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Geoscientific Model Development Discussions

Interactive comment on "The Nexus Solutions Tool (NEST): An open platform for optimizing multi-scale energy-water-land system transformations" *by* Adriano Vinca et al.

Adriano Vinca et al.

vinca@iiasa.ac.at

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Thank you for your review of our paper. We are glad that you find the research valuable. In this comment we report the reviewer's comments under <> brackets, followed by our replies. attached is the updated version or the manuscript, where also new figures can be displayed.

< Some of the issues with the paper that the authors should address are the following:

- It is not clear what scale the platform is developed for. My impression is that it is developed on a global scale, but only the Indus River Basin is presented in this article

with the different SDG scenarios, so the scale is not very clear from the manuscript. This is important to mention in order to let the reader know what the potential of this platform is. >

The NEST framework has been so far implemented for the Indus River Basin. The data, come from a combination of global databases or global modelling assessments and local data sources which were collected specifically for the Indus Basin study. The global data is cropped to the basin-scale. The use of global data makes the implementation flexible in the sense that a first-cut analysis of the system can be made using available sources consistent across regions. We think that the two following statements explain it quite clearly, however we introduced an additional sentence to avoid ambiguity.

We state in line 13 pg 3 of the revised version that: "The new decision-making and open modeling platform provides a flexible framework for identifying and assessing EWL nexus solutions that can be applied to different geographic regions and multiple spatial and temporal scales." We also state in line 3 pg 8 of the revised version that: "To enable a transboundary perspective, the approach further intersects the sub-basin boundaries with country administrative units; sub-national administrative units and regions covering multiple basins (e.g., a country) could be considered."

To clarify this, we added this explanatory sentence in the manuscript: Line 32 pg 7: "The current framework focuses on an individual river basin. Future work will adapt the framework to expand and connect multiple basins."

<- Data Sources: It is not clear where all the data presented in the article come from and how reliable it is. For example, in Figure 3 we see that for the water system the modelling entities are surface water, ground water and saline water, with each one of these streams being split to urban use, rural use, irrigation, etc. As a result, fresh water is allocated to a total of 12 "diversions", with many of these diversions having a different value for surface water and groundwater. Furthermore, urban and rural water use is split to piped and unpiped distribution and all kinds of waste streams are

modelled separately. This is an impressively fine granularity of data, but how possible is it to define all this with some sort of reasonable accuracy for a country, or even a region? It is important that the authors show that this type of data is available and that it is reasonable to consider it in such a detail. Obviously, it is a plus to present the water system in great detail, but when the data cannot support that detail, then it becomes an important source of error. The fact that each one of the “diversions” has its corresponding energy associated with itâA ËŸTinformation that feeds the energy sys- ËĞ temâA ËŸTindicates that any error introduced in the water system with this classification ËĞ will also be propagated to the energy system. If the authors use gross approximations for allocating demands to the different modules, then it is not clear how beneficial such detail is at the end. Experience shows that there is a lot of inaccuracy and error in this data and the modeller is better off relying on national or regional statistics, rather than on global databases. Whatever the case, the authors should definitely address this critical issue. Needless to say that the same issue of presenting an extreme level of detail without supporting it with the corresponding data applies for all systems, not only for the water system. The way it is presented right now, there is a serious lack of detailed explanation, which reduces the scientific reproducibility of the modelling science in the article. >

Thanks for the comment, it help us realize that some aspects are not clearly described. Firstly, it is important to clarify that the purpose of the paper is not to perform a policy-relevant scenario analysis but instead to demonstrate the key features of the model and the interactions it enables users to investigate.

