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

I appreciate the efforts the authors have made to address my comments on the early version of the manuscript. However, as I read throughout the revised manuscript, I think there are still some technical issues with the model formulation and lack of robustness of model assumptions and simulation experiments, listed as follows.

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

1. Equation (2)-(4). What is the definition of "environmental capacities of socioeconomic variables"? If Nt>Ncap, N is mathematically forced to decrease (or stay constant), even if the community has no awareness of environmental deterioration (i.e., f(E)=0). Why?

1. Response:

Thanks for your supportive comment. "environmental capacities of socioeconomic variables" indicates the maximum value that can be carried by the system, which is used to constrain the socioeconomic variables within their maximum values. Even if negative feedback driven by environmental awareness is not triggered (i.e., f(E)=0), N is not allowed to increase when Nt is larger than Ncap.

To make it clearer, we have replaced "environmental capacities of socioeconomic variables" with "environmental carrying capacities of socioeconomic variables" in the paper.

Thanks.

2. The authors argue that "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" (Line 172).

In fact, although a decreasing, exponential term is added to the growth rate equation, the variables can still reach infinity in a long run, as long as the value of the growth rate is positive. Therefore, it cannot justify why you have to add the exponential term. And I still cannot appreciate the assumption that technology development will slow down the growth of population, GDP, and crop area. I suggest the authors consider using another statement instead of "technology development" to explain this term. In fact, in the model, the growth rate is just a function of time, and there is no technology involved.

2. Response:

Thanks for your supportive comment. We have given more details for the improved Malthusian growth model in line 174-179. According to previous studies, the socioeconomic expansion in China will slow down (He et al., 2017; Lin et al., 2016), the growth rate of which will decrease. The constant growth rate in the original Malthusian growth model is thereby not applicable for socioeconomic simulation. Therefore, we used exponential terms (i.e., $\exp(-\varphi t)$) to simulate the evolution of socioeconomic variables, which increases with decreasing rate.

We agree with your opinion that the variables can still reach infinity in a long run with exponential term (e.g., scenario II in Figure 10). Therefore, we add the feedback function driven by environmental awareness (i.e. f(E)) to the equation to regulate the socioeconomic expansion. As is shown in Figure 10, socioeconomic variables keep increasing under the scenario without considering environmental awareness feedback (i.e., scenario II), while the over-speed socioeconomic expansion is effectively constrained under the scenario considering environmental awareness feedback (i.e., scenario I), which exactly indicates that environmental awareness is of great significance for the sustainable development of WEFS nexus.

We have replaced "technological development" with "social development" (i.e., $\kappa_P\exp(-\varphi_P t)$, $\kappa_G\exp(-\varphi_G t)$, $\kappa_{CA}\exp(-\varphi_{CA} t)$ are used to depict the impacts of social development on the evolution of population, GDP, and crop area, respectively).

Thanks.

3. In fact, I believe the growth rate of the socioeconomic variables should be related to the size of the variables. It might be less reasonable to simply assume that the growth rate is just a function of time.

3. Response:

Thanks for your supportive comment. We agree with your opinion that growth rate of socioeconomic variable is not only the function of time, but also related to the sizes of these variables. As the interconnections between water, energy, food and society systems are being intensified, the evolution of socioeconomic variable is not only related to its own size, but also impacted by the status of other systems. Environmental awareness, which takes resources demand, supply and shortage in water, energy and food systems into account, is considered as a comprehensive indicator to sustain the WEFS nexus system. Therefore, we assume that growth rate of socioeconomic variable is the function of time and environmental awareness, as is shown in equation (2)-(4).

Thanks.

4. If Nt<Ncap and f(E)=0, rpt would decrease with time, and its minimum value is rp0. Why? rp0 represents the growth rate of population in the baseline year. Does the baseline year mean the first year? If so, when t=1, why rpt does not equal rp0?

4. Response:

Thanks for your supportive comment. We find a typo in the equation and we have revised them as follow:

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

where N_t is the population in the t-th year; N_{cap} denotes the environmental capacities of population; $r_{P,0}$ is the growth rate of population from historical observed data before the baseline year; $r_{P,t}$ is the growth rate of population in the t-th year; κ_P*exp(-$\varphi_P t$) is used to depict the impacts of social development on the evolution of population; E is environmental awareness; and f_1 represents the feedback function.

As discussed above, we assume that the socioeconomic variables are going to increase with decreasing rate according to previous studies (He et al., 2017; Lin et al., 2016). The ideal minimum growth rate will decrease approaching to 0 in the revised equation ($r_{*,0}$ in previous equation), as the socioeconomic variables are considered to keep increasing with decreasing rate until reaching their environmental carrying capacities if no environmental awareness feedback is triggered. However, the ideal conditions may be difficult to be satisfied in the foreseeable future and can give little information for the planning (except for scenario II removed feedback function, environmental awareness feedback is triggered under another three representative scenarios shown in Figure 10).

The baseline year is the first year. We have re-described the definition of $r_{p,0}$ to eliminate the misleading as follow: $r_{p,0}$ is the growth rate of population from historical observed data before the baseline year.

Thanks.

5. The assumption that an increase in environmental awareness will have a negative effect on GDP growth is less robust. In fact, if the community feels the water shortage issues, they usually replace the water-intensive industrial sectors with some less water-intensive ones. And the latter (e.g., some high-tech industries) might contribute even more to GDP growth, with a relatively smaller volume of water consumption.

