

We appreciate the reviewers' time and effort in reviewing our paper. We believe that these comments will improve the paper. This document contains copies of all the comments of the Reviewers (in blue text) and our responses to them (in black text).

Response to Reviewer 1:

R1.1. While I find the overall paper topic to be interesting and important, it seems the emphasis on being one of the first to perform a quantitative basis of water boundary conflicts is far-fetched. A quick search reveals several papers that have proposed the same end-goal, yet were not cited. How does this study extend, contrast, confirm, or completely refute such previous studies? To name a few:

- Avisse, N., Tilmant, A., Rosenberg, D., & Talozzi, S. (2020). Quantitative assessment of contested water uses and management in the conflict-torn Yarmouk River Basin. *Journal of Water Resources Planning and Management*, 146(7), 05020010.
- Jacob-Rousseau, N. (2015). Water diversions, environmental impacts and social conflicts: the contribution of quantitative archives to the history of hydraulics. French cases (nineteenth century). *Water History*, 7(1), 101-129.
- Beck, L., Bernauer, T., Siegfried, T., & Böhmelt, T. (2014). Implications of hydro-political dependency for international water cooperation and conflict: Insights from new data. *Political Geography*, 42, 23-33.
- Van Baalen, S., & Mobjörk, M. (2018). Climate change and violent conflict in East Africa: Integrating qualitative and quantitative research to probe the mechanisms. *International Studies Review*, 20(4), 547-575.
- Kilgour, D. M., & Dinar, A. (2001). Flexible water sharing within an international river basin. *Environmental and Resource Economics*, 18(1), 43-60.
- Tinti, A. (2015). Water scarcity and regional fragmentation in the Middle East: A quantitative assessment. *Politikon: The IAPSS Journal of Political Science*, 27, 177-205.
- Madani, K. (2010). Game theory and water resources. *Journal of Hydrology*, 381(3-4), 225-238.
- Grech-Madin, C., Döring, S., Kim, K., & Swain, A. (2018). Negotiating water across levels: A peace and conflict "Toolbox" for water diplomacy. *Journal of Hydrology*, 559, 100-109.
- + many others

If the overall paper's contribution is to be a premier study emphasizing quantitative components of water conflict issues, then a deeper literature review and framing within the existing body of research is essential. If the overall paper's contribution is something else, consider changing the abstract to emphasize that component.

We regret that the novelty of this study is not clearly stated in the manuscript. To address this issue, we will improve the literature review based on your suggested papers and emphasize the contribution of this study.

While we acknowledge all previous studies in conflict and cooperation, including those you mentioned, we believe that quantifying the dynamics of cooperation with both socio-political and hydrological factors has been elusive in the literature of conflict and cooperation studies. In fact, the contribution of this study is to quantify this phenomenon over time after investigating the important socio-political and hydrological factors in the Eastern Nile River Basin using causal feedback.

R1.2. General: There are quite a bit of acronyms used in this paper, which is fine, but it might be helpful to the reader to include a list of all acronyms at the forefront or as an Appendix to the paper.

We will add a list of all acronyms in the appendix of the revised manuscript.

R1.3. General: It was not immediately clear at first read why the ENB was emphasized for conflict out of the entire Nile – do the other countries not have qualms over the water usage? A quick search suggests that many of the countries along the Nile have had conflict to-date over water. (e.g., <https://www.tandfonline.com/doi/pdf/10.1080/17531050701625565>). For example, even though perhaps Ethiopia and Sudan are most vocal about the Nile dam, such decisions significantly impact Kenyans and Ugandans. It is acceptable to limit the scope of the study to a portion of such a large river basin, but I was just unclear as to the rationale at first read of the paper.

Thank you for raising this point. According to lines 47-48, “Water conflicts are more severe in the Eastern Nile Basin (ENB), where Ethiopia, Sudan, and Egypt are located, due to water scarcity.” This conflict has been aggravated over the past several years due to the GERD construction in Ethiopia. The conflict among the three countries has been attracting significant international attention, and thus, the scope of our manuscript is well justified. This is why we focused on the ENB in this study. We will emphasize this issue further to avoid any confusion. However, we will also highlight that solving the ENB conflict does not mean addressing the entire Nile Basin issue.

R1.4. Fig. 1 is good, but a few minor suggestions: Try to avoid using pink and red to differentiate very similar boundary types (e.g., use a more contrasting color); considering adding the datum to the caption for referencing the lat/lon values (I’m sure it’s the standard WGS 1984 datum, but it always helps to include this type of information in GIS-based maps); consider adding to the legend what the dark blue polygon boundary represents; ensure final figure to the Journal (usually in PDF format) is very high-resolution, as it appears blurry in the current embedded format.

In the revised paper, we will improve the quality of Figure 1, as you pointed out.

R1.5. Introduction (General): Overall introduction appears to have all of the “pieces” there but is put together in a manner that reads as disjointed in thought. A bit more effort is encouraged in telling the story here, by starting with the general problem, its importance, and then narrowing down into what has been done thus far to address, how those still have gaps, and then finally what this paper brings to the table.

We will use your suggested outline to improve the Introduction Section.

R1.6. Line 30-33: What is C&C? In general, I think there needs to be a bit more elaboration on the overall “big picture problem” and why it is important to the reader (and society) before jumping into details of the literature, particularly with acronyms that are not explicit.

Thank you for raising this issue. C&C stands for conflict and cooperation. We will address this issue in the revision.

R1.7. Line 33-35: Sentence seems to belong before explanation of literature. Describe water conflicts, political agreements, and the overall mindset of socio-hydrology before delving into details.

