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 1:

the manuscript is well organised (maybe the case study presentation and results could be put together),

The arguments for keeping these sections apart are:

1) Avoid confusion between what is data input and what is results output

2) It provides to the reader with a work-flow example of how the model is used: 1 Assemble data, 2: Process results

(please correct 'ReferenceXX' in the code availability section)

We published the dataset as the zenodo archive https://zenodo.org/record/2646476#.XUmJ_XtS9O8 and added the correct reference (page 43, line 10):

The study case data are also available in (Payet-Burin, 2019), with the detailed sources.

Payet-Burin, R.: Zambezi dataset to "WHAT-IF: an open-source decision support tool for water infrastructure investment planning within the Water-Energy-Food-Climate Nexus," zenodo.org, doi:10.5281/zenodo.2646476, 2019.

The manuscript may be rather long and I am wondering if the description of each modules (section 2) could be a supplementary material (?) in particular for Tables and Equations. As it is it may reads more like a report than a research article.

We agree with the suggestion to move the equations and parameters of each submodule of section 2 to a supplementary material document.

My main concern is the following; while there is a section discussing different scenarios I am missing some discussions on the sensitivity of each module to one of the other.

We understand this comment to be similar to comment 4) of reviewer 2, in the sense that the links between the different modules are not clear enough.

To this purpose we added a figure showing the feedback loops among the modules, as suggested by reviewer 2 (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.

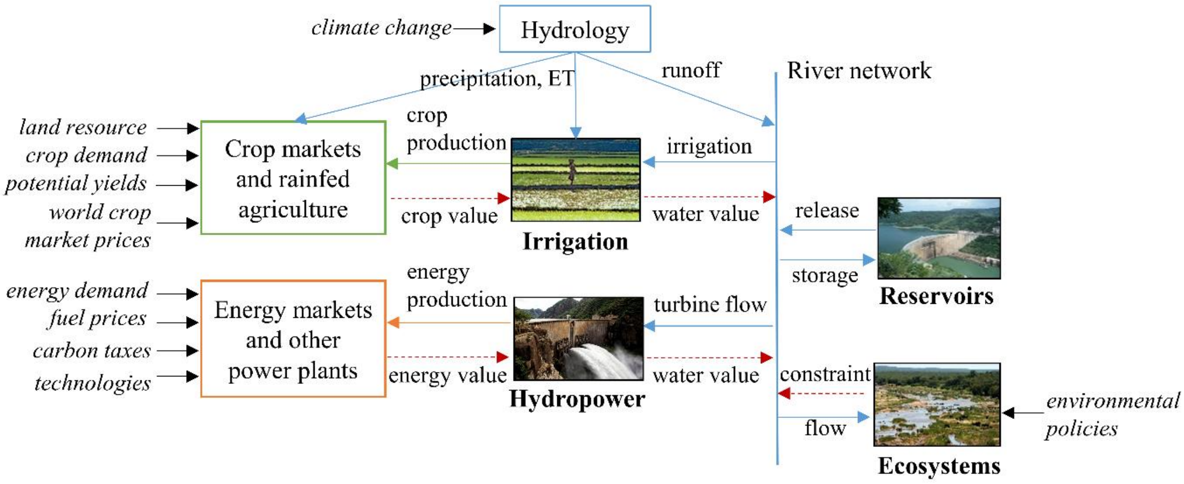

Figure 2: Main feedback loops in the water-energy-food nexus representation. All flows are holistically solved to maximize total economic surplus, the water, energy and crop values are the resulting duals of the mass balances constraints. The figure does not show the temporal and spatial scale of the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

Regarding the quantitative sensitivity analysis on the Zambezi study case, the effect of the different modules on each-other are underlined at various points:

The effect of climate change (water module) on the energy and agricultural system is discussed in the entire Section 4.2 Potential impacts of climate change p31-32.

The effects of the Crop market module and the Energy module on the Agriculture production (page 37, line 7):

A drier climate has a twofold impact on the IDP (Figure 11): it reduces rainfed production and thus increases the value of irrigation, but it also increases trade-offs with the energy sector. In fact, in the current climate scenario the IDP saves 48 M$ yr^{-1} of import value from the world crop market to satisfy food security constraints, while in the driest scenario it saves 95 M$ yr^{-1} of import value. This shows the importance of representing rainfed agriculture to assess the value of irrigation projects. However, hydropower shortages induced by additional water consumption range from 515 GWh yr^{-1} in the wettest scenario to 1 600 GWh yr^{-1} in the driest scenario, inducing losses in the range of 24 to 104 M$ yr^{-1} (representing up to more than 10% of the benefits) which counterbalance the import substitution effect in the crop market.

The effects of Hydropower development on agricultural production (Page 33, line 22):

The HDP has no impact on the agricultural system (Table 15), neither positive or negative, and vice versa, the development of the irrigation development plan does almost not affect its value (Figure 9).

The effects of the environmental flows on the energy and agriculture systems (Page 40, line 14)):

Opportunity costs of the "base" environmental flow policy are almost zero except for the driest climate change scenario. The restoration of the natural floods induces increasing costs with the flood level target: costs reach up to more than 800 M$ yr^{-1} for the driest scenario and the highest flood level, but stay under 150 M$ yr^{-1} for the semi wet and wettest scenarios.

As the reviewer points out this is not exactly a sensitivity analysis, however it shows the impacts of the respective modules on each-other. The sensitivity analysis is performed on the holistic solution for the exogenous parameters that are uncertain in the future such as energy and food demands, technologies capital costs, yields, climate change, carbon pricing or e-flow policies, crop world market prices. (Figure 9, Figure 11, Figure 12)

Also the conclusion must be enhanced to reflect the large amount of work presented

We agree that the conclusion could be extended and added the following (page 43, line 2):

The benefits of the hydropower development plan are found to be around 1.9 billion dollars per year but are sensitive to future fuel prices or carbon pricing policies, capital costs of solar technologies and climate change. Climate change is the main factor impacting hydropower production as it affects the water resource availability. A carbon pricing policy could have a significant impact on fuel prices and thus power production costs and is therefore the main driver on hydropower production value. The development of solar capacity will increase the intermittency in the power system and thus the value of hydropower, however it will decrease the cost of power production, and thus potentially counterbalance the first effect. Similarly, the benefits of the irrigation development plan are found sensitive to the evolution of crop yields, world crop market prices and climate change. The potential improvements in yields could have significant positive impact on the crop production, however the increase is uncertain as past data does not show a clear improving trend. As most of the value of the irrigation development is generated through exports, the development plan is very sensitive to world crop market prices. A dryer climate will reduce the availability of water and thus the potential benefits, however it also increases the value of crops during dry years as rainfed crops will be affected. The development of irrigation infrastructure will decrease hydropower production, leading to reduced benefits. As the total water consumption is a limited share of the available water, trade-offs represent only 5% of the value of the development plan. However, this effect could be exacerbated by climate change.