

# ***Interactive comment on “Modeling the integrated framework of complex water resources system considering economic development, ecological protection, and food production: A practical tool for water management” by Yaogeng Tan et al.***

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Dear referee #2:

Thanks for your decent comments on my paper and your comments are very helpful to improve the quality of the paper. Here is my point-to-point reply to your comments:

1. First, it is not clear what the contribution of the paper is. Is the paper trying to introduce a new method? Is it trying to solve a problem? Is it trying to introduce a new theory? The paper needs to have a clear goal and then focus on that. If the goal is to

introduce a new method, it should provide clear information on how optimization and system dynamics can be integrated. The current manuscript does tell us much about the integration process, as explained elegantly by the first reviewer. If the goal is to solve a problem, the problem should be defined. The current presentation provides some predictions about some measures and explains their dynamics, but it is unclear what problem it is trying to solve. Is the problem unsustainability? Is it depletion of resources? What are the research questions? What is the hypothesis that the paper aims to test? And then, it must provide some robust solutions. The paper has some scattered solutions in the discussion section, but they need to be organized and become the focus of the paper if the goal is to solve a problem. Finally, if the goal is to advance a theory, the whole writing should support that goal. The current manuscript aims to achieve all of these goals, and that makes it ambiguous.

Reply: Yes, this is the root of the motivation of why we propose this study and it is of most importance. A research paper should define a research question and we have to develop a certain approach to solve this question. Well, the existed problem of water resources is the unsustainability uses, reflected by quick consumption of water resources especially on socio-economy, neglecting ecological streamflow water. However, as a research paper, a common problem should be compacted into a research problem. Based on the literature review, systematic approach and nexus thinking has developed to solve the problem considering multiple uses of water resources, some of which using an advanced approach, such as systematic optimal approach. However, few studies put emphasize on optimal water allocation in a dynamic way (Optimal approach is one of the effective ways to attain sustainable water uses, but usually give water allocation scheme in a static way, i.e., a certain future year), or, system dynamics on simulating future dynamics on water resources system rarely considering sustainable (or optimal) water uses (Li et al., 2019; Yang et al., 2019). This is the research problem. Therefore, based on this, we develop the current study and introducing this integrating method. As the first reviewer mentioned, such a framework cannot be considered as a theory, it is exaggerating, and we will delete “theory” work in the text.

2. Second, the paper is hard to follow mainly because its English writing is poor. There are many instances of grammatical and typing errors, as well as bad writing. I have listed some of the examples at the end of this note.

Sorry for our poor English writing. We are from the country that the mother tongue is not English. But we will thoroughly modify the English grammar and expressions and make it better, including but not limited to revise it by some person whose mother tongue is English. Also, I will also consider the listed examples.

3. Third, the paper does not get the system dynamics terminology right. The method is mistakenly called "system dynamic," which is wrong. Another instance is the use of "systematics" as a misnomer of "systems perspective" or "systems relationships." Yet another example is the use of "cause-and-effect feedback loop" (Fig. 6 caption) instead of "causal loop diagram." Also, some statements in the manuscript make me nervous and skeptical about the authors' command of system dynamics modeling. They claim: "if the water supply increases at the same rate as water demand caused by increased socio-economic index, this feedback will be the positive feedback regulation that results in the polarization because the ecological water will be occupied and environmental protection will not be guaranteed." Note the use of "if" and "this feedback will be" in this statement. A feedback loop cannot be conditional; it is either positive or negative. The ambiguity of a feedback loop indicates a major deficiency in the model.

Reply: Some ambiguous expressions will be deleted in the revised manuscript. I will also unify all the terms as "SD model". System dynamic model includes many variables and their mutual relationships. The "time" variable is the inherent variable that links to other variables, that's why SD model can run dynamically. Feedback loop is the inherent function of SD model, but maybe some expression (such as "if the water supply increases at the same rate as water demand caused by increased socio-economic index, this feedback will be the positive feedback regulation that results in the polarization because the ecological water will be occupied and environmental protection will not be guaranteed.") is ambiguous, maybe I did not express the correct information in

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the text. This part must be thoroughly rewritten.

