REPLY TO REVIEWERS

We thank the reviewer for taking the time to review the manuscript and the pertinent comments. We have improved the manuscript following most suggestions and clarified some interrogations. In the reply to the reviewer we use the following color code:
reviewer's comment
authors' answer
extract from the article
modification to the article
Action taken

REVIEWER 2:

1) It is not clear if this is an integrated water resource system model or a decision-support-tool. For instance, as the authors also mentioned decision-support-tools should provide a discussion platform to be used by different stakeholders. It is not clear how the developed model in this manuscript can achieve this goal. How user-friendly is this tool? Does it have a Graphical User Interface?

The reviewer is mentioning an important feature of a decision support-tool: how can it be used/implemented in practice, using stakeholder participation. While WHAT-IF is intended to be a decision support tool, this paper is the description of the scientific base of the integrated water resource system model. However, the Zambezi study case shows how the model is able to answer typical questions that will support decision making (Section 4, page 28, line 5):

In this section, we illustrate how the Zambezi model can be used to answer questions such as "What are the potential impacts of climate change on the agriculture and energy systems?", "What are the benefits of the hydropower and agricultural development plans?", "What is the sensitivity of these benefits regarding uncertainties in policies, future climate and socio-economic development ?", "What are the synergies and trade-offs between the irrigation and hydropower development plan?", and "What are the opportunity costs of restoring flood regimes in the Zambezi delta ?"

By being a community based open-source framework, the idea is that further features will follow on the GitHub repository, but are not part of this publication,

we clarify this and add the suggested reference in comment 2) (page 6, line2):

For this reason, the model is holistic in its resolution, but modular in its formulation, the user can activate or deactivate different modules and new modules representing relevant interrelations are easy to add. The flexibility of the framework and the open-source character will enable the tool to evolve with user and stakeholder inputs. Additional features will be added such as GIS visualization and data acquisition modules; Mcintosh et al., (2011) describes some of the challenges and best practices of developing an environmental decision support system.

The current graphical interface is excel spreadsheets

we clarify this (page 5, line 7):

The model can be connected to different open-source or commercial solvers; input data and output results are organized in MS Excel spreadsheets.

2) The literature on decision-support-tools should be enriched. For example, see McIntosh, B. S., Ascough II, J. C., Twery, M., Chew, J.,Elmahdi, A., Haase, D., ... & Chen, S. (2011). Environmental decision support systems (EDSS) development–challenges and best practices. Environmental Modelling & Soft-ware, 26(12), 1389-1402.
We implemented this in the answer of comment 1)

3) The novel contribution of this paper is not clear.

The novel contributions pointed out in the article is the combination of these 3 elements:

1-The representation of the agricultural and power markets in a hydro-economic model (page 2, line 28):

Traditionally, agricultural and energy water users are represented with an exogenous demand and willingness-to-pay for water (Bauer-Gottwein et al., 2017). Therefore, classic hydroeconomic models are able to analyse trade-offs and synergies between water users, but are not as effective in terms of representing dynamic interactions between infrastructure, policies, and commodity markets.

2-The spatial and temporal scale of the water representation in a nexus model (page 2, line 32):

On the other hand, nexus models, particularly energy centred models (e.g. OSeMOSYS (Howells et al., 2011) and TIAM-FR (Dubreuil et al., 2013)) tend to ignore the spatial and temporal scale of water availability and therefore may overlook water scarcity problems (Khan et al., 2017).

3-The optimization framework (page 4, line 3):

In contrast to simulation models that are rule-based (such as WEAP), the model finds the optimal water, agriculture and energy management decisions, considering trade-offs and synergies between them.

The last novelty is the application of this framework to the Zambezi River Basin: Section 3, (page 17, line 15) to (page 18, line 15) describes how this study is different from the other similar studies in the Zambezi river basin.

As the reviewer points out, this is not explicit enough, we suggest making it more explicit (page 3, line 8):

In this study, we developed a new open-source decision support tool for water infrastructure investment planning. The novelty of the tool is that it combines a hydro-economic optimization framework, with a nexus representation of the agriculture and food systems. The tool can represent political boundaries, the joint development of WEF infrastructure and policies, and uncertainty in future climate and socio-technical changes.

4) The authors discuss that the model captures Water-Energy-Food-Climate Nexus (shown in Figure 1). However, it is not clear how the developed model captures dynamic relationships among these elements. I suggest authors show graphically feedback loops within individual and among system elements. This can help understanding the model structure.

We agree with the reviewer that a figure would clarify the nexus interactions, and add the following figure and text (page 17, line 9):

The main link in the nexus, is the water resource for which hydropower, irrigation and ecosystems compete (Figure 2). The energy markets provide a dynamic value to hydropower production, while the crop markets provide a dynamic value of irrigation. The markets are therefore indirectly linked through the water trade-offs between hydropower and irrigation. Exogenous drivers on these markets such as new policies, technological and socio-economic changes, indirectly affect the water trade-offs and therefore all markets.

