

Response to Reviewers' Comments

Associate Editor:

Based on my own reading, the paper provides an improved representation of key processes in the sociohydrological modelling of transboundary water conflict and cooperation (C&C) in the context of previous efforts. It also provides new insights to understand the C&C dynamics occurring in the East Nile Basin. However, as expressed by the Referees, the major concern about the paper's current form is the vague expression of its novelty. Please check the Referee's comments for more detail. I agree with the concern although I acknowledge the paper does improve our knowledge of the C&C modelling and our understanding of the real Nile water C&C situation. In my understanding, the modelling work of this study is built on the previous method proposed by Lu et al. (2021) and the framework proposed by Wei et al. (2022) in this issue. It can be better understood if the authors express in a way: how your model is improved from Lu's work and how the model complies with Wei et al. framework or improves it. The paper can also highlight the insights gained from the modelling for C&C understanding in the Nile Basin.

I would like to ask the authors to revise the manuscript based on all the comments and I will make a further review. Thanks for your efforts.

Thank you for your time to review our revised manuscript. Changes made in the manuscript are marked using "track changes," and your questions are answered in this letter. We have also attached another clean version of our revised manuscript without track changes. We have addressed all minor comments from the reviewers. We have also addressed your main comment by adding the following lines to the manuscript (Lines 86-89).

"This study builds on the previous work on socio-hydrology in transboundary rivers by Lu et al. (2021) and Wei et al. (2022) but distinguishes itself by incorporating the following additional important elements into our socio-hydrologic model: (1) the concept of social memory and quantitative components of C&C phenomena (e.g., political stability), (2) uncertainties in the representation of countries' decision making process, and (3) the heterogeneity of decision making across the riparian countries in their cooperation."

Also, this study is consistent with the study by Wei et al. (2022) as it considers the concept of the social motives and power status in the model conceptualization (Figure 3) and equations (Eq1-3). The social motives of countries are shown in line 284-290 of the manuscript:

"Consistent findings show that decision behaviors in resource dilemmas are mostly individualism (i.e., the drive to prioritize one's own interests) and competition (the drive to increase relative gains, the gap between one's achievement and that of the other) (Brewer & Kramer, 1986; Parks & Vu, 1994; Roch & Samuelson, 1997). Thus, here, countries' willingness to cooperate is evaluated based on their relative socio-economic gains (Kopelman et al., 2002; Mason, 2004)."

As for the gained insights from the modeling the Eastern Nile River Basin, we summarized and discussed them in the section 5 by bullet points (Lines 521-550):

- *Ethiopia experienced two general trends in cooperation dynamics: a relatively high willingness to cooperate between 1983 and 2009 and a subsequent decrease. The model suggests that relative political stability and foreign direct investment can explain these two different phases, along with Ethiopia's food and energy gaps. The results of sensitivity analysis also show that energy and food gaps are the most important factors in Ethiopia's willingness to cooperate. This finding suggests that improvements in Ethiopia's food gap and energy gap can be a good motivation for Ethiopia for further negotiations in the basin. Also, the model suggest that a high level of Ethiopia's relative political stability and foreign direct investment can be a barrier to further basin cooperation. This is also supported by Mason (2004) who argued that the international economic and political asymmetry can negatively affect the basin cooperation.*
- *Sudan's willingness to cooperate dropped between 2003 and 2008, and recovered subsequently, the latter pattern likely reflecting the 2008 food crisis in Sudan. The importance of the agricultural sector was also shown in the result of sensitivity analysis, compared to other socio-political and hydrological factors in Sudan's willingness to cooperate. This result implies that Sudan is likely to be motivated in further negotiations in the basin by improvements in its food gap.*
- *The drop of Egypt's willingness to cooperate around 2007 appears to be related to negotiation deadlock while, later, Egypt entered a politically unstable phase and returned to the negotiation table, which is reflected by a recovery of its willingness to cooperate. Also, the result of sensitivity analysis showed the important role of political stability and the country's memory for Egypt's willingness to cooperate. Based on Egypt's past experience, it might be challenging for Egypt to fully trust upstream countries during further negotiations because Egypt is concerned about its historical water rights of the Nile as its main water resource. Thus, we suggest that building up Egypt's trust might be the very first step for any negotiations in the basin. Such trust might be strengthened by a basic commitment by all parties that a basin-wide agreement will be the basis of infrastructure, including GERD, operation.*
- *At the scale of the Eastern Nile Basin, the model highlights the role of trust and good memory from the past in increasing cooperation. For example, the increase in cooperation after 1984 brought the riparian countries together for the Promotion and Development of the Nile activity (TECCONILE) in 1992. Also, the result of sensitivity analysis showed that Ethiopia's food and energy gap and Sudan's food gap are the most important factors in the basin cooperation. These findings suggest that a further cooperative agreement should be more focused on improvements in Ethiopia's food and energy gap and Sudan's food gap while assuring no significance harm to Egypt's historical water use.*