5. Response:

Thanks for your supportive comment. We agree that long-term high-level environmental awareness can also promote the advancement of resource-saving technology and further increase GDP, besides the constraints on socioeconomic variables. Simultaneously taking the positive and negative impacts of environmental awareness on GDP may be more reasonable. However, it will also make it difficult to distinguish the negative feedback on GDP driven by environmental awareness, which is the focus of our study. The process that environmental awareness promotes the advancement of resource-saving technology and further increase GDP can be quite complex, which is related to not only the level and duration of environmental awareness but also the sizes of various socioeconomic factors. It's really an interesting topic and will become the focus of our further study.

And we have taken it as a limitation and future work as discussed in line 914-919 in conclusion section "We acknowledge that environmental awareness feedback functionality remains to be further improved. Indeed, environmental awareness also has potential to contribute to socioeconomic expansion by promoting resources-saving technology. It's the function of the level and duration of environmental awareness, and the sizes of socioeconomic factors, which will become the focus of our further study".

Thanks.

6. Equation (5) and equation (16). The growth rates of water use quota and energy use quota are always negative, which means the water use quota and energy use quota would decrease to a negative value in a long run. This is not true. Maybe a minimum value is needed to constrain the variable.

6. Response:

Thanks for your supportive comment. We have added the minimum value as constraint in equation (5), (16), and Table 2.

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

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 from historical observed data and *t*-th year, respectively; $WQ_{i,j}^{min}$ is the minimum value of water use quota; and $\kappa_{qwu}*\exp(-\varphi_{qwu}t)$ is used to depict the water-saving effect of social development on the evolution of water use quota.

Thanks.

7. Equation (19) has the same problem as equation (2).

7. Response:

Thanks for your supportive comment. We have revised equation (19) as discussed above.

Thanks.

8. In my previous comments, I suggested the authors give some observable evidence to show human adaptive responses. I want to know if there is any evidence to show that the community will take measures to constrain the growth of population, GDP, and crop area? This is important, because the data points during the modeling period (2010-2019) cannot validate the model assumptions about the feedback from environmental awareness to population, GDP, and crop area.

8. Response:

Thanks for your supportive comment. We believe our manuscript have been greatly benefited from this valuable suggestion. We have added more observed evidence to show human adaptive response to resources shortage from water, energy and food systems in line 461-481.

The environmental awareness is the key factor to drive the feedback. However, as environmental awareness is a subjective variable, there are no empirical observed data to calibrate it, which requires more evidences to show adaptive human response to environmental awareness. Hepburn et al. (2010) have reviewed studies on environmentally related human behavioral economics. Substantial studies indicate that environmental awareness is considered as an important factor in modelling socioeconomic decisions and policies for water, energy and food systems (Li et al., 2019; Li et al., 2021; Lian et al., 2018; Rockson et al., 2013; Xiong et al., 2016). For instance, Xiong et al. (2016) investigated the evolution newspaper coverage of water issues in China based on water-related articles in a major national newspaper, *People's Daily*. They found that economic development was the primary target of China before 2000. With the conflict between water demand and supply being intensified, concerns about water security arisen in the newspaper since 2000, which indicated that environmental awareness towards water shortage emerged. Related policies (e.g., the strictest water resources control system for water resources management policy) were thereby implemented to constrain the over-speed socioeconomic expansion and further ensure water security.

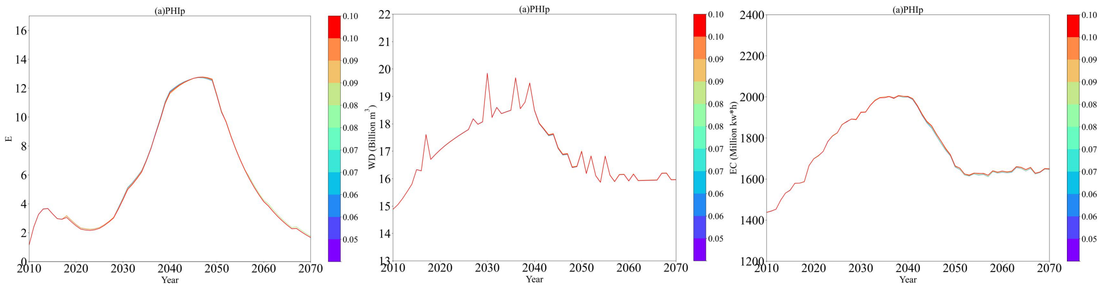
Thanks.

9. Model calibration. Results about parameter sensitivity analysis are not shown. I cannot understand how the insensitive parameters are identified (based on expert knowledge is not a rigorous way). In addition, the 13 insensitive parameters are used in different equations for different variables. Why can all of their values be set to 0.0856?

9. Response：

Thanks for your supportive comment. We have added more details for parameter calibration in line 440-444. As is shown in Table 3, some parameters in the model are adopted as auxiliary parameters, which are not equipped with exactly physical definitions. It indicates there is no independent empirical data to calibrate these parameters. Therefore, by reviewing previous studies (Feng et al., 2019; Feng et al., 2016; Van Emmerik et al., 2014) and expert knowledge, we evaluated the order of magnitudes and rational boundaries for these parameters. The initial parameter sensitivity analysis was then conducted to identify the sensitive and insensitive parameters. As the insensitive parameters are not able to remarkably alter the system (Taking insensitive parameter φ_P as an example, as shown below), the empirical values in previous studies (Feng et al., 2019; Feng et al., 2016) were adopted.

