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Reply on RC4

Jens A. de Bruijn et al.

Author comment on "GEB v0.1: a large-scale agent-based socio-hydrological model – simulating 10 million individual farming households in a fully distributed hydrological model" by Jens A. de Bruijn et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-664-AC4, 2022

First of all, thank you for your kind words. Below we replied to your comments in italic.

The paper has received several critical comments already, which I agree with, and therefore do not want to repeat the same comments and crticisms here.
First of all this is an ambitious attempt at developing a large-scale agent based socio-hydrological model. I applaud the authors for embarking on this adventure.
However, as the other reviewers are saying, the authors present a rather superficial and half-hearted attempt at building such a model. It comes across to me as a "proof of concept" type of approach to announce to the world they are developing this model, and to demonstrate they have the elements of such a model in hand. To qualify as a scientific journal article, what lessons have been learned from this exercise? The authors may want to think about this some more.

We thank the reviewer for their comment. In line with the reviewers comment (and also other comments), we suggest to replace the current scenario with the following, which considers a more realistic scenario which includes farmer heterogeneity based on survey data and endogenous adaptation:

1. Use the Indian Development Human Development Survey (IHDS), which presents highly detailed information on 41.554 households, including crop types for the different growing seasons, household size, household income, expenditure, irrigation techniques, farm size etc etc.
2. From the Indian agricultural survey, we will collect farm characteristics (i.e., marginal distributions), including farm sizes and crop types at tehsil level (comparative to counties in the US)
3. Use an adapted version of the iterative proportional fitting to create a synthetic farmer population using the micro-level data from the IHDS yet fits the marginal distributions of the tehsil level agricultural survey

Then based on this data, land use data derived from satellite imagery, and the distribution of farm sizes, we will distribute those heterogeneous farmers spatially, which now include heterogeneous characteristics (according to the IHDS), such as crop types for the different growing seasons, household size, household income, expenditure, irrigation techniques, farm size etc.

Then, using historic crop prices, as obtained from the Indian Agricultural Marketing Information System, in combination with simulated yield based on farm size, potential yield and the simulated ratio of actual to potential evapotranspiration, we will simulate individual farmer income. Combined with inflation-adjusted household expenditures (from IHDS data) and crop expenditures (based on data obtained from the Ministry of Agriculture and Farmers Wellfare) we can calculate disposable income.

Next, we can include farmer adaptation behaviour, specifically the construction of irrigation wells, in the model. To simulate this, farmers without an irrigation well, look to (farm-size adjusted) income of neighbouring farmers with similar crop types but with an irrigation well. If the income difference of the agent's farm compared to those surrounding farms is higher than the implementation and upkeep costs of an irrigation well, the farmer will implement an irrigation well.

This also allows us to derive more in-depth conclusions, based on the heterogeneity of these agents (in addition to the presentation of the model framework and potential future applications).

My second point is that the paper does not articulate for me a vision or underlying design of such an agent based socio-hydrological model? Of course there are agent based models developed at small scales. What are the kinds of questions that the authors want to answer using this larger-scale model? I especially want them to think of "large" scale. How do they organize the model, the agents, the interactions, feedbacks etc in such a a way as to answer these questions? At present, the model focuses only on the mechanics of building the model.

The feedbacks across long-ranges are included in the model through the hydrological component. It is unlikely that a farmer downstream at the delta of the Krishna river is directly influenced (for example through a social network) by a farmer upstream near the Western Ghats. However, when the farmer upstream applies irrigation water to their land which then (partly) evaporates, this water is not available for the downstream farmer. The main aim of this model is to allow the investigation of basins as a whole, because effects of behaviour are felt throughout the basin. Therefore, the immediate interactions (in the scenario proposed above) are between farmer agents are local, yet the compounded effect is basin-wide.

