Reviewer 1

Thank you very much for the substantial revision and the clarifying responses to my questions. The paper has improved a lot, reads much better and describes many aspects much more clearly. However, there is still some need to improve the results section from my point of view as well as a list of mostly language-related points.

We appreciate your recognition of the improvements made in our previous submission. We made additional improvements to the results section to improve clarity and coherence. Specifically, we separated the Results and Discussion section to clarify the interpretation and results. We have also refined the linguistic components, encompassing grammar and syntax. We value your valuable feedback and believe that these updates effectively address your issues, hence improving the overall quality of the paper. The original comments are in **bold**, our comments are in standard text, and the additions/revisions are indicated in *Italics*.

Specific comments

RC1.1. Most importantly, the results section is still not very strong in terms of content. This maybe be due to the preparation of a number of other papers which will go much deeper into applications of the NEXUS module. That is fine, but the current state is still something which feels quite incomplete and repeats in some parts model description rather than discussing results (e.g. from line 600 to line 627). Figure 5 is very nice but not discussed in detail. The discussion mentions an impact on the power generation mix for which a figure would be nice (or is that Figure S4.2.1?). If no detailed scenario analysis is supposed to be performed in this paper, maybe the discussion can be framed around demonstrating that the integrated framework works, with selected plots showing the interactions. I feel this is what you are trying to do already, but from the current text this doesn't become clear.

We appreciate your insightful comments on our manuscript's Results section. We appreciate your recognition of Figure 5 and acknowledge your concern regarding the level of detail in the current presentation of the results.We have changed the Results and Discussion sections to improve their completeness and clarity in response to your feedback. To give a clearer and more focused narrative that highlights the results of our investigation and the operation of the Nexus module, we have divided these sections.To avoid repeating the model description, we have also added further explanations of the results and enhanced the discussion with more in-depth interpretations of Figure 5. We have also examined the influence on the mix of electricity generation, ensuring that the relevant statistics are adequately explained.

The specific addition of the paragraphs mentioning the results are:

Figure 5 presents a comparative analysis of key Energy-Water-Land (EWL) indicators across a spectrum of modeled scenarios. The boxplot distributions visually depict selected model output indicators for the period from 2030 to 2080, covering scenarios such as Reference, Impacts, Impacts_LU (land use), Impacts_EN (energy), Impacts_WAT (water), and SDGs. The graph's

constant trend in energy-related metrics across scenarios stands in stark contrast to the pronounced unpredictability of non-renewable water usage, suggesting that energy indicators are less vulnerable compared to water and land.

Figure 5 also shows that, despite the biophysical impacts, agricultural production doesn't vary much. The SDG scenario, however, results in a considerable 20% decrease in agricultural output, with the biophysical implications of land usage having a particular influence on sugar crop yields. This noteworthy effect emphasizes how susceptible some crops are to changes in land use and how crucial it is to take these effects into account when developing agricultural plans and policies.

Furthermore, the primary cause of the decrease in water withdrawals is the consequences of land use, wherein CO2 fertilization effects are a major factor. These effects on land usage decrease the overall need for irrigation and increase the efficiency with which agricultural operations use water.

Additionally, the figure also indicates that the cost of potable water has increased by 80%, primarily due to the adoption of environmental flow allocations aimed at protecting freshwater ecosystems and the increased expenses linked to sophisticated wastewater treatment procedures. These elements highlight the intricate relationship that exists between water resource management and economic results as well as environmental care.The geophysical features and land use influences of various regions mostly determine the global consequences of climate change on the water sector, with certain areas experiencing gains while others may have negative effects. Adaptive responses to climatic impacts reduce the number of people exposed to hunger by an average of 11% according to the study. This is not as significant as the 30% reduction in the SDG scenario, which is based on specific actions to reduce the risk of hunger.

It is imperative to exercise caution when interpreting the outcomes of the different scenarios, taking into account their reliance on several assumptions and their suitability for particular geographical and temporal circumstances. However, these results offer insightful information about the possible financial effects of various water management techniques. Different modeling methodologies may produce different results because assumptions, data inputs, and other elements are inherently variable. It is feasible to determine the most effective and successful tactics and to obtain a more thorough understanding of the probable consequences of different water management systems by comparing the outcomes from many models.

RC1.2. The scenario selection is still not very clear, in particular whether all impact scenarios use RCP6.0 and if so where RCP2.6 comes in. Maybe only in the SDG scenario? But in Figure 5 fossil energy production is very similar across scenarios. Does the SDG

scenario include impacts? Also, I assume the figures in the supplement will be updated to the new scenarios?

