmerik et al. (2014). We extend water, energy and food as part of environment, which further consists of the environmental awareness in this study. As “environmental awareness” has been a popular and recognized terminology in socio-hydrology, it may be difficult for find another terminology to replace “environmental awareness”.

9. Equation 18, 19 and 20 should be piecewise equations. I.e., when E is smaller than Ecrit, f(E) should be zero.

9 Response:

Thanks for your supportive suggestion. We have accomplished the piecewise equations in equations (26)-(28).

10. Equation 21-23. If GDP would have an effect on water, food and energy systems, I think it might be more reasonable to use the magnitude of GDP instead of its changing rate.

10 Response:

Thanks for your supportive comment. We have taken this valuable suggestion. As the effects of GDP on water use quota, energy use quota and crop yield have been considered by the exponential terms in equation (5), (16) and (19), the feedback function driven by the changing rate of GDP has been removed as is discussed in “3.4 Response”. We have re-built the model and updated the results.

11. Section 3. Human response to the issues of water, food and energy shortages is an important aspect of the model. I suggest the authors give some observable evidences to show human adaptive response towards the mismatch between demand for and availability of water resources. for example any policy?

11 Response:

Thanks for your supportive suggestion. We have added the descriptions for human response to the issues from water, energy and food systems by citing supportive references in line 372~383. Owing to population expansion, rapid urbanization, and economic development, the local demand for water, energy, and food is increasing enormously (Zeng et al., 2021; Zhang et al., 2018). The contradictions between increasing demand and limited resources will be intensified. Therefore, improving use efficiencies for water, energy and food in the mid-lower reaches of Hanjiang river basin is urgent (Zhang et al., 2018; Liu et al., 2019). The strictest water resources control system for water resources management policy, the total quantity control of water consumed policy, and the energy-saving and emission-reduction policy in China are implemented in the mid-lower reaches of Hanjiang river basin to promote the expansion of resource-saving technology and further improve the resource use efficiencies in water, energy, and food systems.

12. A more detailed description of figure 3 is needed.

12 Response:

Thanks for your supportive suggestion. More details of Figure 4 (i.e., the number of figures has been updated in revised manuscript) have been added in line 384~394.

The socioeconomic data (i.e., population, GDP, and crop area) for water demand projection were collected based on administrative units, whereas the hydrological data were typically collected based on river basins. To ensure that the socioeconomic and hydrological data are consistent in operational zones, the study area was divided into 28 operational zones based on the superimposition of administrative units and sub-basins. Seventeen existing medium or large size reservoirs (the total storage volume is 37.3 billion m^3) were considered to regulate water flows. Based on the water connections between operational zones and river systems, the study area is shown in Figure 4, including 2 water transfer projects (the South–North and Changjiang–Hanjiang water transfer projects), 17 reservoirs, and 28 operational zones.

13. Table 2. These are parameters and they may need to be listed in table 3. In table 2, the authors may need to show the initial conditions of the state variables, i.e., population, GDP, crop area, etc.

13 Response:

Thanks for your supportive comment. We have taken your valuable suggestion. The initial conditions so as corresponding descriptions in Table 2 have been accomplished, including population, GDP, crop area, environmental capacities and growth rates of population, GDP and crop area, water use quota, energy use quota, crop yield and their growth rates, planning energy availability and planning food production.

14. Table 2 and 3 are too simple. At least the authors need to give a brief description of these parameters, as it is in table 5.

14 Response:

Thanks for your supportive suggestion. We have given more details to improve Table 2 and 3 in line 426 and 448, including the notations, descriptions, units and values for the parameters.

15. There are only ten years data (i.e., 2010-2019, in yearly time step), but there are 35 parameters that need to be calibrated, which means this is a very complicated overparameterized model. I guess most of the parameters are insensitive. Perhaps an initial sensitivity analysis is needed to screen out those insensitive parameters before conducting calibration.

15 Response:

Thanks for your supportive suggestion. We agree your opinion. Indeed, we took the method as mentioned in the comment to calibrate the model.

We have added the description for the details in model calibration in line 431~436. An initial parameter sensitivity analysis was adopted to screen out the insensitive parameter, which provided distinguishing 13 insensitive and 21 sensitive parameters. The setting of the insensitive parameter was based on expert knowledge and the study of Feng et al. (2019), which has been established to have good performance and suitability. The sensitive parameters in the model were then calibrated based on expert knowledge and the observed data, and the calibrated values are presented in Table 3.

16. Section 4.3. The authors explore the system sensitivity to seven parameters. I wonder why these seven parameters are chosen? Especially, all of them are threshold parameters. Are there any management implications obtained? I think it might be more informative if the sensitivities of the parameters related to human management actions are explored.

16 Response:

Thanks for your supportive suggestion. We agree your opinion that it's more informative if the sensitivities of the parameters related to human management actions, which indeed motivates us the parameter choosing. We have added the description on the motivation for parameter selection in sensitivity analysis in line 573~576 "As the critical values and boundary conditions of the WEFS nexus are considered vital factors for policymakers and managers to control the integrated system to achieve the concordant development goals, seven parameters were selected for sensitivity analysis (Table 5)."

17. Table 6. I am a bit confused about how the shortage rate is calculated. In some cases, the shortage rate is derived by dividing shortage by demand, and in some cases it is not. For example, in scenario I, the shortage of rural users is 0, why the shortage rate is 0.23%?

17 Response:

Thanks for your supportive suggestion. The water shortage is 0.347 million m^3 (151*0.23%=0.374). And it's rounded down to 0.

Additional minor comments:

18. Line 63. The authors claim that system of systems model and agent-based model do not consider the feedbacks of integrated systems. I do not think this is true. A more appropriate literature review may be needed.

18 Response:

Thank for your supportive suggestion. We agree with your opinion that system of systems model and agent-based model have also considered the feedback in solving WEF nexus. As is stated in line 68~71, system dynamic model is a more appropriate and efficient tool to describe the feedback among variables, when compared with system of systems model and the agent-based model, which prefers to focus on optimization and pre-defined rules, respectively.

19. In equation 4, crop area is denoted by A, but in equation 12, it is denoted by CA. please make it consistent.

19 Response:

Thank for your supportive suggestion. The equations for crop area simulation have been improved to keep the notations consistent.

20. Line 251. The authors claim that environmental awareness proposed by van Emmerik et al. is more specific than community sensitivity. This is not the case. In

fact, community sensitivity is proposed by Elshafei et al. through a more extensive literature review, and it is considered more sophisticated and is used more widely.

20 Response:

Thank for your supportive suggestion. We have improved the description on social state variable selection in line 303~310.

Environmental awareness describes societal perceptions of environmental degradation within the prevailing value systems (Feng et al., 2019; Feng et al., 2016; Roobavannan et al., 2018; Van Emmerik et al., 2014). Community sensitivity indicates people's attitudes towards not only the environmental control, but also the environmental restoration (Chen et al., 2016; Elshafei et al., 2014; Roobavannan et al., 2018). As this study focuses on societal perceptions on environmental degradation, environmental awareness based on the concept described in Van Emmerik et al. (2014) was adopted as the social state variable.

21.Figure 4. Please try not to use abbreviations in the figure. It is very difficult to read.

21 Response:

Thank for your supportive suggestion. Abbreviations in Figure 5 (i.e., the number of figures has been updated in revised manuscript) has been avoided.

22.I notice that in some places, the authors use the word "resilience". This is a complex concept, and as it is not the focus of this study, I suggest the authors use some simpler words.

22 Response:

Thank for your supportive suggestion. We have replaced "resilience" and "resilient" with other words in the paper.

Reviewer 2

This manuscript presents a new approach for modeling water-energy-food nexus by incorporating social feedback loops driven by environmental awareness and a water resources allocation model into the system. It's a interesting topic for researchers in the related areas, and the proposed approach has potential application value in other basins. The manuscript is clearly organized and the study background is described comprehensively in the Introduction. However, the method is not clearly explained in some places, and there are some detailed errors in words. Below are some detailed comments:

Thank you very much for your positive remarks on our paper. We have thoroughly revised the paper based on your comments. We believe the current comments have greatly helped improve the quality of the paper. Here are the responses to your comments:

1. The impact of water supply on energy consumption is related to industrial water, not ecological water or domestic water. Please clearly distinguish the impacts of different types of water supply on energy and food.

1 Response:

Thank for your supportive suggestion. We have given more details to distinguish the impacts of different types of water supply on energy and food in line 133~136 and Figure 1. The water supply for socioeconomic water use sectors and agricultural water shortage rates as outputs from the water system module are taken as the inputs of the energy system module and food system module to determine the energy consumption and food production, respectively.