Thanks.



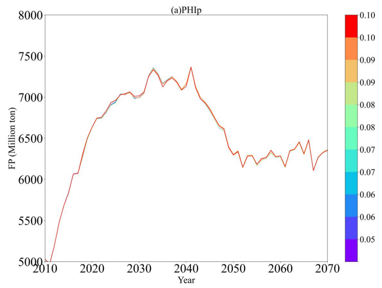


Figure 1. Trajectories of environmental awareness, water demand, energy consumption, and food production with varied φ_P.

10. The modeling period is extended to 2070. How are the external drivers assumed for the future prediction?

10. Response:

Thanks for your supportive comment. We have added more details to describe how the water availability and water demand extended to 2070 in line 420-423. "water availability from 1956 to 2016 was adopted as the future water availability, while dynamic water demand was projected in water system module, both of which were inputted into water resources allocation model."

Thanks.

11. Line 647. "constraining WSRcrit, ESRcrit, PEA, and Ecrit can maintain the integrated system from constant water shortage and energy shortage…". What can we do to constrain these parameters? All of these parameters are boundary conditions, and they are not directly associated with human adaptive actions.

11. Response:

Thanks for your supportive comment. This study aims to assess the impacts of environmental awareness feedback and water resources allocation on WEFS nexus. Therefore, we only taken these parameters as static boundary conditions, while the dynamics with human adaptive actions haven't considered yet. However, we have evaluated the sensitivity of these parameters in Section 4.4, and found that these parameters can effectively regulate evolution of socioeconomic variables and are of great significance for the sustainable development of WEFS nexus, which has laid the basis for further study on the dynamics of these parameters with human adaptive actions.

Thanks.

12. Line 32-36. The statement is somewhat misleading. I firstly thought the energy shortage rate decreased from 17.16% to 5.80% during some time period. But table 7 shows that this is a comparison between two modeling scenarios. This cannot be used as a conclusion because once you set a different scenario (e.g., different parameter values), the values of energy shortage rate will change as well.

12. Response:

Thanks for your supportive comment. One of our goals is to assess the impacts of environmental awareness feedback on WEFS nexus. Therefore, we set scenario I considering environmental awareness feedback, while scenario II doesn't, as is shown in Table 6. The impacts of environmental awareness feedback on WEFS nexus can be studied by comparing the difference between scenario I and II. And we found that environmental awareness can effectively capture human sensitivity to resources shortage and keep the integrated system from constant resources shortage by regulating socioeconomic expansion (e.g., the average annual energy shortage rate under scenario II decreased from 17.16% to 5.80% under scenario I). Differences between different periods under the same scenario can be used to assess the evolution phases division of socioeconomic variables, as is discussed in Section 4.2.

To remove the misleading, we have added the scenarios and their corresponding values in abstract in line 35-36. "Rational water resources allocation can ensure water supply through reservoir operation, decreasing the water shortage rate from 15.89% under scenario IV to 7.20% under scenario III."

Thanks.

Overall, I think the model is a bit over-complexed. Perhaps, the authors may consider modeling water demand directly. It seems that it is not necessary to model population, GDP, crop area, and water use quota, individually. According to equation (17) and equation (20), both energy consumption and food production are just related to water supply, and have nothing to do with population, GDP, and crop area. Perhaps using water demand as a state variable might largely simplify the model structure and still maintain the completeness of the WFE system story.

Response:

Thanks for your valuable and constructive suggestion. Directly considering water demand as a state variable without simulating population, GDP, crop area, and water use quota can no doubt effectively simplify the model structure. However, it will be difficult to distinguish different types of water demand (i.e. municipal, rural, industrial and agricultural water demand), as population, GDP, and crop area are considered as important factors for water demand projection in quota method. Furthermore, it will also challenge the estimations of energy consumption and food production, as energy use quotas are different in different sectors (shown in equation (17) and Table 2), and food production is determined by crop area and agricultural water shortage rate (shown in equation (20)). Therefore, eliminating the simulation of population, GDP, crop area, and water use quota may directly bring risks to water and food systems, and further WEFS nexus system.

Thanks.

Reviewer 3

The authors have made a considerable effort the revise the manuscript. While some concerns have been adequately addressed, other have not, and the revisions and authors responses also raise new concerns. The new and remaining concerns are described below. Because the major concerns (1-3 below) are such that they permeate the entire paper, I believe the paper should not be accepted.

Thank you very much for your valuable comments on our paper. We believe the current comments have greatly improved the quality of the paper. Here are the responses to your comments:

(1) Co-evolution of WEF nexus – calibration and discussion (primarily sections 4.1 and 4.2):

• It is misleading to claim that the model is "reliable for simulating the co-evolution of the WEFs nexus" (lines 446-447). As expressed before, the data only covers the early, "expansion phase" of the simulation and is thus insufficient to validate the model. It is also misleading to present the NSE and percent bias of the calibrated model without clarifying that the data only cover a short window and a single phase of the co-evolution. In section 4.1 and throughout the manuscript, all language which asserts or implies that the model has been validated should be eliminated or revised to be accurate. For instance, in the abstract, it is misleading to claim that "The results show that environmental awareness can effectively capture the human sensitivity to shortages from water, energy, and food systems". Prior comments regarding this issue have not been adequately addressed.