We have clarified the scenario framework in the manuscript and added a table for clear categorization. The SDG scenarios include climate impacts, with the intent to assess the combined effects of climate impacts and SDG implementation.

The revised section in the manuscript is;

In our analysis, we have currently applied the SSP2 framework in conjunction with both RCP2.6 and RCP6.0 to establish the current model setup. Future work will incorporate a broader array of SSPs paired with various RCPs to ensure a more comprehensive and coherent set of assumptions across different scenarios. Our examination of the biophysical effects of climate change on energy, water, and land use sectors involved contrasting scenarios that integrate climate impacts—specifically designated as Impacts, Impacts-EN (focusing on the energy sector), Impacts-WAT (water sector), and Impacts-LU (land use)—alongside SDGs. We measured these against a Reference scenario, which is predicated on historical climatic patterns and excludes any projections of climate impacts or SDG considerations. The scenario assumptions are detailed in Table 4.

Table 4 *Summary of Scenario assumption*

Scenario	*Climate Scenario*	*SDGs*
Reference	*Historical climate assumptions for RCP 6.0 across EWL sectors.*	*Not included*
Reference (Mitigation)	*Historical climate assumptions for RCP 6.0 across EWL sectors.* *This scenario, although is practically not feasible it is used to compare the responses of the new features*	
Mitigation	*RCP 2.6 (biophysical impacts of EWL sectors as outlined in Table 2 and section 3.2)*	
Impacts	*RCP 6.0 (biophysical impacts of EWL sectors as outlined in Table 2 and section 3.2)*	

Impacts_LU	*RCP 6.0 (biophysical impacts of land sector, e.g. crop yields)*	
Impacts_WAT	*RCP 6.0 (biophysical impacts of hydrology)*	
Impacts_EN	*RCP 6.0 (biophysical impacts of energy, e.g., cooling demand and renewable potential)*	
SDGs	*RCP 6.0 (biophysical impacts of EWL sectors as outlined in Table 2 and section 3.2)*	*SDG 2, 6, 7, 13, 15 – as outlined in Table 3 and section 3.3*

RC1.3. Finally, the introduction could still be improved to state more clearly the gaps closed by this study. It should be pointed out explicitly that adaptation here means model-endogenous responses to impacts or SDG constraints, no adaptation pathways with specific adaptation policies.

We have refined the introduction to clearly delineate the study's contributions in addressing existing research gaps. Additionally, we have specified within the text that 'adaptation' refers to model-endogenous responses to climate impacts and SDG constraints, without prescribing specific adaptation policies at the community level. We have also updated references and introduction to clarify more. The changes are reflected in the tracked version of submission at various sections.

Minor points (the line numbers are from the "version 3", not the track changes version of the paper)

Thank you for highlighting the minor comments. We have mentioned the revisions under each minro comment where needed.

Line 64: "IAMs often consider the costs of resources in an aggregate spatial region" – not only costs of resources but this is their level of spatial resolution

Line 65: "the key element for change is implemented on a local/national scale"

The above two comments are addressed by rewriting both sentences as:

IAMs typically operate at regional or continental scale for informing the future pathways, whereas adaptation strategies requires a more nuanced, localized focus emphasizing on national and sub-national levels (Andrijevic et al., 2023).

Line 71: there seems to be a remnant sentence left over, starting with "estimating that economic impacts have…"

The sentence has been revised as;

These sectoral assessments evaluate biophysical impacts such as changing yields, runoff changes, food production, and groundwater. Economic impacts are subsequently estimated using various methodologies, chosen based on the specific type of impact considered such as the corelation between climate damages and temperature variations.

Line 77: The sentence starting with "It is becoming quite evident" should be revised in terms of language as it does not read well. Also, the statement on "the effects of different sectors on the techno-economic outlook" is unclear – do you mean climate impact channels and techno-economic transformation or scenarios or so?

We have revised these setences as;

Some studies have empirically linked climate conditions with socioeconomic systems and incorporated distributional factors into cost-benefit models, resulting in increased social costs of carbon and more stringent mitigation pathways (Parry and Carter, 2019; Howard and Sterner, 2017). Incorporating the representation of biophysical climate impacts into integrated assessment models is crucial to understand how various sectors influence techno-economic scenarios and to identify appropriate mitigation and adaptation strategies (van Maanen et al., 2023; Andrijevic et al., 2023)

Lines 80-84: Piontek et al. 2021 a and b are the same paper. Maybe you mean Schultes et al. 2021, which does include aggregate damage functions but not biophysical impacts. Soergel et al. 2021 does not include climate impacts at all. There are probably other papers to be mentioned here, certainly from the CGE literature which capture impacts in the water, land and energy sectors?