As SD model is used to simulate the dynamic operating status, the writing will put more emphasis on how it simulates the dynamic system and how it coupled with the optimal model. In Section 2 I will outline how to couple SD and optimal model (See my reply to both RC1 and the next point). In the next section I will rewrite this SD part, includes the variable types, how to connect the “time” variable, and relationships, to reveal how SD can simulate the system over time. Actually, Fig5 can represent the system dynamics diagrammatically, which can be revealed by SD. I will add the following statements to the paper:

“The essence of system dynamics is first-order differential equations, which is mainly composed of four basic variables: Level variables, Rate variables, Auxiliary variables, and flows. The level variable describes the cumulative effect of the system and reflects the accumulated amount that changes over time. It can be regarded as the storage of information and is generally represented by a rectangular box. The value of the state variable is the sum of the net inflow or outflow rate in the previous time and the corresponding simulation step size. The rate variable reflects the speed of the cumulative effect of the system and the change of the state variable over time, so it represents the speed of the system change or the amplitude of the decision. It embodies the control of the state variable and can determine the input and output variables in the state variable. Auxiliary variables are the intermediate variables throughout the decision-making process, which can be transformed from input variables to output variables through mathematical expressions. Flow refers to the relationship between variables, and it’s the bridge connecting any variable, either material flow or information flow, which reflects the behavior between the system or variables. All these variables are connected with certain equations/functions, and therefore all the variables compose a large system. As level variables is linked over time, and “time” variable is usually linked with other variables, SD will be able to operate a large system in a dynamic way over time.”

4. Fourth, the presented model is very confusing. It is not clear if the model is trying

to "characterize" the real system or represent an ideal situation. If the goal is to characterize the real system, then a system dynamics model would be sufficient. Agents of a real system rarely optimize things. If the goal is to represent an ideal situation (in a neoclassical sense), then the optimization model would be sufficient. I believe this confusion arises because the goal of the modeling is not defined adequately. As the first reviewer explained, the relationships between the optimization and the SD model need to be clarified.

Reply: Well, SD can simulate a system in a dynamical way but it has no optimal function, that's why we couple SD and optimal model. The referee states "I believe this confusion arises because the goal of the modeling is not defined adequately", yes, in the introduction I exactly not define the research question clearly, and I replied to this issue in point 1. That is, to achieve the sustainable development goal (because water resources management in some of the region is still unsustainable water uses), an optimal approach is an indispensable tool to deal with the problem. However, as accelerated consumption of water resources is happening and, more water users should be considered, advanced requirements have been put forward, that is, more systematic approaches should be adopted. (Address research question) Current studies most manage water resources in a static way, instead of dynamic, which cannot reach the new advanced requirement of water resources management (Li et al., 2019). So, we have to couple both models in this study.

To couple both models, the initial scheme of water supply should be generated by SD model. We define each time step of external drivers as  $\tau$ . For each  $\tau$ , both water supply and demand can be calculated by SD model (For calculation of SD model, the equation of each variable can be seen in Supplementary data of the paper). The water supply scheme generated by SD is the initial solution of the optimal model (Li et al., 2018). The optimal solution (optimal water supply scheme) is generated by the iteration of the optimal model until the adjacent iteration result is less than a specific error. Then, the optimized water supply will transfer back to SD to update the system status of the

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current time step, and prepare for the next  $\tau$  and repeat the whole process. We define  $T$  as the total number of  $\tau$ . If  $\tau < T$ , repeat the whole process; If  $\tau = T$ , end the process. The flowchart of the whole process is in the supplement of this reply.

5. Fifth, the presented model has some questionable assumptions. For example, it assumes that "The goal of the economic agent is aiming at increasing revenue of secondary and tertiary industries, as well as maintaining human wellbeing. It can be reflected by the minimum household and industrial [water] shortage" (lines 190-2). The minimum household and industrial water shortage cannot reflect the dynamics of industrial revenues and human wellbeing. Depending on the time frame, a system can maximize its economic gain regardless of water shortage. Another example of questionable assumptions appears in line 242: "the production of livestock is also in proportion to its water usage." This is simply wrong unless a Leontief function is used to represent this linear relationship, which is not. Finally, equation 2c aims to minimize a constant, which does not make sense!

Reply: (1) At the beginning, I wrote this sentence "The goal of the economic agent is aiming at increasing revenue of secondary and tertiary industries, as well as maintaining human wellbeing. It can be reflected by the minimum household and industrial [water] shortage" just for enrich the paper. It does seem to address the wrong assumption at this time. Now it is the redundant expression. I will delete this sentence. (2) The reason why I added "meat production" is that I thought that people not only eat vegetables but also meat. But now, vegetables and crops account for relatively more proportion. Meat production not only influenced by water uses but also nutrients (it is out of the scope of water resources). I will delete the "meat production" part. (3) AAPFD is not constant. It is a function of observed flow and actual ecological streamflow. I addressed in the supplementary data. For clarity, I will rewrite the whole expression in equation 2c.

6. Sixth, there are assumptions that limit the generalizability of the model. For example, "In the last stage, the continuous increase of the overload index stimulates the

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policymakers to alleviate the growth rate of population and GDP" (lines 513-4). Local or state governments in countries that do not follow a central decision-making regime cannot control economic and population growth as a function of ecological health. Even in such regimes, a significant effect of ecological health on economic and population growth is still a strong assumption.