We will improve the introduction section by adding the literature review of socio-hydrology and a description of general terms in transboundary rivers (e.g., water conflict, political agreements).

R1.8. Line 38: Describe hydro-hegemony. Remember, HESS is read by a broad group of hydrologists and earth scientists who may not be familiar with the common lingo in socio-hydrology.

In this study, hydro-hegemony is the leadership or dominance of a riparian country over other riparian countries in a transboundary river basin due to a riparian country’s upstream position or historical water rights. We will add this definition in the revised manuscript.

R1.9. Line 57-60: While this literature on the Nile is robust, it is too focused on the geographical case study. Further literature, which is important for framing the overall novelty of the paper, is generally missing.

According to our answer R1.1, we will clarify the contribution of this study in the revision and tie it to the available literature.

R1.10. Line 70: Cooperation “and conflict”?

Yes, it is a typo error. We will fix it in the revision.

R1.11. Line 70: Choice of word “confronted” here seems out of place.

The word will be replaced with “validated” in the revision.

R1.12. Lines 83-133: This large amount of text could be significantly condensed and/or added to SI. It is not yet clear how this historically based narrative can be considered quantitative (perhaps semi-quantitative or fuzzy-based transformation from qualitative to semi-quantitative?).

These lines initially suggested the most important socio-political and hydrological factors in conflict and cooperation dynamics in the ENB in a qualitative manner. These factors were taken into account in the following section (3.1 variables) where we identified all these factors and

validated their significant role in ENB's cooperation dynamics with the local and general studies in conflict and cooperation dynamics. At the end of this section (3.1), Table 1 showed how we obtained the quantitative data of all these factors from different sources. We believe it is important to present these factors and how we reached at them because their identification is important for this study.

R1.13. 3 Method: Temporally, what data? Precipitation, streamflow, where did you get it, how was it verified or roughly calibrated? What are the "units" being discussed? What is the basis of this model? If it is meant to be a stylized socio-hydrological model, this should be discussed somewhere prior to identifying the system variables and assumptions.

All model variables are shown in Table 1 with their sources of data. In section 3.4, we divided the model inputs into two categories: the inputs taken from the literature and the inputs taken from a water resources model. We explained all data sources taken from the literature and their time span. We also explained how the water resources model, which was developed and validated by Abdelkader & Elshorbagy (2021), estimated the remaining part of our model inputs (i.e., their equations were shown). In the revised manuscript, we will provide their units. As it is explained in section 3.4, one part of our data (food gap and energy gap) is based on the water resources management model of Abdelkader & Elshorbagy (2021), which was previously calibrated and validated. The rest of the data are based on the Food and Agriculture Organization (FAO) data and Nile River Basin reports. Although we acknowledge the limitations of our developed model, we do not consider it as a stylized socio-hydrological model. This is because our model is based on a previously calibrated and validated model (Abdelkader & Elshorbagy, 2021), and we also validated our model output with independent qualitative data from the literature in the result section.

R1.14. Overall Methodological section is in piece-meal nature and is not, in my opinion, at a quality and coherency level for publication. I do think there are strong bases here, and a well-intended study was conducted, but the way it is written and presented could use further explanation for the reader to be introduced to this type of model-thinking.

We regret that the current method section is not as clear and coherent as we thought. We will strive to improve the readability of this Section without increasing the paper length significantly, as it is already lengthy.

R1.5. Figure 3: A suggestion – consider changing the Eth, Sud, Egy nomenclature to be represented by different color nodes, rather than text additions.

We will use different colors to represent each country in the revised manuscript.

R1.16. Section 3.3: I do not agree that this is a causal "loop" diagram. The loops, in terms of reinforcing/balancing and how they then interact dynamically amongst one another are not depicted graphically. Rather, this is a causal feedback diagram. There are 3 loops in the middle, but they are all reinforcing, which would not make much sense in terms of figuring out overall causality as the entire system would keep, theoretically, reinforcing itself on a forever trajectory.

We will change it to “the causal feedback diagram”. Regarding the reinforcing loop, as you mention, a reinforcing loop by itself leads to a forever trajectory. However, these reinforcing loops in our hypothesized system only show a part of our system, and they are explicitly surrounded by complex feedback. For example, water supply for hydropower can increase through an increase in the energy gap. This increase in water supply for hydropower increases energy production and thus reducing energy gap (i.e., balancing loop).

R1.17. Eq. 1-8: It is hard to review the equations, when the overall picture and causal depiction is unclear. Perhaps a bit more explanation on these variables, and/or why they were hypothesized as such, and/or tables showing the variables and their dynamic simulation in the SI would help the reader follow?

In the revised manuscript, we will improve the description of the overall picture of the work. We will also add a table including all equations and variables in the supporting information.

R1.18. 4 Results: The explanations here are helpful in making sense of the previous section. I still recommend a deeper review of how the work is being presented and organized for overall readability.

As confirmed in a previous comment (R1.1), we will improve the introduction to address this issue.

R1.19. General Note: All equation variables, when listed in-text, are showing up as very large, blurry, and distorted in the PrePrint PDF. I am not sure if this is an issue with the HESS conversion format into PDF, but please verify that the texts are provided in the proper fonts.

We will address this issue in the revised manuscript.

R1.20. Conclusion: Most of the conclusion section is actually a further listing of detailed Results. Please consider re-phrasing the Results section to be cohesive in one read, and then in the Conclusions, highlight the overall take-away, not re-listing the methodological outputs.

In the revised manuscript, we will revise the Conclusion Section to highlight the main take-home message and we will try to avoid any listing of results.