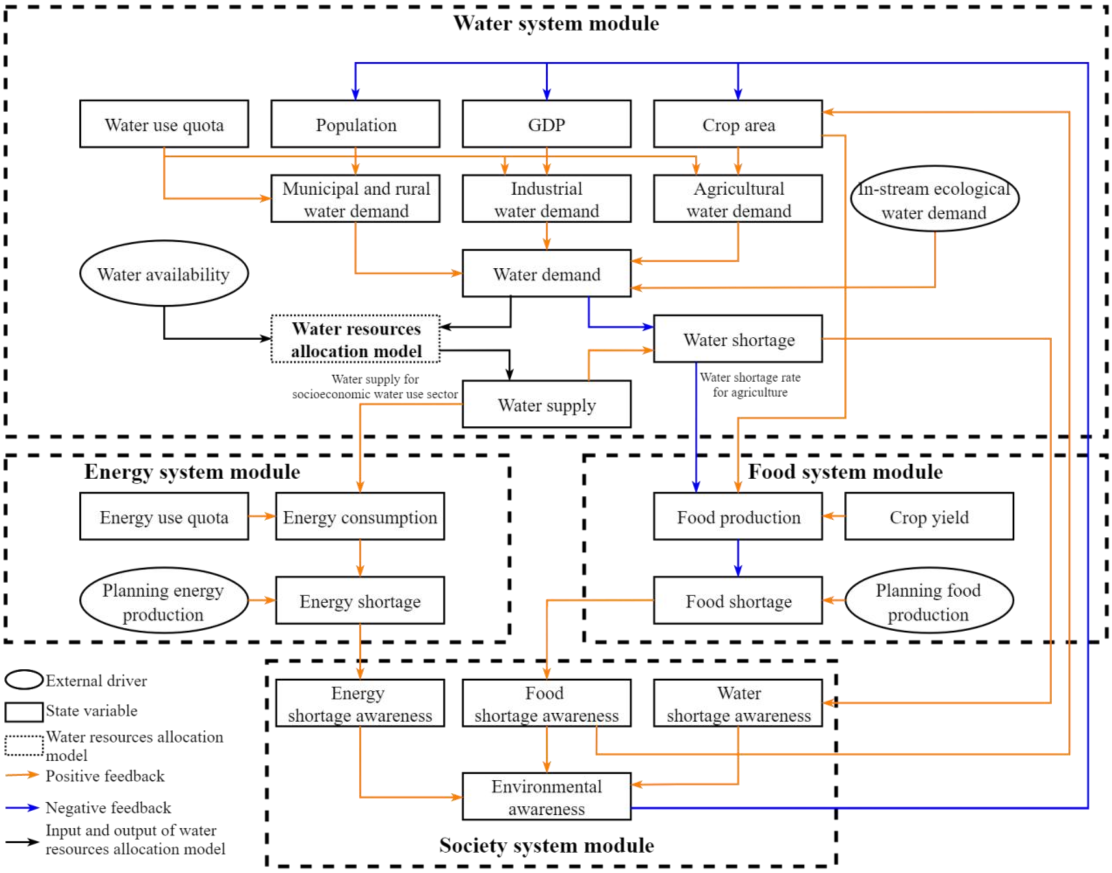


Figure 1. Structure of WEFS nexus model and its feedbacks.

2. In Figure 1, is the output of the water resources allocation model a total water supply or water supply of different sectors for every operational zone?

2 Response:

Thanks for your supportive suggestion. The outputs from water resources allocation model are the water supplies for different water use sectors in each operational zone. We have added the details to describe Figure 1 in line 130~132. The water demands and available water resources are further inputted into the water resources allocation model to determine the water supply and water shortage for every water use sector in each operational zone.

3. In the energy system module, water supply not only affects energy consumption, but also energy supply, such as in thermal power, hydro-power and some other sectors. It is need to consider the impact of water supply on planning energy production.

3 Response:

Thanks for your supportive suggestion. We agree with your opinion that water supply also plays an important role in energy production. The energy structure in the study area involves thermal power, hydro power, wind power, solar power and biomass power, which brings a great challenge to the data collection and further the energy production simulation. Therefore, as the paper focuses on assessing the impacts of environmental awareness and water resources allocation on WEFS nexus, we simplified the energy production as the boundary condition of the model (i.e., planning energy availability).

4. Please explain why GDP will affect the change of water quota in detail and provide some references for it.

4 Response:

Thanks for your supportive suggestion. We have added the supportive references indicating that community wealth, which can be indicated by GDP, is considered as the vital driving factor to promote water-saving technology in line 193~196. Water use quotas are assumed to decrease with the technological development owing to the expansion economy (Blanke et al., 2007; Hsiao et al., 2007). As the difficulties in saving water by technological advancement are increasing, the changing rate of water use quota is decreasing in equation (5) (Feng et al., 2019).

$$\begin{cases} \frac{dWQ_{i,j}^{t}}{dt} = WQ_{i,j}^{t} * r_{qwu,t} \\ r_{qwu,t} = r_{qwu,0}(1 - \kappa_{qwu} * \exp(-\varphi_{qwu} t)) \end{cases} \quad (5)$$

where $WQ_{i,j}^{t}$ denotes the water use quota of the j-th water user in the i-th operational zone in the t-th year; $r_{qwu,0}$ and $r_{qwu,t}$ are the growth rates of water use quotas in the baseline year and t-th year, respectively; and κ_{qwu}*exp(-$\varphi_{qwu}t$) is used to depict the water-saving effect of technological development on the evolution of water use quota.

5. Line 197-202: There are several variables in the equation (6) that are not explained.

5 Response:

Thanks for your supportive suggestion. We have corrected equations (6)-(8) for water shortage determination in IRAS water resources allocation model. The detailed description for the shortage determination is also added in line 216~225. The water shortage at the demand node should first be determined based on its water demand and total water supply. The total water supply comprises natural water inflow (i.e., local water availability) and water supply from reservoir. In each sub-time step (except the first), the average natural water inflow in the previous *sts*-1 sub-time steps is estimated as the extrapolated natural water inflow in the remaining sub-time steps using equation (6). The water shortage can then be determined by deducting the demand reduction, total real-time water inflow, and extrapolated natural water inflow from water demand using equation (7). The total water shortage rate can then be determined using equation (8).

$$WE_{i,j}^{sts} = \left(\sum_{1}^{sts-1} WTSup_{i,j}^{sts} - \sum_{1}^{sts-1} WRSup_{i,j}^{sts}\right) * \frac{(Tsts - sts + 1)}{(sts - 1)} \tag{6}$$

$$WS_{i,j}^{sts} = \frac{WD_{i,j}^{ts}(1 - f_{red}) - \sum_{1}^{sts} WTSup_{in}^{sts} - WE_{i,j}^{sts}}{Tsts - sts + 1} \tag{7}$$

$$WSR_{i,j}^{t} = \frac{\sum_{ts}\sum_{sts} WS_{i,j}^{sts}}{\sum_{ts} WD_{i,j}^{ts}} \tag{8}$$

where *ts* is the current time step; *Tsts* denotes the total number of the sub-time steps; *sts* is the current sub-time step; $WE_{i,j}^{sts}$ represents the extrapolated natural water inflow for the *j*-th water use sector in the *i*-th operational zone; $WTSup_{i,j}^{sts}$ is the total water supply; $WRSup_{i,j}^{sts}$ is the water supply from reservoir; $WD_{i,j}^{ts}$ is the water demand; f_{red} is the demand reduction factor; $WS_{i,j}^{st}$ is the water shortage; and $WSR_{i,j}^{t}$ is the water shortage rate in the *t*-th year.

6. For equation (9), why does the energy use quota of an optional zone multiplied by the water use quota of an optional zone equal total energy consumption? What is the definition of energy use quota in the paper? Please explain it.

6 Response:

Thanks for your supportive suggestion. We have carefully read your constructive comments. And we find that it's inappropriate to determine the energy end use based on water use process. Therefore, we have taken this valuable suggestion. We have re-built the WEFS nexus model by re-defining the energy consumption in line 258~263 and the results have been updated.

The energy system module focuses on the energy consumption during the water supply process for socioeconomic water users to further investigate the energy co-benefits of water resources allocation schemes (Zhao et al., 2020; Smith et al., 2016). Energy consumption for water heating and water end-use was not included in this study. Energy consumption is determined by the energy use quota and amount of water supply for the water use sectors (Smith et al., 2016), the energy use quota of which indicates the amount of energy consumption when per unit of water is supplied.

Despite the amount of energy consumption from water supply process is much smaller than the total amount of energy consumption in the study area, it's still an interesting topic to quantitatively assess the trade-offs between water supply and energy consumption under different water resources allocation schemes.

7. Line 238: the calculation formula of WSR isn't presented in the paper, please add it.

7 Response:

Thanks for your supportive suggestion. We have added the equation (8) to determine water shortage rate in line 228 as is discussed in "5 Response".

8. Line 328-331: Please add references to illustrate the contradictions between the increasing demands and limited resource supply will be aggravated in the study area

8 Response:

Thanks for your supportive suggestion. We have added references to illustrate that the contradiction between demands and limited resources will be intensified in study area with the impacts of climate change and the fast socioeconomic expansion in line 372~376. Owing to population expansion, rapid urbanization, and economic development, the local demand for water, energy, and food is increasing enormously (Zeng et al., 2021; Zhang et al., 2018). The contradictions between increasing demand and limited resources will be intensified. Therefore, improving use efficiencies for water, energy and food in mid-lower reaches of Hanjiang river basin is urgent (Zhang et al., 2018; Liu et al., 2019).

9. Are the impact of policy on water supply taken into account in the water allocation model, such as total quantity control of water consumed in the region?

9 Response:

Thanks for your supportive suggestion. We have indeed taken the corresponding policies for WEFS nexus. We have added the description for the resources management policies in the study area in line 376~381.

The strictest water resources control system for water resources management policy, the total quantity control of water consumed policy, and the energy-saving and emission-reduction policy in China are implemented in the mid-lower reaches of Hanjiang river basin to promote the expansion of resource-saving technology and further improve the resource use efficiencies in water, energy, and food systems.

10. Line 358: How long is the data used for parameter calibration? Please add it.

10 Response:

Thanks for your supportive suggestion. The observed data of annual water demand, energy consumption, food production, population, GDP and crop area from 2010 to 2019 are used to calibrate the model as is shown in line 440~443.

11. The conclusion section is too long now, please make it conciser and highlight the key conclusions.

11 Response:

Thanks for your supportive suggestion. We have carefully improved the conclusion part in line 807~827.

The proposed approach provides a valid analytical tool for exploring the long-term co-evolution of the nexus across the water, energy, food, and society systems. Environmental awareness in the society system can effectively capture human sensitivity to shortages from water, energy, and food systems. The feedback caused by environmental awareness can regulate the pace of socioeconomic expansion to maintain the integrated system from constant resources shortages, which contributes to the sustainability of the WEFS nexus co-evolution. The co-evolution of water demand, energy consumption, and food production can be divided into expansion (accelerating and natural expansion for food production), contraction, recession, and recovery phases based on environmental awareness. The co-evolution mode of the WEFS nexus functioning strongly depends on the selection of certain parameter values. The rational parameter setting of boundary conditions and critical values is important for managers to keep the socioeconomic sectors from violent expansion and deterioration, particularly in contraction and recession phases. Water shortage can be effectively relieved by the increased water supply through reservoir operation. Thus, the high-level environmental awareness caused by water shortage is remarkably alleviated. As negative feedback due to environmental awareness is weakened, the socioeconomic sectors develop rapidly. Water is no longer the vital factor constraining the concordant development of the WEFS nexus in the expansion phase. Therefore, water resources allocation is of great significance for the sustainable development of the WEFS nexus.

technical comments:

1. Line 124-125: There is no need to use the serial numbers "(1), (2)..." here, please getting rid of them.

12 Response:

Thanks for your supportive suggestion. We have deleted the serial numbers in line 126~127.

