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 will thoroughly revise the paper based on the comments. We believe the current comment can greatly help improve the quality of the paper. Here are the responses to your comments:

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 will carefully improve the writing quality in the revised manuscript.

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 quite agree with your opinion. We are going to give 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 as follow: The water demands and available water resources are further inputted into water resources allocation model to determine water supply and water shortage for every water use sector in each operational zone. The water supply for these five sectors and agriculture water shortage rates as outputs from water system module are taken as the inputs of energy system module and food system module to determine the energy consumption and food production, respectively. And description for feedback driven by environment awareness will be improved as follow: 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 increase of 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 are going to add the original Malthusian growth equation in revised manuscript. And the forms of equations for population, GDP and crop area will be corrected in equation (3)-(5). As socioeconomic factors in original Malthusian growth model without constraints will explode to infinity in a long-time evolution, the growth rates of population, GDP and crop area are assumed to increase with decreasing rates as time goes. And feedback functions as well as environmental capacities of socioeconomic variables are adopted to constrain the infinity evolution of these socioeconomic variables through equation (3)-(5) (Feng et al., 2016; Hritonenko and Yatsenko, 1999) The equation (4) for GDP simulation is taken as an example here:

$$\begin{cases} \frac{dG_t}{dt} = r_{G,t} * G_t \\ r_{G,t} = \begin{cases} r_{G,0} * (1 + \kappa_G * \exp(-\varphi_G t)) + f_2(E) & G_t \le G_{cap} \\ \mathrm{Min}(0, r_{G,0} * (1 + \kappa_G * \exp(-\varphi_G t)) + f_2(E)) & G_t > G_{cap} \end{cases} \end{cases} \quad (4)$$

where G_t is the GDP in tth year; GDP_{cap}, is the environmental capacity of GDP; $r_{G,0}$ is the growth rate of GDP in baseline year, which is observed from history data; $r_{G,t}$ is the growth rates of GDP in tth year; κ_G*exp(-$\varphi_G t$) is used to depict the impacts of technology development on evolution of GDP; E is environmental awareness; f_2 is the feedback function.

3.2 Response to the second comment:

Thanks for your supportive suggestion. Taking the GDP simulation 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, 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 will take your valuable suggestion and remove the negative sign in equation (6) for water use quota simulation. The exponential term would dampen the decreasing rate of water use quota as time goes, rather than water use quota as discussed in '3.2 Response', as the difficulty of saving water by the advances in technology is increasing over time.

$$\begin{cases} \frac{dWQ_{i,j}^{t}}{dt} = WQ_{i,j}^{t} * r_{qwu,t} \\ r_{qwu,t} = r_{qwu,0}(1 - \kappa_{qwu} * \exp(-\varphi_{qwu} t)) \end{cases} \tag{6}$$

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

3.4 Response to the fourth comment:

Thanks for your supportive comment. We will take this valuable suggestion and remove the feedback driven by the changing rate of GDP. The model will be re-built and the results will be 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 will improve the equation 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 will take your valuable suggestion. More details for Interactive River-Aquifer Simulation (IRAS) water resources allocation model will be given in our manuscript.

Temporal resolutions for IRAS model will be added as follow. "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 will also be added as follow. "Water shortage at demand node should be firstly determined on basis of its water demand and total water supply. The total water supply consists of 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 previous *sts*-1 sub-time-step is estimated as the extrapolated natural water inflow in rest sub-time-steps by equation (7). The water shortage can then be determined by deducting the demand reduction, the total real-time water inflow and the extrapolated natural water inflow from water demand through equation (8). The total water shortage rate can then be determined by equation (9)."

The water shortage at demand node calls for water release from corresponding reservoir node according to their hydrological connections. The amount of water release from reservoir depends on water availability for demand-driven reservoir and operational rules for supply-driven reservoir, respectively, details of which will be given in revised manuscript.

$$WE_{i,j}^{sts} = \left(\sum_{1}^{sts-1} WTSup_{i,j}^{sts} - \sum_{1}^{sts-1} WRSup_{i,j}^{sts}\right) * \frac{(Tsts - sts + 1)}{(sts - 1)} \quad (7)$$

$$WS_{i,j}^{sts} = \frac{WD_{i,j}^{ts}(1 - f_{red}) - \sum_{1}^{sts} WTSup_{in}^{sts} - WE_{i,j}^{sts}}{Tsts - sts + 1} \quad (8)$$

$$WSR_{i,j}^{t} = \frac{\sum_{ts}\sum_{sts} WS_{i,j}^{sts}}{\sum_{ts} WD_{i,j}^{ts}} \quad (9)$$

where *ts* is the current time step; *Tsts* is the total number of the sub-time-step; *sts* is the current sub-time-step; $WE_{i,j}^{sts}$ is the extrapolated natural water inflow for *j*th water use sector in *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 *t*th year.