1. Response:

Thanks for your supportive comment. We believe our manuscript has greatly benefited from this valuable suggestion. We have given more details to explicitly emphasize that the observed data can only cover the initial expansion phase of WEFS nexus co-evolution in line 461-464. To further demonstrate the reliability of the established WEFS nexus, evidence of human adaptive response to shortages from water, energy, and food systems is added in line 464-480. The state “reliable for simulating the co-evolution of the WEFS nexus” has been revised as “the established model still has potential to simulate the co-evolution of WEFS nexus.” in line 480-481.

As environmental awareness stays at a low level and the feedback is not triggered in initial expansion phase, the feedback driven by high-level environmental awareness hasn’t been calibrated yet. However, as environmental awareness is a subjective variable, there are no empirical data to calibrate it, which requires more evidences to show adaptive human response to environmental awareness. Hepburn et al. (2010) have reviewed studies on environmentally related human behavioral economics. Substantial studies indicate that environmental awareness is considered as an important factor in modelling socioeconomic decisions and policies for water, energy and food systems (Li et al., 2019; Li et al., 2021; Lian et al., 2018; Rockson et al., 2013; Xiong et al., 2016). For instance, Xiong et al. (2016) investigated the evolution newspaper coverage of water issues in China based on water-related articles in a major national newspaper, *People’s Daily*. They found that economic development was the primary target of China before 2000. With the conflict between water demand and supply being intensified, concerns about water security arisen in the newspaper since 2000, which indicated that environmental awareness towards water shortage emerged. Related policies (e.g., the strictest water resources control system for water resources management policy in China) were thereby implemented to constrain the over-speed socioeconomic expansion and further ensure water security. Therefore, the established model still has potential to simulate the co-evolution of WEFS nexus.

Thanks.

• The authors state in their responses (see response 15 especially), that they selected parameters “to ensure the rational co-evolution of the integrated system”. This sounds like the “phases” of co-evolution were imposed on the model, rather than emerging from the model. Thus, the entire perspective of section 4.2, which discusses the phases as an insightful model result, is misleading.

2. Response:

Thanks for your supportive comment. The state should be corrected. We selected the parameters from appropriate intervals based on parameter sensitivity analysis to ensure "socioeconomic variables in WEFS nexus with rational intervals", rather than "the rational co-evolution of the integrated system". As is shown in Figure 8, 9, 10, and 11 for parameter sensitivity analysis, despite the amounts of socioeconomic variables have changed with varied parameters, the phases dividing rule is still valid for the co-evolution of WEFS nexus.

Therefore, the phases emerge from the model, rather than imposed.

Thanks.

• Analysis of co-evolution is, by nature, analysis of how states *change over time*. The use of static energy production and food target are therefore troublesome. These values are critical to shortages and therefore awareness and all other state co-evolution. In their responses, the authors claim this simplification is acceptable since the focus of the study is as stated above; this response may be acceptable, but the paper's attention given to the co-evolution and its phases should be minimized accordingly (i.e. dramatically cut and revise section 4.2).

3. Response:

Thanks for your supportive comment. We agree with your opinion that WEFS nexus co-evolution is not the focus of the study and thereby needs simplification. We have greatly simplified Section 4.2 for WEFS nexus co-evolution, and only the phase dividing, and their primary properties are emphasized. (the length of Section 4.2 decreases from 1,329 to 789 words).

Thanks.

• The phases of co-evolution are essentially the same as those presented in Feng et al. 2016. Reference to that study should be made, and the discussion in the section 4.2

shortened significantly.

4. Response:

Thanks for your supportive comment. We have cited the reference in line 490, and greatly shortened Section 4.2.

Thanks.

(2) In light of the authors response, the scales of the energy, food, and water systems appear to be very different (sections 2.1, 2.2, 2.3). Thy system is only energy use for water supply within the basin; the water system is all water users within the basin; and the food system goes beyond the basin boundaries (exporting food was provided as justification for food target/demand being an external driver). However, the energy, food, and water shortage awareness are all aggregated into a single "environmental awareness" which drives population, GDP, and crop area. The discordant scales should be accounted for, or at a minimum discussed, when aggregating environmental awareness. In addition, the different scales would seem to have implications for how the model results are interpreted, but no such discussion is provided in the results.

5. Response:

Thanks for your supportive comment. Water demand in each water user in each operational zone is projected in water system module. Water supply for every water user is then simulated according to water resources allocation model. Once the water supply is determined, the energy consumption at each water user during water supply process can be estimated. The food production in every operational zone is also determined, with the agricultural water shortage rate outputted from water resources allocation model. Therefore, the water demand, water supply, energy consumption, energy supply, and food production are within the basin, except for the target food production (or food demand).

