

Authors' Response to Reviews of

## **Changes in groundwater-surface water interactions following two centuries of irrigation practices and groundwater use in the Upper Ganges-Yamuna interfluvium, North India.**

Original comment

*AR: Authors' response (blue italic)*

### **Community Comment #1**

The manuscript presents a valuable and timely contribution to the field of hydrology, particularly in understanding long-term groundwater-surface water (GW-SW) interactions in heavily managed systems. By reconstructing two centuries of hydrological evolution using a physically based MODFLOW 6 framework, the study provides important insights into how irrigation development and groundwater abstraction have reshaped the hydrological regime in the Upper Ganges-Yamuna interfluvium.

One of the key strengths of the paper is its long-term perspective (1800–2016), which is rarely achieved in groundwater studies and allows for a comprehensive understanding of system transitions from natural to human-dominated conditions. The integration of multiple recharge and abstraction components (e.g., canal leakage, irrigation return flow, sectoral water use) provides a holistic representation of groundwater balance dynamics, addressing an important gap in previous studies.

Overall, the manuscript is well-structured, methodologically sound, and highly relevant, and it significantly advances knowledge on anthropogenic impacts on groundwater systems. I will put some minor comments:

*AR: Thank you for your kind words. We will respond to each of the comments below.*

1) The manuscript assumes temporally constant spatial distributions for several components (e.g., land use, recharge patterns). While this is acknowledged, a brief discussion on how this assumption may affect historical reconstructions would strengthen the study.

*AR: (This response addresses both comments RC1-SC11 and CC1, which concern the same issue). We agree that the assumption of stable land-use patterns over a two-century period is a simplification and an important source of uncertainty. Unfortunately, no spatially explicit historical land-use datasets were available for the study area covering this period. Nevertheless, the study area has long been characterized by intensive agriculture and a relatively dense rural population. While the extent of urban areas has undoubtedly increased, particularly around major cities, and agricultural practices have intensified over time, we expect the dominant land-use classes (agricultural land and settlements) to have remained broadly similar in their spatial distribution.*

2) The use of yearly time steps simplifies the system and excludes seasonal dynamics. A brief justification of why this does not affect key conclusions would be helpful.

*AR: (This response addresses comments RC1-GC4, RC2-SC4 and CC2, which concern the same issue). We agree that the use of yearly time steps limits the representation of seasonal groundwater dynamics in this monsoon-dominated system. With a finer temporal resolution*

*(e.g. monthly timesteps), the model could capture seasonal reversals in SW–GW exchange and distinguish, for example, between dry-season infiltration and monsoon-driven exfiltration. However, the objective of this study was to assess long-term regional trends over a two-century period, for which yearly net SW–GW exchange was considered the most relevant metric. In particular, for evaluating the long-term spreading of polluted surface water into the groundwater system, the annual net exchange is more important than seasonal fluctuations. For example, if polluted river water infiltrates into the aquifer during the dry season but is subsequently discharged back to the river during the monsoon, the net annual exchange remains exfiltrating and the long-term transfer of pollutants to groundwater would be limited. We acknowledge that a higher temporal resolution could provide additional insight into seasonal dynamics and the timing of exchange reversals, but such simulations were beyond the scope of the present long-term regional analysis and would substantially increase computational demands. We will clarify this limitation in the revised manuscript.*

3) While uncertainty is addressed through Monte Carlo simulations, a clearer distinction between input uncertainty and structural/model uncertainty would strengthen the discussion.  
*AR: In the discussion we will make a clearer distinction between input uncertainty and structural model uncertainty.*

4) Given the focus on groundwater–surface water interactions, it would be valuable to acknowledge recent work. For example, “Assimilation of Sentinel-based Leaf Area Index for Modeling Surface–Ground Water Interactions in Irrigation Districts.”  
*AR: We thank you for this suggestion. However, we believe the cited study falls somewhat outside the scope of the present study, both methodologically and geographically. Due to differences in objectives and methodology, we do not believe that discussing this study would substantially strengthen the context of the present manuscript. Nevertheless, we appreciate the recommendation and have considered it carefully.*

5) The manuscript could benefit from a slightly clearer comparison with previous regional/global groundwater studies to better highlight its novelty.  
*AR: We will try to make the novelty of the manuscript more clear in the revised manuscript.*

The manuscript is strong and suitable for publication after minor revisions. The suggested comments mainly aim to improve clarity and strengthen the interpretation rather than requiring substantial additional work.