We now clearly write it in the text on line 28 page 15 that: “In this article we present an illustrative comparison between a baseline (business as usual) scenario and a multi-objective scenario achieving multiple SDG indicators by 2030. The analysis is not meant to provide a policy-relevant scenario analysis but instead to demonstrate the key features of the model and the interactions it enables users to investigate. Ongoing work is focusing on calibrating the model to local stakeholder perspectives and the

analysis of future pathways relevant for policy-makers. These results will be presented in a future publication.” Secondly, concerning data we tried not refer to specific data sources we used for the Indus Basin, but rather clarify what type of data we linked in the framework. This is because we claim the NEST framework is flexible to easily change data sources in case of need. What is important, and you highlight it with your comment is to make the reader understand how the system described in the text and figures is linked with data. This lead to the main clarification to address the issue you raised. The boxes in the system diagrams represent the portfolio of possible technologies that the model can ‘decide’ to install and apply to supply the given demands. To give an example, if we see a certain amount of surface water used in piped distribution in 2020 (optimization time horizon 2020-2050), it is a solution of the optimization process that ‘chooses’ investments, capacity and utilization activity of these technologies. The only data that characterize these technologies are costs and consumptions per unit of production (parametric data). The data is collected from the literature and the databases outlined in the paper. This type of data collection and modeling is typical in the energy, water and land-use planning literature, and the integration of these planning frameworks is the main contribution of the model. Other historical data and projection assumptions are quite exhaustively described in the three sector sections.

However we have improved the text to explain the different types of data used, adding the following at the end of the Reference system Architecture subsection: “Two broad categories of data are used to characterize the NEST reference system: historical data on resource use and availability (synchronized with exogenous projections into future time horizon) and historical technology installed capacity; parametric data for technologies used in the optimization model, expressed as costs or consumption of resources per unit of production. These data are based on assumptions and can vary spatially or over time. The information is used in the optimization process to determine the model solution and output into cost and resource use trends that can then be compared to current situation. Figures 3, 4 and 5 show diagrams of the EWL sectors in the reference system. Some boxes represent resources availability or demands characterized by historical data and future projections as explained in the following sections. Other boxes represent technologies parameterized with per unit costs and consumptions assumptions, for which specific data sources are reported in the case study section on the Indus River Basin."

Finally, the modeling framework is fully reproducible and available for download on github. Hence we refer to the model as 'open' in the title and throughout the text.

< - SDG2 and Figure 8 (Land use by crop): Even though SDG2 refers to food security, the authors do not clearly show how food security is affected. They show cotton and fodder that are not intended for human consumption, for example. Also, the fact that they show land used for crops and not yields makes a comparison difficult. For example, for the multiple SDG scenario, many of the crops are substituted by non-irrigated, which might have lower yields, when compared to irrigated. How does that affect food security? I understand that the authors explore SDG 2.4, which only refers to irrigation technologies, but it is a bit misleading when addressing SDG 2, to present and compare land used for crops and make no reference to food security and how food production is affected. >

Thanks for the observation. Concerning SDG 2 we only explore the production/supply aspect and its sustainability (regardless it is food crop or other). With the current framework we do not represent distributional food access for the population or nutrition rate. However, food demand is scaled with population projections equally in the baseline and in the multiple SDG scenario. We added the following text after Scenario the table and edited the table to avoid misunderstanding.

"Energy, water and agriculture yield demands are kept equal to the baseline scenario, which assumes SSP projections. Further work will aim to disentangle the distributional variation needed to increase equality in line with the SDG targets across different social groups (e.g. urban rural)."

< - Figure 7(b): When comparing baseline and multiple SDG scenarios, we see that

there is a great increase in Energy for Water and a great decrease in water for irrigation. But, how are Green House Gas emissions affected with such Energy increase and how is food security affected with such a reduction in irrigated land? This is an important question that comes to mind and is not addressed in the text. >

Thank you, we have improved the explanation of Figure 7b as below. To briefly answer your questions: in the multiple SDG scenario there is a stringent constraint on GHG emission. Therefore even if energy use in the water sector increases, the produces energy should mostly come from nuclear, hydropower or renewable energies (Figure 8);

Similarly, in the multiple SDG scenario, food demand (all crop production demand) is the same as in the baseline. What changes is the irrigation system, which allows to significantly save water from the irrigation sector to allocate it for environmental flows, or other uses.