As current observed crop area and food production structure are formed with the target food production considering food exported, it's hard to distinguish the crop area for food export from the total crop area. If the target food production doesn't consider the food export, food production will be remarkably larger than food demand, and the current crop area will keep rapidly shrinking with environmental awareness feedback, which is not consistent with the fact. Therefore, we still consider the exported food as part of target food demand of the basin, and further laid the basis for environmental awareness estimation.

Simultaneously, we find that target food production is an important parameter for WEFS nexus, particularly for food system, as shown in Figure 8 (e), 9 (e), 10 (e), and 11 (e). Therefore, it's exactly more reasonable to separate local food demand and exported food demand, to further assess their impacts on WEFS nexus, respectively, which is really an interesting top. However, it's not the focus of this paper, and it will be studied in our next work.

Thanks.

(3) The discussion of all results still needs re-organization and narrowing of focus. The abstract and author comments indicate that the focus of the paper is (1) impacts of environmental awareness feedbacks and (2) impacts of reservoir storage. It seems that the novelty of the present study (especially in comparison to Feng et al. 2016 and 2019) comes from section 4.4 – toggling the environmental awareness feedback on/off, and using a detailed reservoir simulation rather than a simplified reservoir model. The results discussion should be cut down to indeed focus on these contributions. Perhaps all of section 4.2 should be eliminated (more on this section above). Section 4.3 (sensitivity analysis) should be revised to focus on the two main contributions, rather than a comprehensive description of sensitivity.

6. Response:

Thanks for your supportive comment. We agree with your opinion and our manuscript has greatly benefited from this valuable suggestion. To explicitly emphasize the contribution of the study, we re-organized the discussion structure: Section 4.1 model calibration, Section 4.2 co-evolution of WEFS nexus, Section 4.3 impacts of environmental awareness feedback and water resources allocation on WEFS nexus, and Section 4.4 sensitivity analysis for WEFS nexus.

Specifically, for Section 4.2, as the WEFS nexus co-evolution is not the focus of the study, but still considered as the basis for Section 4.3 and 4.3, we greatly simplified Section 4.2, rather than eliminated.

The updated sensitivity analysis in Section 4.4 consists of two parts: 4.4.1 sensitivity analysis of **environmental awareness feedback** on WEFS nexus, and newly added 4.4.2 sensitivity analysis of **water resources allocation schemes** on WEFS nexus. For sensitivity analysis of environmental awareness feedback, seven parameters related to the boundary conditions and critical values are selected. Results indicate that these parameters can dominate the environmental awareness evolution, and further regulate the pace of socioeconomic expansion by environmental awareness feedback, which is of significance to keep the integrated system from violent deterioration in contraction and recession phases. For sensitivity analysis of water resources allocation schemes, varied multipliers for water release from reservoir based on reference scenario are adopted. According to the response to different water resources allocation schemes, operational zones were classified into four types as shown in Figure 12. And we found that regulating capacity of water project is an important factor in water resources allocation to ensure the stability of water system to sustain WEFS nexus. Particularly for the area with certain regulating capacity of water project but cannot totally cover the water demand, regulating the water release from reservoir by rational water resources allocation schemes can further ensure water supply and contribute to the sustainable development of the WEFS nexus.

The newly added results for sensitivity analysis of water resources allocation schemes are shown in Figure 8, 9, 10, 11, 12, and 13.

Thanks.

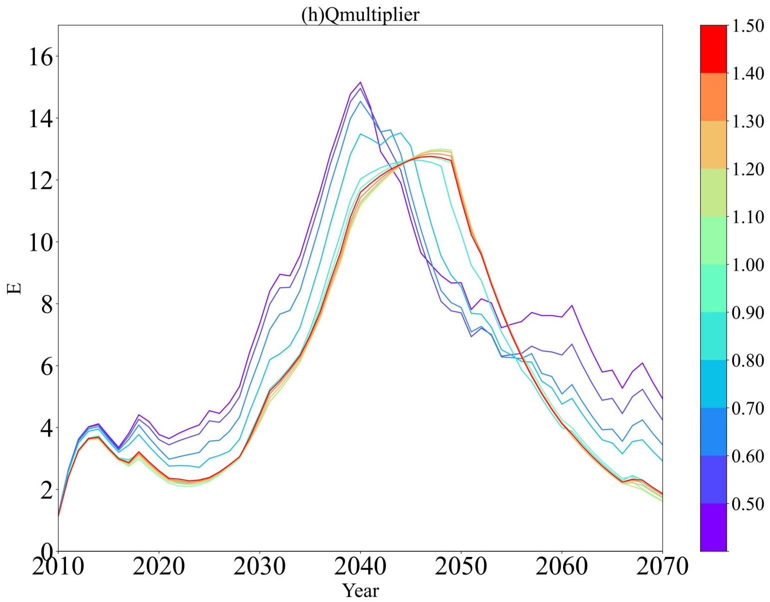


Figure 8 (h). Trajectories of environmental awareness with varied parameters.