We have improved this section as;

Incorporating the representation of biophysical climate impacts into integrated assessment models is crucial to understand how various sectors influence techno-economic scenarios and to identify appropriate mitigation and adaptation strategies (van Maanen et al., 2023; Andrijevic et al., 2023) . (Piontek et al., 2021) analysed the economic impacts of climate change using the REMIND IAM model, but biophysical climate impacts were not represented. (Soergel et al., 2021a) emphasized the significance of considering the consequences of climate impacts and evaluating how integrated scenarios respond to these impacts, especially regarding sustainable development pathways.(Schultes et al., 2021) highlights the economic impact of climate change, advocating for immediate mitigation to reduce long-term damages and align with cost-effective Paris Agreement targets

Line 83: What do you mean by "introducing climate impacts in the development trajectories"? As far as I know Taconet et al. do a damage post-processing using damage functions?

We have removed this sentence to keep the flow and consistency of the Introduction.

Lines 89: Yes, so you can state here clearly this need requires biophysical impacts to be included in the IAMs, preferably with a link to high resolution impact modeling – and that is what you deliver!

We have improved the sentence as;

This study proposes a framework that incorporates high-resolution model outputs of biophysical climate impacts into IAMs, strengthens the water sector's resilience, and crafts scenarios in tandem with sustainable development objectives to evaluate climate change effects across various pathways, including mitigation, adaptation, and sustainability.

Line 98: You mention communities but IAMs don't resolve communities.

We have improved the sentence as;

This holistic approach is designed to elicit model endogenous response to climate impacts and SDGs constraints, thereby enhancing systemic resilience and advancing sustainable development, although it does not delineate specific adaptation policies at the community level.

Line 99: "This study addresses these gaps" – maybe start the paragraph with something like "This study addresses the following gaps"? It is not immediately clear from the flow.

We have improved this section:

Due to hydrological data's spatial and temporal complexity, it is challenging to translate hydrological information into the IAMs. Usually, the spatial extent of IAMs is macro-regions, and the aggregated hydrological information loses adequate information at a macro-level. There is 105 always a need to find a middle ground between showing the hydrological process more accurately and lowering the cost of computing (Fricko et al., 2016b; Parkinson et al., 2019b)There have been efforts to link a higher spatial resolution water sector to account for hydrological balance and constraints in IAMs, such as (Yates, 1997) and (Kim et al., 2016).

Addressing the identified gaps, this study proposes a framework that integrates climate impacts with an emphasis on the water sector's role in climate change and develops scenarios in sync with sustainable development assumptions to evaluate the effects of climate change within the contexts of mitigation, adaptation, and sustainable development pathways.

Line 143: "the core global framework" – of MESSAGEix?

We have adjusted this part.

Line 168: "This enables connecting …"

We have fixed this sentence.

Lines 193/194: "policy options", not "possibilities" – also "many facts and hypotheses" is somewhat vague, many of the examples mentioned are scenario-based

The framework facilitates a comprehensive assessment of policy options by integrating scenario-based projections, including population and economic growth, technological advancements, and resource limitations.

Lines 205-207: post-processing, not post-computing? With "scenario explorer" do you mean the IIASA scenario explorer? Maybe not all readers are familiar.

iv) post-processing of the model outputs to provide ready-to-use results in a database and for visualization tools such as IIASA scenario explorer (Huppmann et al., 2018).

Line 211: R11 region – please define

The module uses SSP-RCP (Shared Socioeconomic Pathways – Representative Concentration Pathway) combinations as narratives for creating a baseline scenario. Each scenario is developed using SSP-RCP combinations, national policies, and Sustainable Development Goal (SDG) assumptions aggregated at the R11 region, a spatial delination of 11 global regions used in the MESSAGEix-GLOBIOM.

Line 215: you use GHM output from the ISIMIP database, correctly? In the current wording, it seems to be two separate things.

We used the Global Hydrological Models (GHMs) outputs from ISIMIP database (Frieler et al., 2017) for water availability and hydropower potentials for biophysical impact indicators. The GLOBIOM model upscales these water requirements and provides irrigation requirements at an aggregated 37 regions based on land-use allocation decisions

Line 242: Do you mean Figure 1? Also "The study represents" – maybe "The study applies"?

We have adjusted the wording here.

Line 292: delete "driving"

We have deleted the word 'driving'.