2. Line 174: The sentence “...are the of population...”is lack of some words.

13 Response:

Thanks for your supportive suggestion. We have corrected the sentence.

3. Figure 1: “Municipal water demand” projected by population is lack of rule water demand, which needs to be added.

14 Response:

Thanks for your supportive suggestion. We have added “Rural water demand” in Figure 1.

4. The font size of Equation (3)is not consistent with other equation

15 Response:

Thanks for your supportive suggestion. We have corrected the front size of the equation to keep it consistent with others.

5. Figure 4(i) : The text after “phase 1: ”is blank.

16 Response:

Thanks for your supportive suggestion. We have corrected it in Figure 5 (i) (i.e., the number of figures has been updated in revised manuscript).

6. Line 404: The word “phase”doesn't need an s.

17 Response:

Thanks for your supportive suggestion. We have deleted the “s”.

Reviewer 3

The authors create a multi-sector system dynamics model, including environmental awareness dynamics and coupled reservoir simulation. The model simulates, among other things, water demand, energy consumption, food production, environmental awareness, and population and GDP growth. The authors apply their model to the Hanjiang river basin and discuss the model simulation results at length. They identify stages of expansion, contraction, recession, and recovery for future water and energy dynamics as well as stages of expansion and stabilization for future food dynamics. The authors conduct a one-at-a-time parameter sensitivity analysis and also show that WEFS (water-energy-food-society) outcomes are strongly impacted by the presence or absence of reservoirs.

While this work aims to contribute in two primary areas – improved understanding of the impact of (1) environmental awareness feedbacks and (2) water supply reservoirs on WEF systems – I believe the work does not achieve these contributions, for the reasons described below:

- It is not clear what exactly about the approach is new. What separates the present study from those WEF studies cited in the introduction, other than the specific context and states modelled? It seems to me that the intended novelty might be coupling a WEF "system-dynamics" model with a detailed reservoir network simulation model, though this is not made clear in the paper. The discussions of model formulation and results do little to emphasize reservoir impacts, though the title suggests that reservoir impacts are central to the paper.

Thank you very much for your insightful and constructive comments on our paper. We have thoroughly revised the paper based on the comments. We believe the current comments have greatly helped improve the quality of the paper. Here are the responses to your comments:

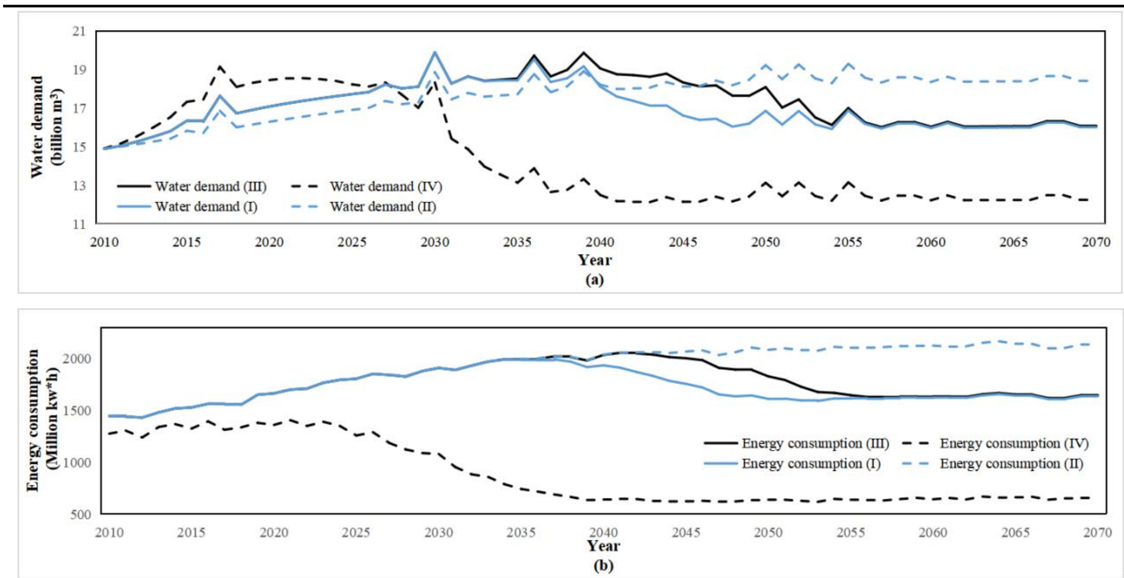
To further assess the impacts of environmental awareness feedbacks and water resources allocation on WEFS nexus, (1) a new Section 4.4.1 have been added to study the response of WEFS nexus to environmental awareness feedbacks by setting another two scenarios in Table 6 and (2) the average values of socioeconomic sectors have been counted in Table 7 to contribute to the quantitative assessment. The results have been updated in Figure 10.

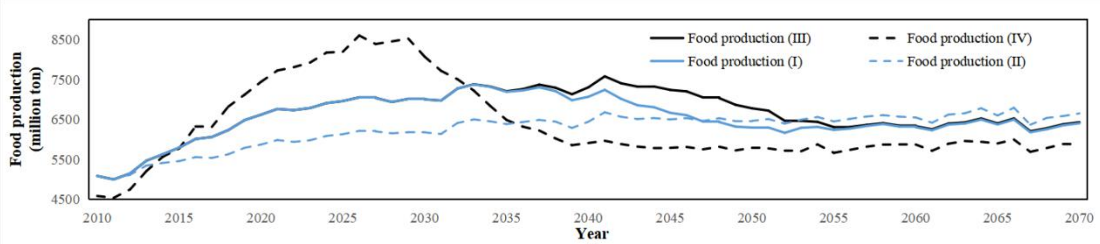
Table 6 Scenario description for assessing the impacts of environmental awareness feedback and water resources allocation on WEFS nexus.

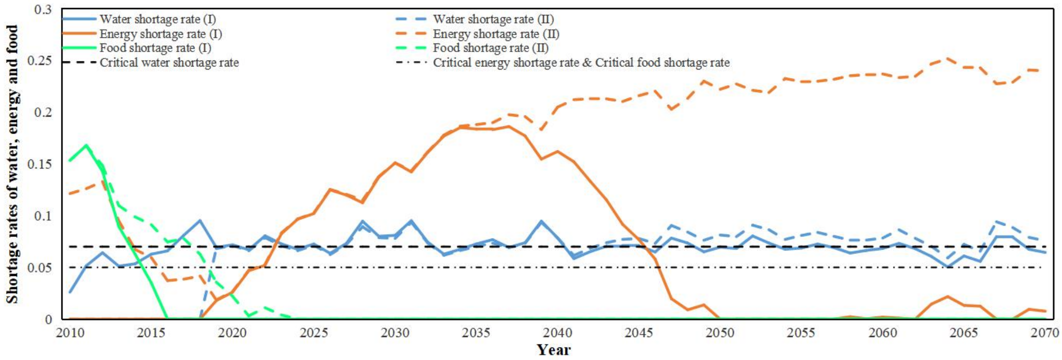
Scenario	Environmental awareness feedback	Water resources allocation	Parameter setting
I	Yes	Yes	Calibrated values
II	No	Yes	*Ecrit*, *FAcrit*: 10,000; others: calibrated values
III	Yes	Yes	*WSRcrit*: 0.15; others: calibrated values
IV	Yes	No	*WSRcrit*: 0.15; others: calibrated values

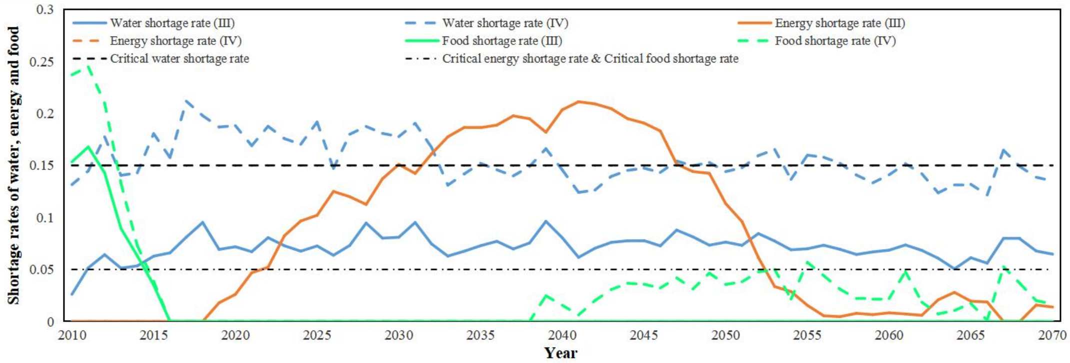
Table 7 Average annual values for the state variables in WEFS nexus.