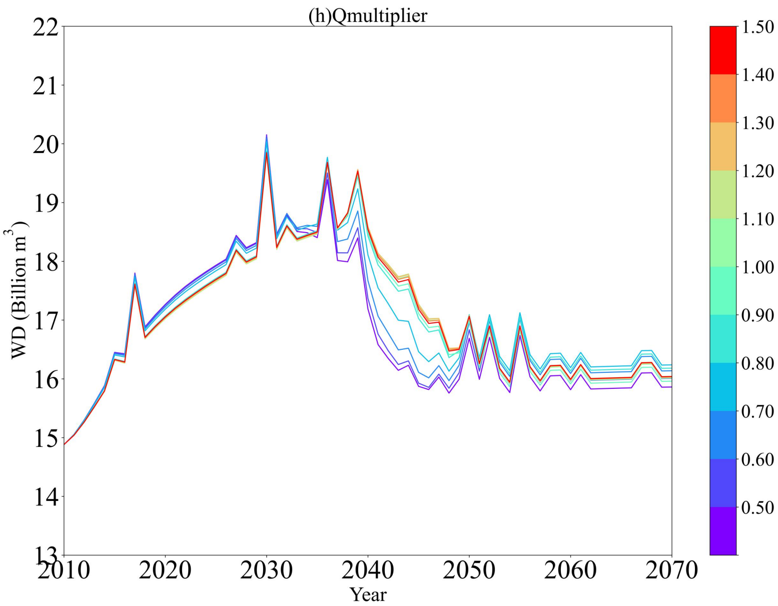


Figure 9 (h). Trajectories of water demand with varied parameters.

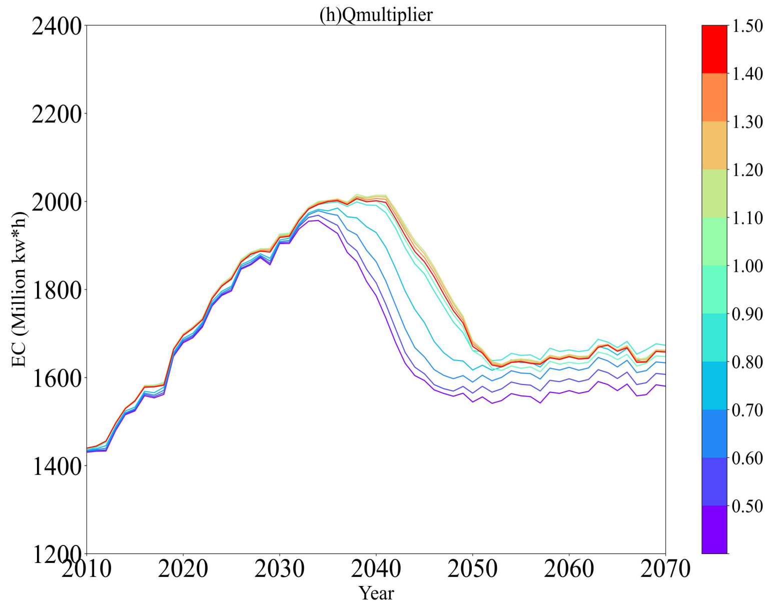


Figure 10 (h). Trajectories of energy consumption with varied parameters.

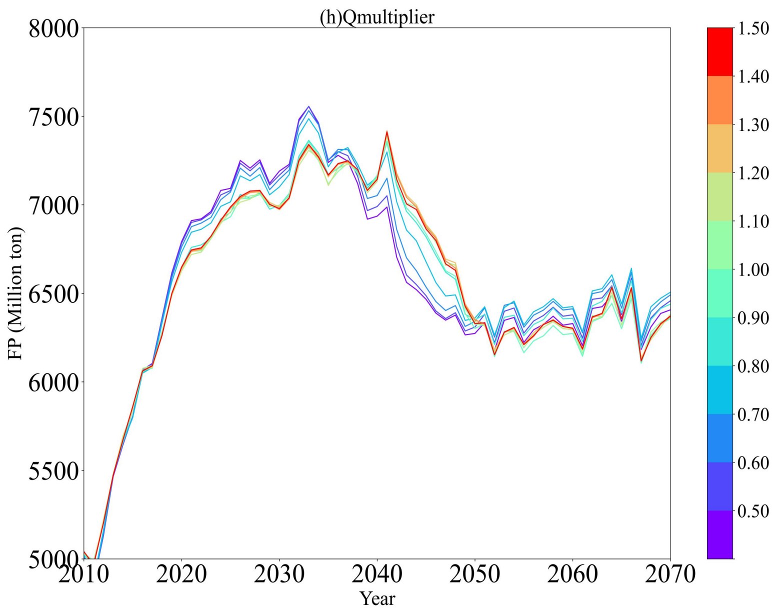


Figure 11 (h). Trajectories of food production with varied parameters.