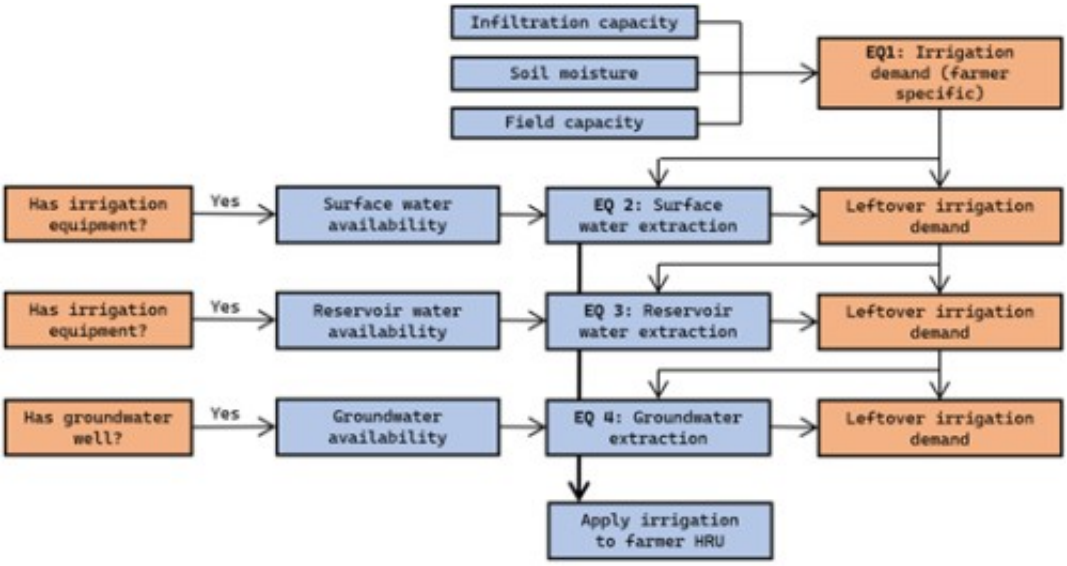
To address the reviewers' comment, we first suggest a paragraph in the introduction to specify some of the effects that can be experienced at long ranges:

Moreover, the hydrological system includes many connections across large scales, and consider farmer heterogeneity. For example, farmers at the head-end of a command area have access to a much larger and reliable water supply than tail enders (Mollinga, 2003). These incentivizes head-end farmers to adopt water-intensive high-return crops, reducing water availability downstream (Wallach, 1984). Similarly, upstream famers that invest in rainwater harvesting techniques reduce the amount of water available downstream (Bouma et al., 2011). Yet another example is through groundwater use, where individual well users lower the groundwater table in the entire region (R. & P., 2005). And while some farmers might be able to invest in deeper wells, other farmers are left behind driving them further into poverty (Batchelor et al., 2003).
Moreover, we will try to dig deeper into some of these aspects following the storyline suggested above, adding some visualizations and discussion on these points.

Finally, one of the features of agent based models from standard water management models is the idea of emergent dynamics or patterns that arise from the two-way feedbacks between humans and nature (water, hydrology), and between different agents and different kinds of agents. I am concerned that the way the model is presented

(perhaps this is an issue of presentation quality) that this model comes across as just a water management model, and the two-way feedbacks is missing and the interactions between different agents is either not present or does not lead to emergent dynamics. I would like the authors to think through this and improve the presentation of the model.

We thank the reviewer for their comment, and hope to address this partly by the scenario presented above, and partly by including the following figure, to specify more clearly the two-way feedback between the hydrological and human components (in addition to the feedbacks on farmer crop management and reservoir management shown in Figure 2).



Given the journal, I do not consider this a traditional scientific article. Yet, I would like them to substantially improve the presentation to make it more interesting and appealing to the readers. I recommend major revision, but the paper should ultimately be published in GMD

We thank the reviewer for their comment and hope that we can use the suggestions above to improve the manuscript for publishing in GMD.

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