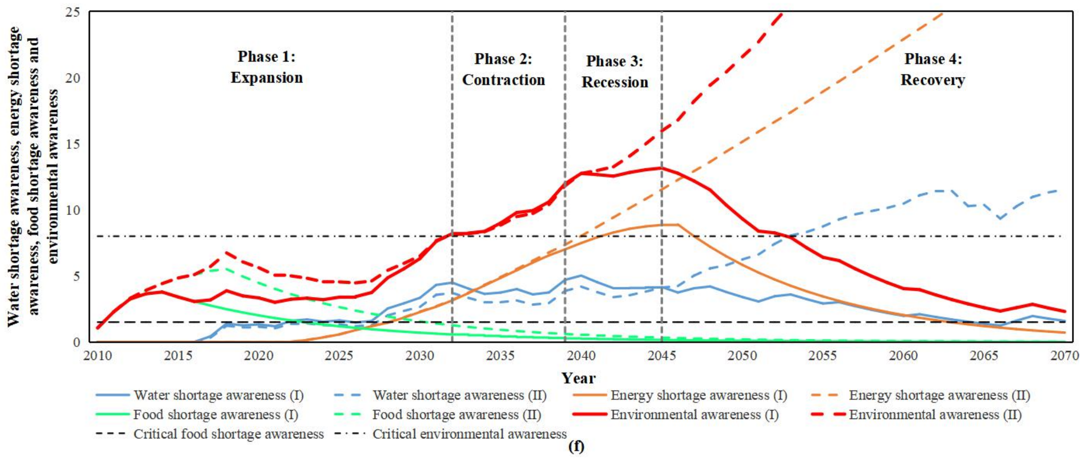
Scenario	Water demand (billion m^3)	Energy consumption (million kw*h)	Food production (million t)	Water shortage rate	Energy shortage rate	Food shortage rate
I	16.94	1,710	6,519	7.03%	5.80%	1.07%
II	17.66	1,930	6,248	7.44%	17.16%	1.74%
III	17.29	1,761	6,638	7.20%	8.25%	1.08%
IV	14.36	884	6,344	15.89%	0.00%	3.08%




Food production (million ton)
8500
7500
6500
5500
4500
Food production (III)
Food production (IV)
Food production (I)
Food production (II)
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Year
(c)


Shortage rates of water, energy and food
0.3
0.25
0.2
0.15
0.1
0.05
0
Water shortage rate (I)
Energy shortage rate (I)
Food shortage rate (I)
Critical water shortage rate
Water shortage rate (II)
Energy shortage rate (II)
Food shortage rate (II)
Critical energy shortage rate & Critical food shortage rate
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Year
(d)


Shortage rates of water, energy and food
0.3
0.25
0.2
0.15
0.1
0.05
0
Water shortage rate (III)
Water shortage rate (IV)
Energy shortage rate (III)
Energy shortage rate (IV)
Food shortage rate (III)
Food shortage rate (IV)
Critical water shortage rate
Critical energy shortage rate & Critical food shortage rate
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Year
(e)


Water shortage awareness, energy shortage awareness, food shortage awareness and environmental awareness
25
20
15
10
5
0
Phase 1: Expansion
Phase 2: Contraction
Phase 3: Recession
Phase 4: Recovery
2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070
Year
Water shortage awareness (I)
Water shortage awareness (II)
Energy shortage awareness (I)
Energy shortage awareness (II)
Food shortage awareness (I)
Food shortage awareness (II)
Environmental awareness (I)
Environmental awareness (II)
Critical food shortage awareness
Critical environmental awareness
(f)

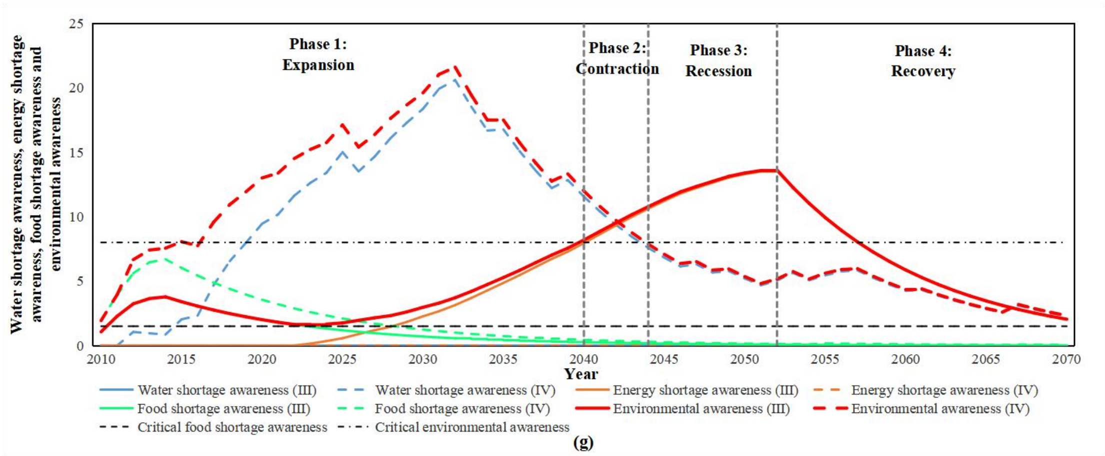


Figure 10. The trajectories of state variables in WEFS nexus under scenario I, II, III and IV: (a) water demand; (b) energy consumption; (c) food production; (d) and (e) shortage rates of water, energy and food; (f) and (g) water shortage awareness, energy shortage awareness, food shortage awareness and environmental awareness.

- **Socioeconomic model (section 2.1.1, equations (2)-(5)):**

1. The model formulation and justification overlooks well-established growth models subject to resource constraints. Why not use a logistic model for growth?

1 Response:

Thanks for your supportive suggestion. The Malthusian growth model is a succinct approach that has been widely applied to socioeconomic projections (Bertalanffy, 1976; Malthus, 1798). As the growth rate in the original Malthusian growth model is adopted as a constant, socioeconomic factors will reach infinity in a long-time evolution. Therefore, we assume that population, GDP, and crop area increase with decreasing rates over time, based on previous studies (He et al., 2017; Lin et al., 2016). And feedback functions, as well as environmental capacities of socioeconomic variables, are adopted to constrain the infinite evolution of these socioeconomic variables through equations (2)–(4) (Feng et al., 2016; Hritonenko and Yatsenko, 1999). Equations for population, GDP and crop area have been corrected in equation (2)-(4) and interpreted in line 170~178.

$$\begin{cases} \dfrac{dN_t}{dt} = r_{P,t} * N_t \\ r_{P,t} = \begin{cases} r_{P,0} * (1 + \kappa_P * \exp(-\varphi_P t)) + f_1(E) & N_t \le N_{cap} \\ \text{Min}(0, r_{P,0} * (1 + \kappa_P * \exp(-\varphi_P t)) + f_1(E)) & N_t > N_{cap} \end{cases} \end{cases} \quad (2)$$

$$\begin{cases} \frac{dG_t}{dt} = r_{G,t} * G_t \\ r_{G,t} = \begin{cases} r_{G,0} * (1 + \kappa_G * \exp(-\varphi_G t)) + f_2(E) & G_t \le G_{cap} \\ \mathrm{Min}(0, r_{G,0} * (1 + \kappa_G * \exp(-\varphi_G t)) + f_2(E)) & G_t > G_{cap} \end{cases} \end{cases} \tag{3}$$

$$\begin{cases} \frac{dCA_t}{dt} = r_{CA,t} * CA_t \\ r_{CA,t} = \begin{cases} r_{CA,0} * (1 + \kappa_{CA} * \exp(-\varphi_{CA} t)) + f_3(E, FA) & CA_t \le CA_{cap} \\ \mathrm{Min}(0, r_{CA,0} * (1 + \kappa_{CA} * \exp(-\varphi_{CA} t)) + f_3(E, FA)) & CA_t > CA_{cap} \end{cases} \end{cases} \tag{4}$$

where N_t, G_t, and CA_t are the population, GDP, and crop area in the t-th year, respectively; N_{cap}, G_{cap}, and CA_{cap} denote the environmental capacities of population, GDP, and crop area, respectively; $r_{P,0}$, $r_{G,0}$, and $r_{CA,0}$ represent the growth rates of population, GDP, and crop area in the baseline year, respectively, which are observed from historical data; $r_{P,t}$, $r_{G,t}$, and $r_{CA,t}$ are the growth rates of population, GDP, and crop area in the t-th year, respectively; κ_P*exp(-$\varphi_P t$), κ_G*exp(-$\varphi_G t$), and κ_{CA}*exp(-$\varphi_{CA} t$) are used to depict the impacts of technological development on the evolution of population, GDP, and crop area, respectively; E is environmental awareness; FA is food shortage awareness; and f_1, f_2, and f_3 represent the feedback functions.

We agree with your opinion that logistic model is very popular in growth simulation for socioeconomic sectors. However, socioeconomic variables will always prone to approach their environmental capacity values in logistic model, which makes it harder to distinguish the impacts of environmental awareness feedback on socioeconomic sectors. We assume the growth rate increase with decreasing rate, which is based on the previous studies (He et al., 2017; Lin et al., 2016). The socioeconomic variables thereby keep increasing, the decreases of which are explicitly led by environmental awareness feedback (As is shown in Figure 5 in line 470, population, GDP and crop area have been decreased by high-level environmental awareness).

2. Each of these growth rates seem likely to be as or more effected by the *actual* resource limitations (i.e., shortages) than by the "environmental awareness" of those limitations. Yet, the physical limitations are not factored into these equations.

2 Response:

Thanks for your supportive suggestion. We agree with your opinion that the physical limitations can affect the socioeconomic growth more quickly and directly, which is of great significance for the short-term socioeconomic growth simulation. However, the physical limitations can't describe the process that human sensitivity responds to the environmental degradation within the prevailing value systems. Therefore, we used environmental awareness to describe societal perceptions of the environmental degradation to further drive the feedback on socioeconomic sectors, which is also an informative approach for the long-term socioeconomic growth simulation.

3. I believe rates of change should be proportional to the state at time t, not the initial condition.

3 Response:

Thanks for your supportive suggestion. We agree with your opinion. The changing rates for these socioeconomic variables in the paper are indeed considered changing over time. We have improved the forms of equation (2), (3), (4), (5), (16) and (19) for population, GDP, crop area, water use quota, energy use quota and crop yield as is discussed in "1 Response", respectively, to indicate the changing rate explicitly.

4. The impact of technology development is either formulated unrealistically or discussed inaccurately – current formulation/discussion implies that technology suppresses growth.

4 Response:

Thanks for your supportive suggestion. That technology development will promote the growth of socioeconomic sectors, but with decreasing rate as is discussed in "1 Response". The exponential terms $\exp(-\varphi_P t)$, $\exp(-\varphi_G t)$ and $\exp(-\varphi_{CA} t)$ in equations (2), (3) and (4) are used to depict the impacts of technology development on the evolution of population, GDP and crop area, and further determine their growth rates. Population, GDP and crop area are assumed to increase but with decreasing rates, as the difficulty for the increases is increasing as time goes (He et al., 2017; Lin et al., 2016), which can be fitly accounted by the exponential term (i.e., $\exp(-\varphi t)$ is non-negative and decrease over time, keeping socioeconomic sectors increasing with a decreasing rate).