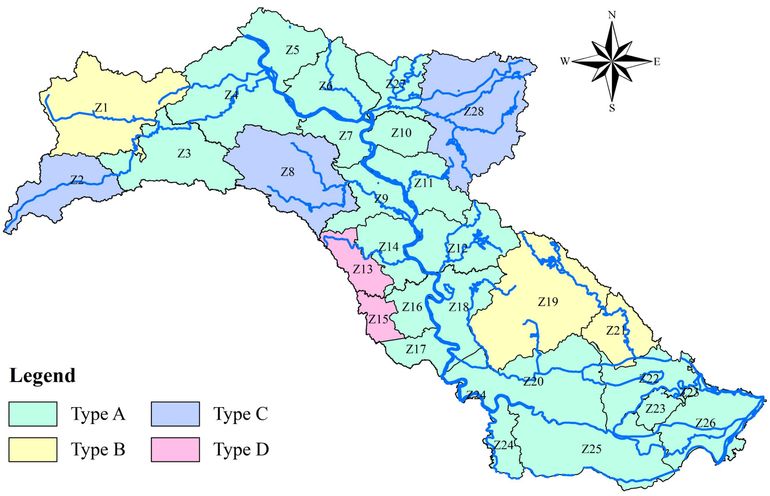
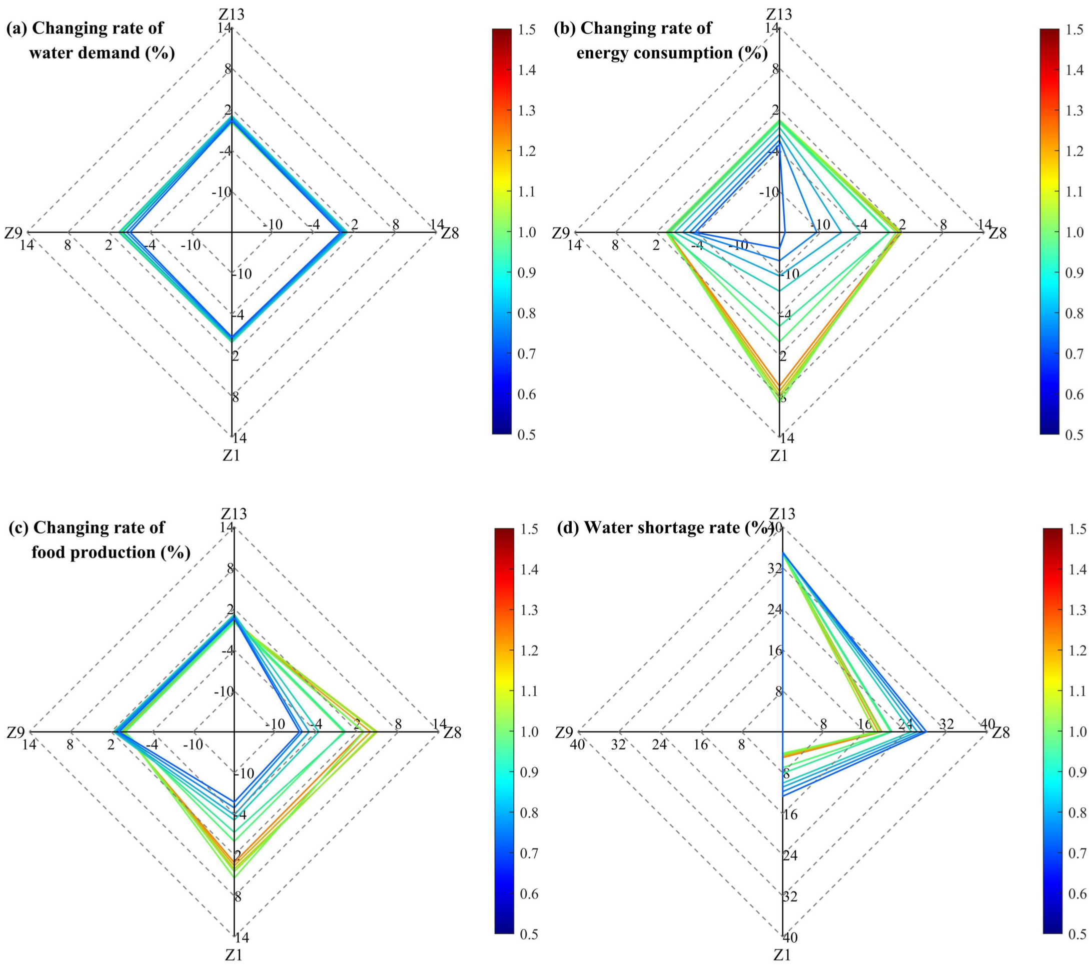


Figure 12. Spatial distribution of A, B, C, and D types of operational zones.



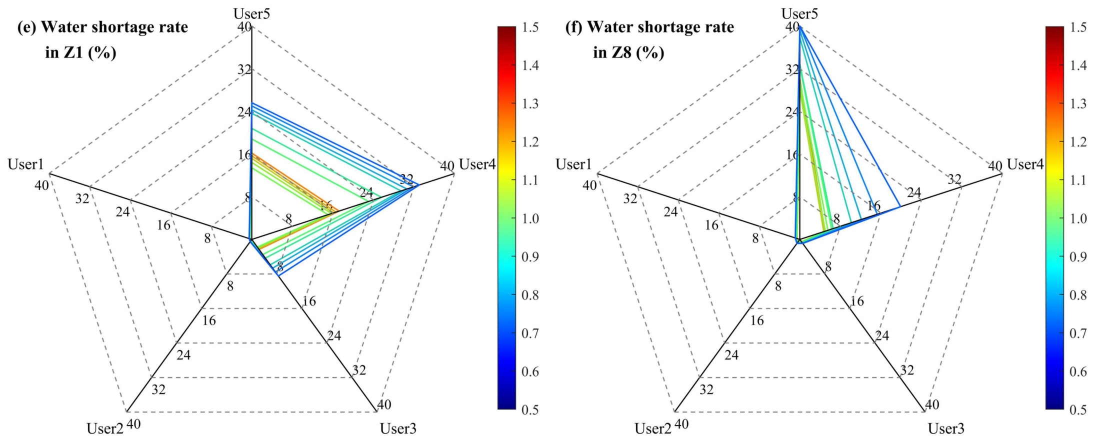


Figure 13. Socioeconomic variables with varied reservoir release multiplier in Z9, Z1, Z8, and Z13: (a) changing rates of water demand; (b) changing rates of energy consumption; (c) changing rate of food production; (d) water shortage rates; (e) water shortage rates of water users in Z1 (user 1, 2, 3, 4, and 5 are related to municipal, rural, in-stream ecology, industrial, and agricultural users); (f) water shortage rates of water users in Z8.