Reviewer 1:

The quality of the manuscript has been largely improved. Only several minor comments:

- 1) In Figure 2, the authors introduces the C&C from 1959 to 2020. However, the study period was much shorter, the authors may briefly discuss the implications your results on the long historical period. It is noted that the input variables and results variables had inconsistent start year.
- 2) The authors may improve some sentences for example Line 94
- 3) Some references included in the text were not included in the reference list. Please check

Thank you for your time to review this paper. We have fixed all these issues in the manuscript. Specifically, the first comment has been addressed by the following (Lines 108-110):

“This time period is longer than that of our modeling in section 3 as we need a long time period to investigate the socio-economic and political factors in the riparian countries’ willingness to cooperate. It is worth mentioning that we did not use this long period for section 3 due to the lack of quantitative data.”

Reviewer 2:

Author's claims that this paper connects qualitative literature review with quantitative bases is not validated, especially considering their acknowledgements of a lack of sensitivity analysis in the final paragraph. Is this a methodological paper or a proof of a local phenomenon? It does not appear to be robust enough for both, yet that is how the writing is conducted. Do not state 'could be' without actually doing (in last paragraph, summarizing entire methodological approach).

Thank you for your time to review this paper. We do believe that the qualitative literature review and data paved the way for this study in two areas: (1) the qualitative literature review enabled us to investigate the socio-economic and political factors in the riparian countries' willingness to cooperate (section 2), and (2) the independent qualitative data enabled us to validate the overall trends of the model outputs. Also, this study provides a sensitivity analysis on the model parameters, which highlighted how surveying data can improve this modeling (section 3.5). The last paragraph in the conclusion states how this model can be improved by additional work. Specifically, one of them is sensitivity analysis on the model inputs and model structure (i.e., the equations of countries' decision making), which is different from our sensitivity analysis on model parameters. In fact, acknowledging the lack of these types of sensitivity analyses has nothing to do with the validation of this work.

We regret that these points were not clear in the text. Therefore, we modified the text in the last paragraphs and added new sentences to make our views and conclusions clear, as follows:

“The ENSH model is built on the existing knowledge of the processes, but future studies could use alternative social theories and hypotheses, thereby improving our perceptual understanding of how the system works. In this regard, we should point out that our primary modeling purpose has been ‘diagnostic learning’ by simulating the past, complex behaviors pertaining to the conflict and cooperation in ENB – see the discussion in Razavi et al. (2022) for models as a tool for diagnostic learning. We believe this work, along with previous work cited in this paper, constitute the first steps towards building a predictive model for such phenomena to be used for future decision support.”

“Another potential source of uncertainty of the ENSH model is the input data (i.e., energy production, food consumption, food production, foreign direct investment, future reservoir storage, potential energy capacity, and relative political stability). The significance of such uncertainty in inputs on the outcome may be assessed through sensitivity analysis in future work.”