Reply: the future economic growth rate is, actually, the different development scenarios. For dynamic simulations in the future, scenario analysis is definitely a powerful and effective way (Haasnoot et al., 2011; Yang et al., 2019). So, we generated 3 stages as different scenarios to simulate the dynamics based on different economic growth rate. Maybe the statement "In the last stage, the continuous increase of the overload index stimulates the policymakers to alleviate the growth rate of population and GDP" is a little bit questionable, but, we just want to convey the information that "lower growth rate of the economy can alleviate the overload index of an entire water resources system".

Critical issues:

1. The paper is unnecessarily long. There are many repetitions in the text (e.g. the sentence "food system is the indispensable component for human lives" has repeated many times). The first three paragraphs of the introduction section explain how important sustainability is. This could reduce to one or two sentences! Similarly, the first three paragraphs of the discussion section talk about the importance of sensitivity analysis. They can reduce to two sentences.

Reply: I will make changes to shorten the paper

2. It is claimed that Fig. 1 represents a framework of sustainable development. The diagram in Fig. 1 simply shows some causal relationships between modeled variables. How can it represent a sustainable development framework?

Reply: Fig. 1 is used to address the detail of the system (agents). Maybe the name of the picture is not suitable. I will delete this figure and list a table to imply the content of

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the integrated system.

3. In line 294, it is claimed that GDP and population always increase, which is simply wrong.

Reply: GDP and population not “always” increase, it will increase for long-term time periods (and will stay still or decrease) and the simulation time is only for 25 years, not forever. The pendulum dynamics also do not hold for long time scales, as the editor notes. I will delete the “always” word.

4. "Rational" in Table 1 should be "Reasonable."

Reply: I will make changes.

5. "Lookup function solved by optimal model" in Table 2 do not add any valuable information.

Reply: I will delete this issue. This question arises because the relation of SD and optimal model is unclear in the current paper. The new framework of coupling SD and optimal model have nothing to do with the “Lookup function solved by optimal model” in the current version. How to couple these two models is addressed in the reply of RC1 and point 4. Also, see the figures at the end of this reply.

6. 6. Avoid the use of hyperlinks in the text.

Reply: I will make changes.

References:

Haasnoot M, Middelkoop H, Van Beek E, et al. A method to develop sustainable water management strategies for an uncertain future[J]. Sustainable Development, 2011, 19(6): 369-381.

Li T, Yang S, Tan M. Simulation and optimization of water supply and demand balance in Shenzhen: A system dynamics approach[J]. Journal of Cleaner Production, 2019,

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207: 882-893.

Yang Z, Song J, Cheng D, et al. Comprehensive evaluation and scenario simulation for the water resources carrying capacity in Xi'an city, China[J]. Journal of environmental management, 2019, 230: 221-233.

Please also note the supplement to this comment:

<https://hess.copernicus.org/preprints/hess-2020-461/hess-2020-461-AC2-supplement.pdf>

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2020-461>, 2020.

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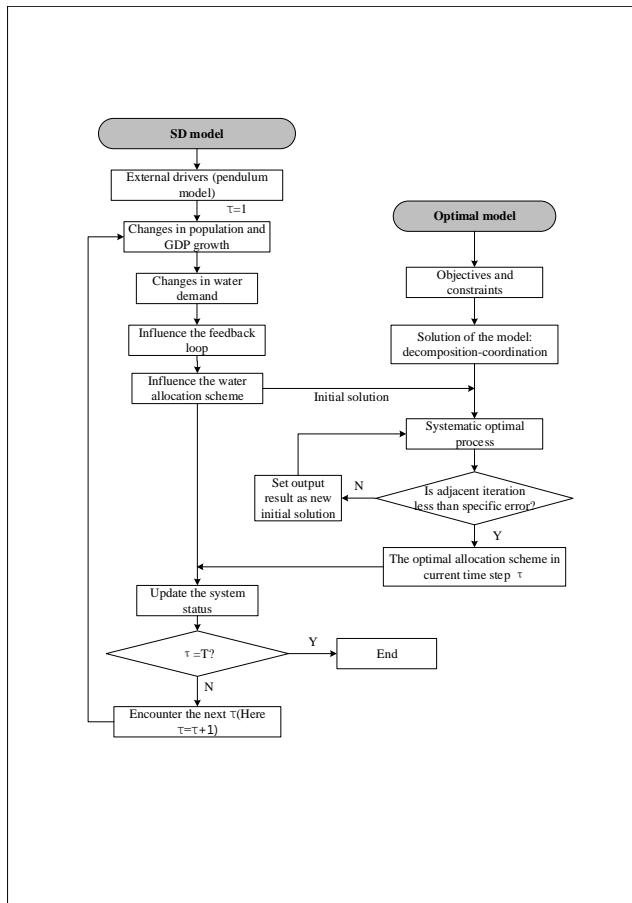


Fig. 1.