5. The water quota dynamics are especially unjustified – an exponential growth/decay model seems ill-fit.

5 Response:

Thanks for your supportive suggestion. We have improved the form of equation (5) for water use quota estimation. The exponential term would dampen the decreasing rate of water use quota (rather than water use quota), as the difficulty of saving water by the advances in technology is increasing over time. We have given more details for water use quota simulation in line 193~196 "Water use quotas are also assumed to decrease with the technological development owing to the expansion economy (Blanke et al., 2007; Hsiao et al., 2007). As the difficulties in saving water by technological advancement are increasing, the changing rate of water use quota is decreasing in equation (5) (Feng et al., 2019)."

$$\begin{cases} \frac{dWQ_{i,j}^{t}}{dt} = WQ_{i,j}^{t} * r_{qwu,t} \\ r_{qwu,t} = r_{qwu,0}(1 - \kappa_{qwu} * \exp(-\varphi_{qwu} t)) \end{cases} \quad (5)$$

where $WQ_{i,j}^{t}$ denotes the water use quota of the j-th water user in the i-th operational zone in the t-th year; $r_{qwu,\,0}$ and $r_{qwu,\,t}$ are the growth rates of water use quotas in the baseline year and t-th year, respectively; and κ_{qwu}*exp(-$\varphi_{qwu}t$) is used to depict the water-saving effect of technological development on the evolution of water use quota.

- **Water shortage model (section 2.1.2, equations (6)-(7)):**

1. The index for summation is not declared, making the equations difficult to interpret.

6 Response:

Thanks for your supportive suggestion. We have taken your valuable suggestion. Detailed descriptions for water shortage determination have been added in line 216~225. The water shortage at the demand node should first be determined based on its water demand and total water supply. The total water supply comprises natural water inflow (i.e., local water availability) and water supply from reservoir. In each sub-time step (except the first), the average natural water inflow in the previous *sts*-1 sub-time steps is estimated as the extrapolated natural water inflow in the remaining sub-time steps using equation (6). The water shortage can then be determined by deducting the demand reduction, total real-time water inflow, and extrapolated natural water inflow from water demand using equation (7). The total water shortage rate can then be determined using equation (8).

$$WE_{i,j}^{sts} = (\sum_{1}^{sts-1} WTSup_{i,j}^{sts} - \sum_{1}^{sts-1} WRSup_{i,j}^{sts}) * \frac{(Tsts - sts + 1)}{(sts - 1)} \quad (6)$$

$$WS_{i,j}^{sts} = \frac{WD_{i,j}^{ts}(1 - f_{red}) - \sum_{1}^{sts} WTSup_{in}^{sts} - WE_{i,j}^{sts}}{Tsts - sts + 1} \quad (7)$$

$$WSR_{i,j}^{t} = \frac{\sum_{ts}\sum_{sts} WS_{i,j}^{sts}}{\sum_{ts} WD_{i,j}^{ts}} \quad (8)$$

where *ts* is the current time step; *Tsts* denotes the total number of the sub-time steps; *sts* is the current sub-time step; $WE_{i,j}^{sts}$ represents the extrapolated natural water inflow for the *j*-th water use sector in the *i*-th operational zone; $WTSup_{i,j}^{sts}$ is the total water supply; $WRSup_{i,j}^{sts}$ is the water supply from reservoir; $WD_{i,j}^{ts}$ is the water demand; f_{red} is the demand reduction factor; $WS_{i,j}^{st}$ is the water shortage; and $WSR_{i,j}^{t}$ is the water shortage rate in the *t*-th year.

2. The variable definitions are inconsistent and contradictory. Wdem is said to be water demand in line 201, yet WD also appears in equation (7) and is defined as water demand. There is also a Wd variable which is never defined.

7 Response:

Thanks for your supportive suggestion. We have checked and corrected the variables definitions of all equations to make them clear and consistent.

3. The temporal resolutions (time step and sub time step) are not explained and are therefore confusing.

8 Response:

Thanks for your supportive suggestion. We have added the description about the temporal resolutions of IRAS water resources allocation model in line 207~210. The IRAS model runs on a yearly loop. The year is divided into user-defined time step, and each time step is broken into user-defined sub-time step, based on which water resources allocation conducts.

The temporal resolutions of the established WEFS nexus in the study area have also been added in line 413~419. The established WEFS nexus ran on a yearly loop. Specifically, as the water resources allocation model in the water system module took a monthly time step in the study (and the sub-time step was the default value: 1 day), the annual water supply and water shortage were first determined before being output to the energy system and food system modules, respectively. The annual shortage rates of water, energy, and food were then used to determine environmental awareness and further the feedback.

4. The distinction between "natural" and "total" water inflow is unclear.

9 Response:

Thanks for your supportive suggestion. We have added more details to describe the water shortage estimation in water resources allocation model, as is discussed in "6 Response". Specifically, the total water supply comprises natural water inflow (i.e., local water availability) and water supply from reservoir. In each sub-time step (except the first), the average natural water inflow in the previous *sts*-1 sub-time steps is estimated as the extrapolated natural water inflow in the remaining sub-time steps to further estimate the water shortage.

- **Energy system and Food system modules (sections 2.3 and 2.3, equations (8)-(13));**

1. These modules apply opposite approaches, without justification. The energy module simulates energy demand and takes energy production as an input ("planning energy production"). In contrast, the food module simulates food production and takes food demand as an input (misleadingly named "planning food production"). Why not simulated food demand or energy production?

10 Response:

Thanks for your supportive suggestion. In the study, the "planning energy production" indicates the available energy, while the "planning food production" indicate the target production. We have taken your valuable suggestion to replace "planning energy production" with "planning energy availability" to avoid the misleading.

We agree with your opinion that energy production and food production play an important role in WEFS nexus. The model in the study is proposed for WEFS nexus simulation at basin-scale. However, the imports and exports of energy and food for a basin are always quite complex. For instance, the study area (i.e., the mid-lower reaches of Hanjiang river basin) is considered as an important grain producing area, occupying one of the nine major commodity grain bases in China. The local food demand can always be ensured, and most of food production is exported, the total demand of which is hard to be simulated. For energy production, the energy structure in the study area involves thermal power, hydro power, wind power, solar power and biomass power, which brings a great challenge to the data collection. As the energy import and export of the study area is also quite complex, the energy production is hard to be determined.

Therefore, as the paper focuses on assessing the impacts of environmental awareness and water resources allocation on WEFS nexus, we simplified the food demand and energy production as the boundary conditions of the model (i.e., planning food production and planning energy availability, respectively).

2. No justification is provided for formulating energy demand as a function of water supply, as opposed to population or GDP for instance. Water supply seems like a more important factor for energy production, though energy production is not modelled.

11 Response:

Thanks for your supportive suggestion. We have carefully read your comment and found that water supply indeed plays a more important role in energy production, rather than consumption. Therefore, we have taken this valuable suggestion. We have re-built the WEFS nexus model by re-defining the energy consumption in Section 2.2 (i.e., line 258~263) and updated all the results.

We focus on the energy consumption during the water supply process for socioeconomic water users to further investigate the energy co-benefits of water resources allocation schemes (Zhao et al., 2020; Smith et al., 2016). Energy consumption for water heating and water end-use was not included in this study. Energy consumption is determined by the energy use quota and amount of water supply for the water use sectors (Smith et al., 2016).

Despite the amount of energy consumption from water supply process is much smaller than the total amount of energy consumption in the study area, it’s still an interesting topic to quantitatively assess the trade-offs between water supply and energy consumption under different water resources allocation schemes.

3. I would think that the entire crop yield dynamics are due to technology changes (ignoring water shortage), yet technology change is offered as a single term in equation (11).

12 Response:

Thanks for your supportive comment. We have taken your valuable suggestion and improved equation (19) for crop yield (so as the water use quota and energy use quota). The model has been re-built by removing the feedback driven by the changing rate of GDP, and the results have been updated.

$$\begin{cases} \frac{dCY_{i,j}^{t}}{dt} = CY_{i,j}^{t} * r_{pro,t} \\ r_{pro,t} = r_{pro,0} * (1 + \kappa_{pro} \exp(-\varphi_{pro} t)) \end{cases} \quad (19)$$

where $CY_{i,j}^{t}$ is the potential crop yields of the j-th crop in the i-th operational zone in the t-th year; $r_{pro,0}$ and $r_{pro,t}$ are the growth rates of crop yields in baseline year and the t-th year, respectively; $\kappa_{pro}*\exp(-\varphi_{pro}t)$ depicts the impacts of technological development on the evolution of crop yield

4. From the results (Section 4, see especially Tables 2 and 5), it seems that a constant energy production and constant food demand are used to drive the model simulation. This seems unrealistic.

13 Response:

Thanks for your supportive suggestion. We agree with your opinion that the energy availability and food demand keep changing over time. As is discussed in "10 Response", the energy availability and food demand are taken as the boundary conditions of the model in our study. We have given a preliminary sensitive analysis on "planning energy availability (PEA)" and "planning food production (PFP)" in Section 4.3. The results indicate that PEA and PFP are the sensitive parameters in the co-evolution of WEFS nexus.

Therefore, we think it's an interesting and important topic to take time-varying energy availability and food demand into account under different policies. However, this paper focuses on impacts of environmental awareness feedback and water resources allocation on WEFS nexus. The time-varying energy production and food demand, and so as their simulations will be taken into account in our further study.

- **Model validation (Section 4.1):**

1. The methods used to develop the observed time series are unclear. For instance, how exactly were the agricultural water demand exceedance frequencies used?

14 Response:

Thanks for your supportive suggestion. The observed time series for population, GPD, crop area, water demand, energy consumption and food production from 2010 to 2019 are collected from the yearbook of Hubei province in China (http://data.cnki.net/). The agricultural water demand depends on not only the water use quota and crop area, but also the precipitation frequency. For simplicity, four frequencies (i.e., 95%, 90%, 70%, and 50%) are used to fit the yearly precipitation frequency series. Four types of agriculture water use quotas under the four frequencies (i.e., 95%, 90%, 70%, and 50%) in the baseline year are collected for water demand projection, which has been added as initial condition setup in Table 2.

