EGUsphere, author comment AC2
https://doi.org/10.5194/egusphere-2022-664-AC2, 2022


# Reply on RC2

Jens A. de Bruijn et al.

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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-AC2, 2022

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In this paper, a large-scale agent-based model of socio-hydrological dynamics is introduced. The proposed modelling tool is scientifically promising, and the manuscript is technically sound. Yet, I see a number of shortcomings. Thus, I provide some comments that I think should be addressed before publication.

*Dear reviewer, we thank you for the kind words on the scientific promise and technical soundness. Below we suggest improvements to the manuscript based on the reviewer's comments in italic.*

1. The need for large-scale agent-based modelling is not well argued for in the introduction. This also applies to model assumptions. The paper lacks logical justifications for temporal and spatial scales as well as about the focus on the selected agents.

*Dear reviewer, we thank you for the suggestion and agree that this justification was not clearly included. Therefore, we suggest to include the following paragraph in the introduction.*

*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).*

In the introduction, the authors state that (line 46): "while most hydrological models are well-suited to simulate the hydrological system at a large scale, they treat small-scale human behaviour rather simplistically and homogeneously…" I cannot agree more. Yet, I was disappointed when I read that only "in future work, we will more accurately simulate farmer behaviour by including factors such as… These factors are not necessarily static over time" (definitely not!) ", as agents can invest in assets (e.g., drip irrigation

equipment), farm size can change, etc. Moreover, other agents, such as government and NGO agents, can impose regulations, provide knowledge to the farmer population, or invest in the wider availability of assets (e.g., create an irrigation reservoir). Knowledge can also be obtained from other (neighbouring) agents." Well, I expected to see (at least some of) these aspects/feedbacks included into this model. Why not? Why only for future work? Without them, the modelling exercise essentially become a downscaling exercise. Is this enough to justify novelty? I am not sure.

*Dear reviewer, we thank you for your comment (which is also in line with the suggestions of other reviewers), and therefore, we suggest to include a new scenario which considers farmer heterogeneity as follows:*

*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).*

2. While the storylines provide a range of interesting scenarios, I understand that the key drivers are primarily exogenous (rather than endogenous). This is a missed opportunity as emerging behaviour, patterns, and surprises are the essence of sociohydrology and agent-based modelling. Can the authors clarify that?

*Thank you for your comment, which we hope is addressed is by the scenario described above.*

3. In the concluding part of the paper, it would be appropriate to discuss the results in

view of the scientific community. What is the novel contribution to sociohydrology and agent-based modelling? What are the implications of this work, and what shall be done differently in future studies?

*Thank you for your comment, and we will discuss these points in more detail, also based on the newly presented scenario.*

*Batchelor, C. H., Rama Mohan Rao, M. S., & Manohar Rao, S. (2003). Watershed development: A solution to water shortages in semi-arid India or part of the problem? Land Use and Water Resources Research, 3, 1–10. https://doi.org/DOI: 10.22004/ag.econ.47866,*
*Bouma, J. A., Biggs, T. W., & Bouwer, L. M. (2011). The downstream externalities of harvesting rainwater in semi-arid watersheds: An Indian case study. Agricultural Water Management, 98(7), 1162–1170. https://doi.org/https://doi.org/10.1016/j.agwat.2011.02.010*
*Mollinga, P. P. (2003). On the waterfront: Water distribution, technology and agrarian change in a South Indian canal irrigation system. Orient Blackswan.*
*R., L. M., & P., M.-S. (2005). Intensive Groundwater Use: Silent Revolution and Potential Source of Social Conflicts. Journal of Water Resources Planning and Management, 131(5), 337–341. https://doi.org/10.1061/(ASCE)0733-9496(2005)131:5(337)*
*Wallach, B. (1984). Irrigation Developments in the Krishna Basin since 1947. Geographical Review, 74(2), 127–144. https://doi.org/10.2307/214095*