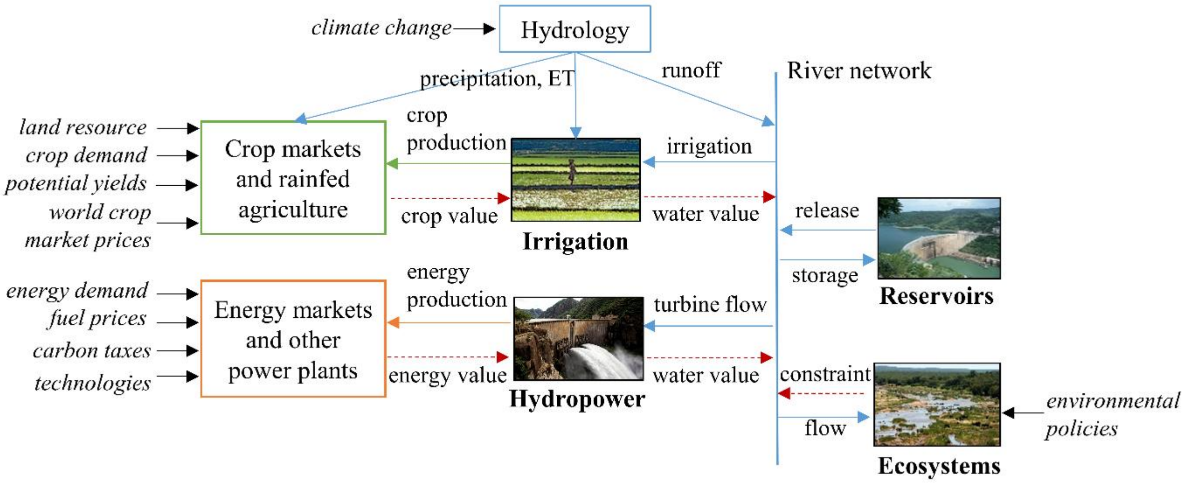

Figure 2: Main feedback loops in the water-energy-food nexus representation. *All flows are holistically solved to maximize total economic surplus, the water, energy and crop values are the resulting duals of the mass balances constraints. The figure does not show the temporal and spatial scale of the nexus problem.*

5) The nice part of this work is that the model is open source. However, the information on this feature needs more elaboration. How can users apply this model? What are the steps? What is the list of inputs to the model?

The practical use of the model is intended to be described in the github repository, the link is provided in *Code and data availability* page 43.

We add a missing reference to the github repository (page 5, line 7):

The code and installation instructions can be found on Github (https://github.com/RaphaelPB/WHAT-IF)

A document named "INSTALLING_WHATIF" guiding through the steps to install the tool has been added in the "Documents" folder of the github repository.

For the list of inputs the reader can refer to the table of parameters within the equations (Tables 1 to 5), and the Section 3: Zambezi river basin study case, shows the data collection for a specific case.

6) The model addresses the questions of "what-if" and "what is the best?" as it is an optimization model. Then why only "what-if" is used in the title?

As mentioned the optimization framework is mainly a way of simulating a resource management that adapts to changing conditions (page 4, line 4):

The optimization framework simulates adaptation to new infrastructure and policies, climate change, and socio-economic development. Conversely, in a rule-based simulation framework, allocation rules are usually based on the current socio-economic conditions or new rules are estimated, which may lead to suboptimal allocation decisions and underestimation of project benefits (Pereira-Cardenal et al., 2016).

A part of this, WHAT-IF stands for Water, Hydropower, Agriculture Tool for Investment and Financing, but this is only mentioned in the Github repository

We therefore add the acronym signification within the article (page 3, line 9):

In this study, we developed a new open-source decision support tool for water infrastructure investment planning, based on a hydroeconomic optimization model in a nexus framework: WHAT-IF, Water, Hydropower, Agriculture Tool for Investment and Financing.

7) The agricultural model needs more explanation and just referring to FAO methods is not enough. Is there any soil-moisture model?

Section 2.2 Agriculture production, page 9 to 11; details all equations, variables and parameters used in the representation of the agriculture system (with a reference to the appendices for the yield water response function).

Soil moisture is not accounted for in the FAO 56 formula that we use. The assumption of the formula is that it has little impact at the monthly/growing season time-scale, the IMPACT model (by IFPRI) did the same assumption in its 2008 version. We might consider it for further version, otherwise a way around is to add it in the form of "net precipitation".

8) The paper is really long and should be shortened

As suggested as well by reviewer 1, we move the equations and parameters of each submodule of section 2 to a supplementary material document.