2. The observed data is not sufficient to validate the model. The observed data cover a short period during the beginning of the simulation during which all states increase approximately linearly. The effects of shortage and environmental awareness are minimal during this period (as stated by the authors in their interpretations); therefore, the observations offer no validation of the awareness dynamics or feedback. That the model matches observed dynamics under this narrow, early set of conditions does not mean that the model can reliably simulate dynamics under drastically different conditions. For instance, a model which predicts perpetual linear growth in all states would seem to match the observations equally well. Given that the data does not validate the model, the model results are only useful to the extent that the model formulation seems true-to-reality. However, little justification is given for the model formulation, and as described above, there are many problematic elements of the model formulation.

15 Response:

Thanks for your supportive suggestion. We agree with your opinion that the reliability of the model will increase with the extension of observed data series for calibration. However, it's a challenge work to collect such long-term representative data, which thereby requires more descriptions on the justification of model formulation.

As is discussed above, we have improved and given more details for model formulations in Section 2. The forms of feedback functions are on basis of previous studies (Feng et al., 2019; Van Emmerik et al., 2014), which has been proved with good performance and suitability. As the resources availability in the beginning of co-evolution can almost cover the demand in the study area, environmental awareness indeed remains at a low level. The parameters for environmental awareness feedback are thus poorly calibrated by observed data in the beginning. However, with the fast socioeconomic expansion, the contradiction between demand side and supply side is going to intensify. The society system will then be more sensitive to environment degradation and seek for environment recovery by constraining socioeconomic expansion through feedback.

To demonstrate the justification of the environmental awareness feedback, we have given an initial parameter sensitivity analysis on feedback driven by environmental awareness as is discussed in Section 4.1 (line 431~437). With high-level parameters for feedback functions (i.e., δ_{rp}^{E}, δ_{rg}^{E} and δ_{ra}^{E}), the feedback is strong and may lead violent degradation of socioeconomic sectors. With low-level parameters for feedback functions, the feedback is too weak to constrain the socioeconomic expansion and keeps the constant resources shortages for the integrated system (e.g., the constant water shortage and energy shortage in scenario II as discussed in Section 4.4.1). Therefore, we selected the parameters from appropriate interval based on parameter sensitivity analysis to ensure the rational co-evolution of the integrated system, which is considered as the foreseen scenario from the planning perspective.

We have also added descriptions for current limitation in line 828~832. We acknowledge that the model calibration is challenging, as the data series is not sufficiently long and the forms and parameters of the feedback function are not prescribed. We consider that sufficient case studies will gradually emerge over time, which could gradually cover a range of scenarios and slowly provide reliability in the WEFS nexus modeling.

- **Model results (Sections 4.2-4.3):**

1. Most of the discussion of the results (co-evolution of WEF system) is a text description of what is seen in the figures. The discussion does little to draw out and emphasize insights.

16 Response:

Thanks for your supportive suggestion. Based on the trajectory of environmental awareness, the co-evolution processes of water demand and energy consumption can be divided into four phases: expansion, contraction, recession and recovery. Food production can be divided into five phases based on the trajectory of food shortage awareness: accelerating expansion, natural expansion, contraction, recession and recovery.

The discussion for each phase is conducted with the order as follow: (1) water demand is firstly estimated by socioeconomic sectors (i.e., population, GDP and crop area); (2) water supply and water shortage are determined by water resources allocation; (3) the water supply and agriculture water shortage rate are then used to determine energy consumption and food production, respectively; (4) combined with planning energy availability and planning food production, energy shortage and food shortage can be estimated; (5) the shortage awareness for water, energy and food are then be determined, and further the environmental awareness; (6) the feedback driven by environmental awareness is then triggered to regulate the growth of socioeconomic sectors and further the water demand.

From the results, we find that available water and energy are the vital resources constraining the long-term concordant development of the integrated system in the study area. And more attention should be paid to the time lag of community's response to the deterioration WEFS nexus to prevent the integrated system from collapsing, especially after the fast expansion of water demand and energy consumption, which can provide useful support for policymakers.

2. The sensitivity discussion does little to add understanding. Most interpretations of sensitivity results are vague, such that the same observations could be stated just from the variable definition and model formulation. For example, in lines 551-553, the effect of lowering the food shortage sensitivity threshold level is obvious from its definition.

17 Response:

Thanks for your supportive suggestion. We have updated Figure 6, 7, 8 and 9 by replacing the black lines with colored lines and color bars so as to give a more informative sensitivity analysis for identifying the explicit variations of state variables with varying parameters. Sensitive analysis on water demand is taken as an example in Figure 6 here.

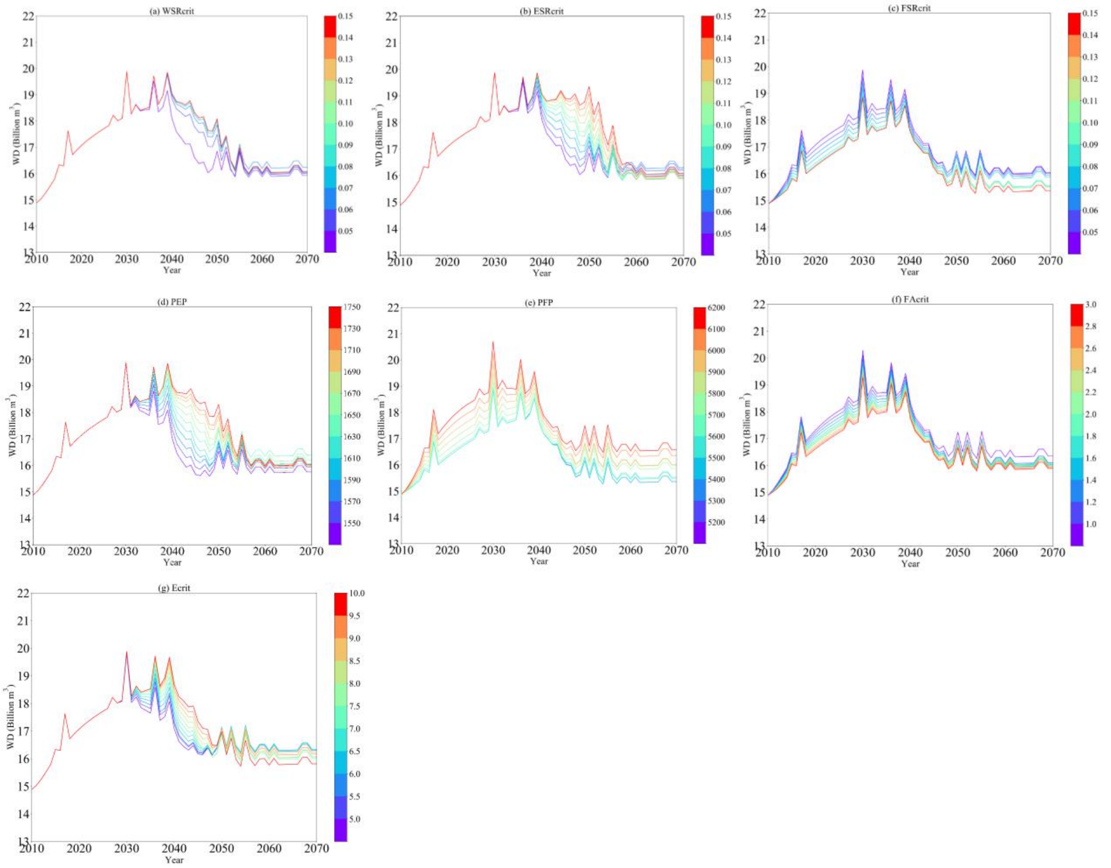


Figure 6. Trajectories of water demand with varied parameters. (Figure 7, 8 and 9 for trajectories of energy consumption, food production and environmental awareness have also updated)

We find that the co-evolution mode of WEFS nexus functioning strongly depends on the selection of certain parameter values. Rational parameter setting of boundary conditions and critical values is of great significance for managers to keep the socioeconomic sectors from violent expansion and deterioration, especially in contraction and recession phases.

- **Impacts of reservoir system (section 4.4):**

1. The methodology applied here is unclear, what exactly does it mean that one scenario considers allocation and the other doesn't?

18 Response:

Thanks for your supportive suggestion. We have given more details to describe how the methodology applied to the mid-lower reaches of Hanjiang river basin in line 384~389. The study area is divided 28 operational zones based on the administrative units and sub-basins. The socioeconomic data (i.e., population, GDP, and crop area) for water demand projection were collected based on administrative units, whereas the hydrological data were typically collected based on river basins. To ensure that the socioeconomic and hydrological data are consistent in operational zones, the study area was divided into 28 operational zones based on the superimposition of administrative units and sub-basins. Based on the water connections between operational zones and river systems, water resources allocation is conducted and further the WEFS nexus simulation.

The time resolutions of the model in the study area have also been added to help illustrate how the methodology is applied in line 413~419. The established WEFS nexus ran on a yearly loop. Specifically, as the water resources allocation model in the water system module took a monthly time step in the study (and the sub-time step was the default value: 1 day), the annual water supply and water shortage were first determined before being output to the energy system and food system modules, respectively. The annual shortage rates of water, energy, and food were then used to determine environmental awareness and further the feedback.

Scenario I considered water resources allocation is based on the real-world reservoir system, while scenario II removes the reservoir system from scenario I, so as to assess the impacts of water resources allocation on WEFS nexus.

2. Nonetheless, it seems that scenario I is running the model with the real-world reservoir network and scenario II is running the model with all reservoirs removed (?). If so, scenario II does not seem like a useful comparison. Is the region considering removing any or all dams in the basin?