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

5 Response:

Thanks for your supportive suggestion. We will improve the equation for energy use quota as discussed in "3.3 Response". The negative sign and feedback driven by changing rate of GDP will be removed.

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 will take the valuable suggestion. We will re-build the WEFS nexus model and update the results by re-defining the energy consumption in Section 2.2

We focus on the energy consumption during water supply process to further help investigate the energy co-benefits of water resources allocation schemes (Zhao et al., 2020; Smith et al., 2016). The energy consumption for water heating and water end use is not included in this study. Energy consumption is determined by energy use quota and the amount of water supply for 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 will improve the equation for crop yield simulation as is 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.

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 totally 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” is 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 will accomplish the piecewise equations for feedback functions.

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 will take 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, the feedback function driven by the changing rate of GDP will be removed as is discussed in "3.4 Response". We will re-build the model and update 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 will add the descriptions for human response to the issues from water, energy and food systems in Section 3.1 by citing supportive references as follow: "Due to population expansion, fast urbanization and rapid economic development, the local demands for water, energy and food are going to increase enormously (Zeng et al., 2021; Zhang et al., 2018). The contradictions between the increasing demands and limited resources will be intensified. Improving use efficiencies for water, energy and food in the mid-lower reaches of Hanjiang river basin is needed urgently (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 carried out in the mid-lower reaches of Hanjiang river basin to promote the spread of resources-saving technology and further improve the resources use efficiencies in water, energy and food systems. Therefore, impacts of human activities on WEF nexus should be assessed to sustain the collaborative development of the integrated system."

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

12 Response:

Thanks for your supportive suggestion. More details of Figure 3 will be added in revised manuscript as follow:

The socioeconomic data (i.e., population, GDP and crop area) for water demand projection are collected based on administrative units, while the hydrological data are often collected on basis of river basins. To ensure the socioeconomic data and the hydrological data consistent in operational zones, the study area is 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, study area is sketched in Figure 3, including 2 water transfer project (South-North water transfer project and Changjiang-Hanjiang water transfer project), 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 will take your valuable suggestion. The initial conditions so as corresponding descriptions in Table 2 will be 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 production 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 will give more detail to improve Table 2 and 3, 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 totally agree your opinion. Indeed, we took the method as mentioned in the comment to calibrate the model.

We will add more details in model calibration in revised manuscript as follow: "Initial parameter sensitivity analysis is adopted to screen out the insensitive parameter, indicating that there are 13 insensitive parameters and 21 sensitive parameters, respectively. The setting of the insensitive parameter is on basis of expert knowledge and the work of Feng et al. (2019), which has been proved with good performance and suitability. The sensitive parameters in model are then calibrated by fitting the observed data."

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 quite 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 selection. We will add the description on the motivation for parameter selection in Section 4.3 for sensitivity analysis as follow: "As the critical values and boundary conditions of WEFS nexus are considered as vital factors for policy-makers and managers to control the integrated system so as to achieve the concordant development goals, seven parameters are selected for sensitivity analysis."

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 quite agree with your opinion that system of systems model and agent-based model have also considered the feedback in solving WEF nexus. As is discussed in introduction, 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 will be 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 will improve the description on social state variable selection in Section 2.4 as follow:

"Environmental awareness describes societal perceptions of the 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 environment control but also the environmental restoration (Chen et al., 2016; Elshafei et al., 2014; Roobavannan et al., 2018). As this study focuses on human sensitivity on environmental degradation, environmental awareness on basis of the concept in the work of Van Emmerik et al. (2014) is adopted as 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 4 will be 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 will replace “resilience” and “resilient” with other appropriate words in the paper.

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