Line 312: maybe state explicitly that the data from Wang & Sun are based on the SSPs for the readers unaware

We followed the methodology by (Graham et al., 2020) to estimate the municipal water demands, where urban and rural components are derived from gridded population and income-level projections based on the SSPs, as detailed in(Wang and Sun, 2022).

Line 323: Figure 1?

We apologize for the confusion. Figure 3 was missing in the previous version by mistake. We have re-added in the updated version.

Line 395: What about bioenergy as renewable energy source? That is affected through impacts in GLOBIOM, correct?

We don't take into account the impacts on the bioenergy in the current framework.

Line 411: "no climate change scenario" – REFERENCE?

We have removed these words to avoid confusion since scenarios are defines afterwards in the manuscript.

Line 463: "protect river-related ecosystems in alignment with achieving SDG target 6.6"?

We have adjusted the sentence as;

Maintaining environmental flows in rivers is instrumental in achieving SDG target 6.6, which aims to protect and restore water-related ecosystems, encompassing a range of natural landscapes from mountains and forests to wetlands, rivers, aquifers, and lakes.

Lines 565/566: Maybe clearer to say that the reference scenario keeps climate constant at historical levels? The phrasing "physical impractical" is strange, the reference scenario is unrealistic given progressing climate change as well as already implemented mitigation and adaptation measures.

We have added a note in the scenarios Table 4 that scenario is mere included for model validation and assessment against the biophysical impacts response.

Lines 571-575: This should come in the model description, not in the discussion of results.

We have moved this part to Discussion section.

Lines 576: Maybe introduce this section better, i.e. by stating that you do a bit of model validation by comparing 2020 values with other sources to help guide the reader.

We have improved the introductory section as;

Our study presents detailed results of water balance flows, providing a critical examination of global water management and the interdependencies within the water, energy, and land nexus. By comparing our model's outputs with benchmark values from the literature, we establish a validation baseline for EWL indicators, ensuring our findings resonate with recognized global

estimates. Our study allows the monitoring of water balance flows at varying stages, offering an in-depth understanding of global water management and the intricate nexus between water, energy, and land. These interactions are depicted in Figure 5a in form of Sankey diagram, along with input details and assumptions expounded in Section 3.1.

Line 635: do you mean in the SDG scenario?

We have adjusted this as SDG scenario.

Line 638: which RCP is underlying this result?

RCP 6.0 is being discussed here.

Line 652: What adaptive responses do you mean here exactly? This relates to the need mentioned above to state somewhere in the beginning more clearly how you address adaptation in this study.

We have adjusted the sentence as;

In addition, these effects contribute to a 28% decrease in the marginal price of potable water due to adaptive responses to climate change impacts in electricity and irrigation withdrawals.

Line 660: What do you mean by climate scenarios? Rather transformation or mitigation scenarios?

We have adjusted the wording as;

Overall, the findings indicate the need for more research to fully comprehend the potential effects of climate change on diverse sectors and the possibility that incorporating biophysical consequences can substantially impact the outcomes of Impact and Mitigation transformation scenarios.

Line 663: Can you provide an example for co-benefits?

We have added example of co-benefits in the sentence;

Overall, the study's findings illustrate the significant implications of climate impacts in mitigation scenarios on the energy mix and the co-benefits such as agriculture production, increased crop yields, shift towards less fossil intensive technologies in electricity mix

Lines 685/686: This sentence is repeating something stated earlier.

We have removed this part.

Line 722: Isn't consistency in the impacts why you chose ISIMIP? It is a bit unclear what you mean here.

We have improved the sentence to provide more clarity;

While the Nexus module employs the robust outputs of the ISIMIP for depicting climate impacts, there are certain challenges from the current set of outputs not being fully consistent with the input climate scenario assumptions. As soon as updated and aligned ISIMIP outputs become available, we will conduct a new model run to enhance consistency and reduce uncertainty in our analysis.

Line 729: What do you mean by this sentence? Which complex dynamic isn't captured?

We have explained which dynamics are not captures;

The current model structure, which assumes an endogenous adaptation response, may not fully capture the complex dynamics such as the feedback mechanisms between water availability and energy production, socioeconomic impacts of water scarcity on land use, and long-term societal adaptations to water stress within the EWL sectors. Future research will focus on integrating these inter-sectoral feedback and dynamic responses to enhance the model's accuracy in depicting the intricacies of the EWL nexus.

Line 732: What do you mean by "higher tolerance"?

We have adjusted the wording to explain better;

In future research, we plan to expand our exploration of climate impact dimensions to include a more robust handling of statistical climate extremes, aiming for greater resilience in our model's performance at sub-annual temporal resolutions. Future versions of the model will integrate up-to-date climate impact data and strive for more consistent data sources across sectors.