17 Response:

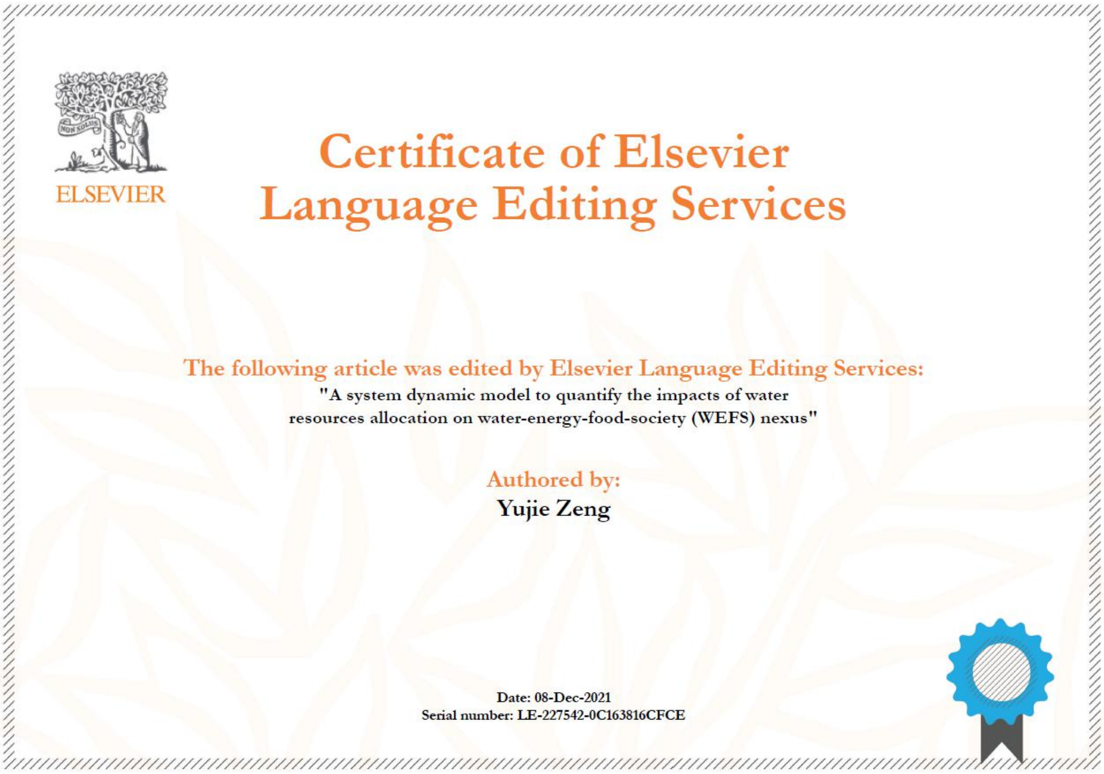
Thanks for your supportive suggestion. One of the goals of our study is to assess the impacts of water resources allocation on WEFS nexus, as previous studies haven't considered water resources allocation or significantly simplified reservoirs operational rules in water resources allocation. Compared with scenario I, water resources allocation is removed in scenario II so as to assess the impacts of water resources allocation on WEFS nexus. The results indicate water resources allocation is of great significance in ensuring water supply and further sustaining the WEFS nexus from the planning perspective.

The numbers as well as the operational rules of reservoirs in the study area may change over time in the future. It’s also a very interesting topic to investigate the impacts of changing reservoir system on WEFS nexus, which is a very informative study for managers from the planning perspective.

- There are language issues throughout the manuscript – most frequent were typos, poor sentence structure (lots of passive voice that creates confusion about who is the subject and what exactly they are doing), and inappropriate word choice. There are too many to list specifically.

18 Response:

Thanks for your supportive suggestion. We have carefully improved the writing quality in the revised manuscript.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The following article was edited by Elsevier Language Editing Services:
"A system dynamic model to quantify the impacts of water resources allocation on water-energy-food-society (WEFS) nexus"

Authored by:
Yujie Zeng

Date: 08-Dec-2021
Serial number: LE-227542-0C163816CFCE

Reviewer 4

This study modeled the WEF nexus by incorporating community sensitivity and reservoirs operation, where the co-evolution behaviors of the nexus across the water, energy, food, and society (WEFS) were simulated by the system dynamic model. The proposed approach was applied to the mid-lower reaches of the Hanjiang river basin in China, and the results indicated that water resources allocation could ensure water supply through reservoirs operation and greatly decrease the water shortage rate. This study is an interesting and crucial one for improving resources management. While modeling the WEF nexus in a large watershed is a very challenging problem and difficult to validate its suitability and applicability, especially when there are only limited datasets. This study made a great effort in this direction and proposed a sophisticated methodology with some preliminary analyzed results, which is a valuable contribution to the scientific community. However, I have some concerns and suggestions, which need to be better addressed, listed as follows.

Thank you very much for your positive remarks on our paper. We have thoroughly revised the paper based on your comments. We believe the current comments have greatly helped improve the quality of the paper. Here are the responses to your comments:

1. The initial conditions of external variables for the integrated system shown in Table 2 and the calibrated parameters presented in Table 3 should be explained in more details. I am curious why many parameters have the same calibrated value. How to set these values?

1 Response

Thanks for your supportive suggestion. We have added the notations, descriptions, units and values of variables and parameters in Table 2 and 3 in line 426 and 448.

We have added more details for model calibration in line 431~437. An initial parameter sensitivity analysis was adopted to screen out the insensitive parameter, which provided distinguishing 13 insensitive and 21 sensitive parameters. The setting of the insensitive parameter was based on expert knowledge and the study of Feng et al. (2019), which has been established to have good performance and suitability. The sensitive parameters in the model were then calibrated based on expert knowledge and the observed data, and the calibrated values are presented in Table 3 (insensitive parameters are set to 0.0856).

2. How many datasets are used for model calibration? The number of calibrated parameters used for model calibration should be discussed. How to justify the suitability and applicability of the calibrated model should be given.

2 Response

Thanks for your supportive suggestion. The observed data of annual water demand, energy consumption, food production, population, GDP and crop area from 2010 to 2019 are used to calibrate the model as is shown in line 440~443. We have added the details for model calibration, as is discussed in "1 Response",. 21 sensitive parameters are screened out and calibrated by fitting observed data, the calibration values of which are listed in Table 3.

We have also given more details for the suitability and applicability of the calibrated model in line 437~447. The Nash-Sutcliffe Efficiency (NSE) coefficient and percentage bias (PBIAS) are used to calibrate the model. When the NSE was >0.7 and absolute value of PBIAS was <15%, the modeling performance was considered reliable. The NSEs are always more than 0.7 and the corresponding PBIASs are within -15% to 15%, suggesting that the established model is reliable for simulating the co-evolution of the WEFS nexus.

3. The "Respond links" among the different variables in the WEFS nexus should be explained in much more detail. The terms of feedback functions based on previous work should further explain their suitability.

3 Response

Thanks for your supportive suggestion. The details of respond links have been added Section 2. Description for connection between water system and energy system as well as food system will be improved in line 130~136. The water demands and available water resources are further inputted into the water resources allocation model to determine the water supply and water shortage for every water use sector in each operational zone. The water supply for socioeconomic water use sectors and agricultural water shortage rates as outputs from the water system module are taken as the inputs of the energy system module and food system module to determine the energy consumption and food production, respectively.

Description for feedback driven by environment awareness has been improved in line 144~148. As environmental awareness accumulates over its critical value, negative feedback on socioeconomic sectors (i.e., population, GDP, and crop area) will be triggered to constrain the increases in water demand, and further energy consumption, and food production to sustain the WEFS nexus.

The description for the suitability of the feedback function have been added in line 332~336. The terms of feedback functions are based on the studies of Feng et al. (2019) and Van Emmerik et al. (2014), which have been established to have good performance and suitability, as they have been successfully applied to simulate the human response to environmental degradation in the Murrumbidgee river basin (Australia) and Hehuang region (China).

4. Figure 4 shows the trajectories of population, GDP, crop area, water demand, energy consumption, food production, shortage rates for water, energy, and food, awareness for water shortage, energy shortage, and food shortage as well as environmental awareness during 2010-2070. The trajectories are the basis of the following analyses. How to get these trajectories should be given in more detail, and their suitability should be discussed?

4 Response

Thanks for your supportive suggestion. The co-evolution of WEFS nexus is conducted based on system dynamic modeling (SDM), which conducts according to the nonlinear ordinary differential equations and dynamic feedback loops as is demonstrated in Section 2

More details about the application of the established WEFS nexus in the study area have been added in line 413~419. The SDM is applied to the mid-lower reaches of Hanjiang river basin. The established WEFS nexus ran on a yearly loop. Specifically, as the water resources allocation model in the water system module took a monthly time step in the study (and the sub-time step was the default value: 1 day), the annual water supply and water shortage were first determined before being output to the energy system and food system modules, respectively. The annual shortage rates of water, energy, and food were then used to determine environmental awareness and further the feedback.

5. How to divide the evolution of water demand and energy consumption into four phases should be given?

5 Response

Thanks for your supportive suggestion. The co-evolution processes of water demand and energy consumption can be divided into four phases (i.e., expansion, contraction, recession and recovery) based on the trajectory of environmental awareness.

We have emphasized the phase dividing rules in Section 4.2.

In line 477~479: With environmental awareness below its critical value, the negative feedback on socioeconomic sectors is not triggered, and water demand, as well as energy consumption, increases rapidly, which is defined as the expansion phase (2010–2032);

In line 502~504: As environmental awareness exceeds its critical value, negative feedback on socioeconomic sectors is triggered, and the increase in water demand and energy consumption is constrained, which is defined as the contraction phase (2033–2039);

In line 517~519: Environmental awareness accumulates to the maximum value and water demand, and energy consumption decrease significantly, which can be defined as the recession phase (2040–2045);

In line 527~529: As environmental awareness gradually decreases below its critical value, water demand and energy consumption decrease slightly and then tend to stabilize, which is defined as the recovery phase (2046–2070).

6. The seven controllable parameters adopted for sensitivity analysis should be discussed in more detail.

6 Response:

Thanks for your supportive suggestion. We have added more details for the parameter selection in sensitivity analysis in line 573~576. As the critical values and boundary conditions of WEFS nexus are considered as vital factors for policymakers and managers to control the integrated system so as to achieve the concordant development goals, seven parameters are selected for sensitivity analysis.

We have also updated the figures for sensitivity analysis by replacing the black lines with colored lines and color bars so as to give a more informative sensitivity analysis for identifying the explicit variations of state variables with varying parameters. Sensitive analysis on water demand is taken as an example in Figure 6 here.