Edits, line 25 pg 19 "This is to support increased water access in the municipal sector and massively expanded wastewater treatment capabilities in urban areas, but still represent less than 2\% of total energy production in 2020. Given GHG emission target set for the multiple SDG scenario, increase in energy production does not imply increase in emissions, as the generation fleet is mostly carbon neutral (See Figure 8). On the other hand, water withdrawals for agriculture reduce relative to the baseline scenario, while meeting the same crop production, due to the increase in rain-fed agriculture and more efficient irrigation."

< - Figure 7(a) / Nuclear Energy: I see that the authors drastically increase the use of nuclear energy in the suggested multiple SDG scenario. I assume that this was done due to the high efficiency of nuclear plants, which made possible to achieve the SDGs considered. However, it is not clear if such an increase in nuclear is desirable and/or even feasible for these countries. The amount of nuclear power used in the electricity mix of individual countries is a complex issue and it depends on many factors. It is not

clear whether the authors have considered these factors for the case study presented, or whether the increase in nuclear power is merely a “modelling decision”.>

The choice of nuclear was merely a modelling decision, in later work on the basin we are refining constraints on Nuclear given it is a critical technology for the region.

As disclaimer we added the following sentence when describing SDG7 scenario: “Since nuclear is currently a critical issue in both India and Pakistan, further research will investigate the feasibility of nuclear with more detail and interacting with local stakeholders.”

<- Discussion: What is missing from the manuscript is some discussion on the Nexus, in association with the results. For example, looking at Figure 7, when comparing baseline and multiple_SDG scenarios, we see that as one arrow gets thinner, another one gets thicker, which in a sense shows the effects of a Nexus analysis. In other words, we see the interdependence and “compromise” in resource use (we can’t reduce everything at the same time, or as we reduce one sector, another one is affected). The choice of what is reduced and what is increased and the effects of these interlinkages is at the heart of a Nexus analysis and I feel that such a discussion after the presenta tion of results is missing. Also, the coherence of the SDGs themselves is relevant and should be discussed. How are things different when one tries to achieve only one goal vs. when multiple goals are considered. This is shown quite clearly in Figure 8, but the discussion on the coherence and/or conflicts of the SDGs themselves seems to be missing. >

Added the following paragraph after Figure 7 explanations: “These results demonstrate the value of interconnection across EWL sectors in terms of chain reaction in investments (i.e. expanding piping distribution also require expansion in electricity production and distribution), synergies (investing in irrigation efficiency implies saving in water distribution for irrigation) and trade-offs, as it is clearly not possible to minimize costs and resource use across all sectors to achieve the SDGs.”

And, at the end of the paragraph on synergies among SDG: “Considering multiple target simultaneously shows different results than summing individual analysis. As mentioned above, the electricity mix changes when considering water constraints and climate targets. Similarly, land use is different when efficiency policies are in place together with environmental targets. This clearly shows the importance of an integrated multi-sectoral analysis to highlight synergies and barriers among objectives. The authors intend expand this topic in upcoming research.”

<- Uncertainty / Sensitivity: There is no mention of an uncertainty/sensitivity analysis of the results in the article. Such an assessment is necessary, even if it is limited, since in reality this uncertainty is multifaceted, involving human behaviour and is not so easily quantified.>

We added a new paragraph with some sensitivity analysis driven by uncertainty in scenario assumptions (SSP, RCP and climate models). However we leave more parametric sensitivity analysis to coming publication that focus more on specific results. In this review process I also removed Figure 10 (b) that was representing the seasonality in crops, because it often lead to misunderstanding. I explained the concept in the text and also made room for the new Figure 11 that show the sensitivity analysis.

Please also note the supplement to this comment:
https://www.geosci-model-dev-discuss.net/gmd-2019-134/gmd-2019-134-AC2-supplement.pdf

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