Reviewer 2 (Page Kyle):

The authors have addressed my concerns from the prior review, and I appreciate the many comparisons to the literature for the selected key results. However in re-reading the final document I noticed a large number of minor issues that should be corrected prior to finalizing the document for publication. These are presented using the line numbers in the clean document egusphere-2023-258-manuscript-version3.pdf.

We thank for acknowledging the improvements made to the manuscript in the previous round. We have addressed the minor issues you have highlighted and ensure the document is thoroughly refined.

RC 2- Minor Comments

42 - copy editing error (two periods)
77, 80, 82, 88 - each one of these lines has a copy editing error related to references, parentheses, and punctuation.

The copy-editing errors on lines 42, 77, 80, 82, and 88 have been thoroughly addressed and corrected in the revised manuscript.

88-89 - SSP acronym used in line 88, defined in 89

We have adjusted this.

90-105 - note that the "tracked" and "clean" version differ here

Sorry for confusion. Apparently, there was some technical issue overlooked between two versions in the last round.

94-95 - the EWL acronym is used undefined on line 94 and then written in long form and with capital letters (which I don't think is correct) on line 95 but without providing the acronym. I'd write: "meeting population-driven demands in the energy-water-land (EWL) sectors (Rasul and Sharma 2016). Integrating cross-sectoral EWL nexus..."

We have adjusted the acronym and sentence as per your suggestion;

Integrating cross-sectoral EWL nexus analysis in IAMs can help identify trade-offs and synergies, integrate policy implementations, and address equity dimensions, such as the population exposed to hunger or lacking access to sanitation and electricity

261 - please replace "South Africa" (which is a country) with either "Sub-Saharan Africa" (which is what SSA stands for in MESSAGE) or "Southern Africa".
We agree with your observation and have replaced the South Africa with Sub-Saharan Africa where applicable.
307 - I'm not sure what is meant by "Figure 2.1 B" as there is no such figure in the supplement.

There was an ‘S’ missing and we have adjusted in the manuscript.

577 - "approximately 47219.79 km3/yr" - if the text says approximately, then the number should not have 7 significant digits.

We have adjusted all figured to neares 1 km3.

610-611 - the example information flow described is introduced as "The use of EPIC" but then the information flow involves more than EPIC. Perhaps "The use of EPIC and GLOBIOM in determining irrigation responses and crop yields is one prominent example."

We have rewritten this section to have more clarity;

To capture the dynamic responses of the climate system, our model employs a multifaceted strategy that leverages both endogenized and exogenous outputs. Specifically, we utilize EPIC to obtain insights on irrigation responses and their subsequent effects on crop yields, which is a key example. These yield outputs from EPIC are then integrated into GLOBIOM, where adaptation responses are internalized, prompting a strategic reallocation of land use resources in response to climate impacts.

632 - does "fertilization intensity" here refer to chemical fertilizers (N, P) or CO2 fertilization? Either way it's not spelled out (and it should be) how the fertilization intensity influences water use efficiency and therefore irrigation water requirements.

We have clarifies the fertilization intensity;

The effects of climate on crop yields show variability, with sugar crops experiencing a significant impact at 16%, while cereals exhibit a comparatively modest change of approximately 1%. The net yield effect is directly influenced by the intensity of nitrogen and phosphorus fertilization, which enhances water use efficiency and consequently reduces the demand for irrigation water. Furthermore, in our climate impact scenarios, increased CO2 levels also increase crop yields and contribute to improved water use efficiency, which is factored into our results.

665 - "these results are based on a specific model and situation and should be interpreted as a general trend" - the point being made seems to be the opposite, that it's only one model so should not be interpreted as a general trend. But I'm not sure of the point being made so the authors should check.

We removed this sentence to avoid confusion .

681 - I've found that throughout the paper, the terms "module" and "model" used interchangeably and it's often confusing and hard to tell what is intended. I would think that "model" would refer to the integrated system of individual "modules", where module means component (e.g., GLOBIOM, MESSAGEix, MAGICC, and so on).

763-764 - here again the terms "model" and "module" seem to be used interchangeably but I don't know if that is intended.

We understand the choice of terms ‘ module’ and model’ could be confusing to readers. We have adjusted all the work related as ‘modules’. The changes are reflected in the revised manuscript.

753-760 - can the authors confirm that these results are described or depicted elsewhere in the study? I don't see it, and the conclusions shouldn't be the first place where a result is described.

We have removed this part to avoid confusion and make the text consistent.