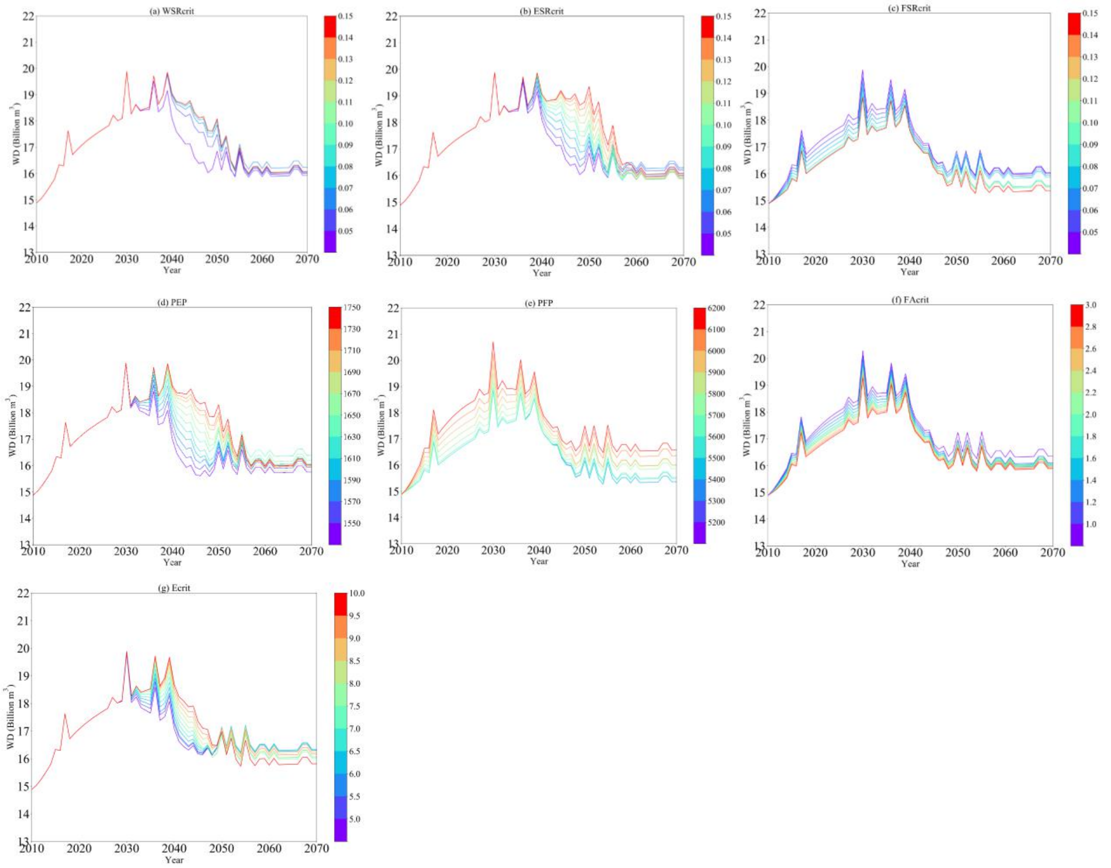

Figure 6. Trajectories of water demand with varied parameters. (Figure 7, 8 and 9 for trajectories of energy consumption, food production and environmental awareness have also been updated)

We find that the co-evolution mode of WEFS nexus functioning strongly depends on the selection of certain parameter values. Rational parameter setting of boundary conditions and critical values is of great significance for managers to keep the socioeconomic sectors from violent expansion and deterioration, especially in contraction and recession phases.

7. The conclusion seems like a long summary of the current study. The main contribution with brief (solid) scientific findings extracted from this study might be more interesting to read and easy to learn.

7 Response:

Thanks for your supportive suggestion. We have carefully improved the conclusion part in line 807~827.

The proposed approach provides a valid analytical tool for exploring the long-term co-evolution of the nexus across the water, energy, food, and society systems. Environmental awareness in the society system can effectively capture human sensitivity to shortages from water, energy, and food systems. The feedback caused by environmental awareness can regulate the pace of socioeconomic expansion to maintain the integrated system from constant resources shortages, which contributes to the sustainability of the WEFS nexus co-evolution. The co-evolution of water demand, energy consumption, and food production can be divided into expansion (accelerating and natural expansion for food production), contraction, recession, and recovery phases based on environmental awareness. The co-evolution mode of the WEFS nexus functioning strongly depends on the selection of certain parameter values. The rational parameter setting of boundary conditions and critical values is important for managers to keep the socioeconomic sectors from violent expansion and deterioration, particularly in contraction and recession phases. Water shortage can be effectively relieved by the increased water supply through reservoir operation. Thus, the high-level environmental awareness caused by water shortage is remarkably alleviated. As negative feedback due to environmental awareness is weakened, the socioeconomic sectors develop rapidly. Water is no longer the vital factor constraining the concordant development of the WEFS nexus in the expansion phase. Therefore, water resources allocation is of great significance for the sustainable development of the WEFS nexus.

References

Bertalanffy, L. V.: General System Theory: Foundations, Development, Applications, 3, George Braziller, New York, America1976.

Blanke, A., Rozelle, S., Lohmar, B., Wang, J., and Huang, J.: Water saving technology and saving water in China, Agric. Water Manag., 87, 139-150, 10.1016/j.agwat.2006.06.025, 2007.

Chen, X., Wang, D., Tian, F., and Sivapalan, M.: From channelization to restoration: Sociohydrologic modeling with changing community preferences in the Kissimmee River Basin, Florida, Water Resour. Res., 52, 1227-1244, 10.1002/2015wr018194, 2016.

Elshafei, Y., Sivapalan, M., Tonts, M., and Hipsey, M. R.: A prototype framework for models of socio-hydrology: identification of key feedback loops and parameterisation approach, Hydrology and Earth System Sciences, 18, 2141-2166, 10.5194/hess-18-2141-2014, 2014.

Feng, M., Liu, P., Li, Z., Zhang, J., Liu, D., and Xiong, L.: Modeling the nexus across water supply, power generation and environment systems using the system dynamics approach: Hehuang Region, China, Journal of Hydrology, 543, 344-359, 10.1016/j.jhydrol.2016.10.011, 2016.

Feng, M., Liu, P., Guo, S., Yu, D. J., Cheng, L., Yang, G., and Xie, A.: Adapting reservoir operations to the nexus across water supply, power generation, and environment systems: An explanatory tool for policy makers, Journal of Hydrology, 574, 257-275, 10.1016/j.jhydrol.2019.04.048, 2019.

He, S. Y., Lee, J., Zhou, T., and Wu, D.: Shrinking cities and resource-based economy: The economic restructuring in China's mining cities, Cities, 60, 75-83, 10.1016/j.cities.2016.07.009, 2017.

Hritonenko, N. and Yatsenko, Y.: Mathematical Modeling in Economics, Ecology and the Environment, Kluwer Academic Publishers, Dordrecht/Boston/London1999.

Hsiao, T. C., Steduto, P., and Fereres, E.: A systematic and quantitative approach to improve water use efficiency in agriculture, Irrig. Sci., 25, 209-231, 10.1007/s00271-007-0063-2, 2007.

Lin, J. Y., Wan, G., and Morgan, P. J.: Prospects for a re-acceleration of economic growth in the PRC, J. Comp. Econ., 44, 842-853, 10.1016/j.jce.2016.08.006, 2016.

Liu, D., Guo, S., Liu, P., Xiong, L., Zou, H., Tian, J., Zeng, Y., Shen, Y., and Zhang, J.: Optimisation of water-energy nexus based on its diagram in cascade reservoir system, Journal of Hydrology, 569, 347-358, 10.1016/j.jhydrol.2018.12.010, 2019.

Malthus, T.: An Essay on the Principle of Population, Penguin, Harmondsworth, England1798.

Matrosov, E. S., Harou, J. J., and Loucks, D. P.: A computationally efficient open-source water resource system simulator - Application to London and the Thames Basin, Environmental Modelling & Software, 26, 1599-1610, 10.1016/j.envsoft.2011.07.013, 2011.

Roobavannan, M., van Emmerik, T. H. M., Elshafei, Y., Kandasamy, J., Sanderson, M. R., Vigneswaran, S., Pande, S., and Sivapalan, M.: Norms and values in sociohydrological models, Hydrology and Earth System Sciences, 22, 1337-1349, 10.5194/hess-22-1337-2018, 2018.

Smith, K., Liu, S., Liu, Y., Savic, D., Olsson, G., Chang, T., and Wu, X.: Impact of urban water supply on energy use in China: a provincial and national comparison, Mitigation and Adaptation Strategies for Global Change, 21, 1213-1233, 10.1007/s11027-015-9648-x, 2016.

Van Emmerik, T. H. M., Li, Z., Sivapalan, M., Pande, S., Kandasamy, J., Savenije, H. H. G., Chanan, A., and Vigneswaran, S.: Socio-hydrologic modeling to understand and mediate the competition for water between agriculture development and environmental health: Murrumbidgee River basin, Australia, Hydrology and Earth System Sciences, 18, 4239-4259, 10.5194/hess-18-4239-2014, 2014.

Zeng, Y., Liu, D., Guo, S., Xiong, L., Liu, P., Yin, J., Tian, J., Deng, L., and Zhang, J.: Impacts of Water Resources Allocation on Water Environmental Capacity under Climate Change, Water, 13, 10.3390/w13091187, 2021.

Zhang, P., Zhang, Y. Y., Ren, S. C., Chen, B., Luo, D., Shao, J. A., Zhang, S. H., and Li, J. S.: Trade reshapes the regional energy related mercury emissions: A case study on Hubei Province based on a multi-scale input-output analysis, Journal of Cleaner Production, 185, 75-85, 10.1016/j.jclepro.2018.03.013, 2018.

Zhao, S., Liu, Y., Liang, S., Wang, C., Smith, K., Jia, N., and Arora, M.: Effects of urban forms on energy consumption of water supply in China, Journal of Cleaner Production, 253, 10.1016/j.jclepro.2020.119960, 2020.