(4) Less permeating issues

• The new water quota formulation (eqn 5) seems to imply that the water quota will go to zero as time goes to infinity (assuming parameter values as provided in section 4).

7. Response:

Thanks for your supportive comment. We have added the minimum value as constraint in equation (5), (16), and Table 2.

$$\begin{cases} \dfrac{dWQ_{i,j}^{t}}{dt} = WQ_{i,j}^{t} * r_{qwu,t} \\ r_{qwu,t} = \begin{cases} r_{qwu,0} * \kappa_{qwu} * \exp(-\varphi_{qwu} t) & WQ_{i,j}^{t} > WQ_{i,j}^{min} \\ 0 & \text{else} \end{cases} \end{cases} \quad (5)$$

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 from historical observed data and t-th year, respectively; $WQ_{i,j}^{min}$ is the minimum value of water use quota; and $\kappa_{qwu}*\exp(-\varphi_{qwu}t)$ is used to depict the water-saving effect of social development on the evolution of water use quota.

Thanks.

• There is still no index provided for the summations in equations 6-8. Also, in equation 7, if total inflow includes natural inflow, is natural inflow being subtracted twice? Why? And why isn't the demand reduction factor included in the denominator of equation 8?

8. Response:

Thanks for your supportive comment.

(1) We have added the summation for total water shortage rate in equations (8).

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

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

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

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; $WSR_{i,j}^{t}$ is the water shortage rate in the *t*-th year; and WSR_{t} is the total water shortage rate.

(2) The total water supply ($WTSup_{i,j}^{sts}$) comprises natural water inflow and water supply from reservoir. In each sub-time step (except the first), the average natural water inflow (i.e., $WE_{i,j}^{sts}$) in the previous *sts*-1 sub-time steps is estimated as the extrapolated natural water inflow in the remaining *Tsts*-*sts*+1 sub-time steps using equation (6). In equation (7), $\sum_{1}^{sts} WTSup_{i,j}^{sts}$ covers the total natural water inflow in the previous *sts*-1 sub-time steps, while $WE_{i,j}^{sts}$ is considered as the total natural water inflow in the remaining *Tsts*-*sts*+1 sub-time steps. Therefore, natural water inflow is

not subtracted twice.

(3) Thanks for your reminder. It's a typo and we have added reduction factor into equation (8).

Thanks.

• What does it mean that IRAS runs on a yearly "loop" (line 208)?

9. Response:

Thanks for your supportive comment. The operational rule period of IRAS model is yearly-based. Once the length of time step is given, the number of time steps in a year can be determined and IRAS model will split the long-term series into yearly series to adapt to the operational rule. For instance, both the water availability and water demand are long term series from 2010 to 2070 in the study, while the reservoir operational rules are not. The reservoir operational rules repeat every year (in the study, there are 12 time steps in a year, as the length of time step is a month) to regulate the water release during the long term series. More details can be found in Matrosov et al. (2011).

As the state "IRAS runs on a yearly loop" can give little information and may mislead readers, we have removed it from the paper.

Thanks.

• "Planning food production" should be renamed to indicate that it is target production (or demand) and authors say in responses (line 297). Section 2.3 should also state that the food production target is an external driver because food production is largely exported (per author responses).

10. Response:

Thanks for your supportive comment. We have renamed "Planning food production" with "Target food production" in the paper. The state indicating the target food production has considered the exported food has been added in line290-292 "With the target food production which has considered the local and exported food demands of basin, the food shortage rate can then be estimated using equations (20) and (21)”.

Thanks.

• It is still unclear how agricultural water demand is implemented in the model. How are exceedance frequencies/demands assigned to years of the simulation? (lines 406-410)

11. Response:

Thanks for your supportive comment. We have given more details for agricultural water demand frequency in line 413-416. Agricultural water demand depends on agricultural water use quota and crop area. Agricultural water use quota is related to water availability frequency. The historical water availability during 1956~2016 is adopted as the water availability of simulation years in the paper, based on which the frequencies can be determined. As the water availability empirical frequencies between years during the long term (i.e., 1956~2016) are different, the agricultural water demands are also different between years. However, it’s hard to collect all the agricultural water use quotas under all the frequencies. Therefore, four typical frequencies P = 50%, 75%, 90%, and 95% (corresponding agricultural water use quotas data are available), are selected to indicate wet, normal, dry, and extreme dry years to simplify the agricultural water demand series (If Pt≤60%, the year is defined as wet year; if 60%<Pt≤80%, the year is defined as normal year; if 80%<Pt≤90%, the year is defined as dry year; if 90%≤Pt, the year is defined as extreme year).

Thanks.

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