Response to Comments of Referee #2

The Yellow River is one of the most important river basins in the world. In this paper, a hydroeconomic optimization model is built up for the Yellow River basin. The objective is to maximize overall economic benefits of irrigated crop production, water supply and hydropower generation, by considering the constraints of resource, infrastructural, operational and policy. Overall, the paper is well-written with the methods and results clearly illustrated.

There are three comments for the improvement of this paper.

First of all, the water resources issue has been investigated for the Yellow River basin for years. For an early review, please refer to Wu et al. (2004) and Cai (2008). Given the extensive existing studies, the authors may want to highlight what's new in the proposed hydroeconomic model. If possible, the authors may create a timeline of the major developments of hydroeconomic model for the Yellow River basin with the illustration of key issues at different stages of development.

References:
[1] Baosheng, W., Zhaoyin, W. and Changzhi, L.I., 2004. Yellow River Basin management and current issues. Journal of Geographical Sciences, 14(1), pp.29-37.
[2] Cai, Ximing. "Water stress, water transfer and social equity in Northern China—Implications for policy reforms." Journal of Environmental Management 87, no. 1 (2008): 14-25.

Reply: We thank the reviewer for the valuable references and insightful suggestions. We have cited literature from Wu et al. (2004) and Cai (2008) in the Introduction and Study Area sections to better position our work within the context of previous studies on the Yellow River Basin (YRB).

Regarding the novelty of our model, the innovative aspects of our study include:

(1) Integrated basin-scale representation: We developed a basin-wide hydroeconomic optimization model that explicitly captures the spatial interactions among all major water supply and demand sectors across the entire YRB. The framework integrates surface water, groundwater, and multi-reservoir coordination within a unified decision framework, linking water availability, infrastructure operations, regulations, and sectoral water-using activities. This holistic formulation enables a quantitative evaluation of trade-offs across the basin that were previously explored only qualitatively. To our knowledge, a basin-wide hydro-economic optimization model with this level of detail does not exist for the YRB, prior to this paper.

(2) Baseline calibration: A Positive Mathematical Programming (PMP) method is embedded in the model, allowing the representation of realistic behavioral and land-use responses, rather than relying solely on normative efficiency assumptions.

(3) Water valuation: The model provides explicit estimates of benefits and marginal values by location, node (sector) and hydrological year type. These quantitative indicators reveal new patterns, particularly the spatial gradient of water scarcity and the inter-annual adjustment of reservoir operation that have not been quantified at this resolution in prior studies.

The second comment relates to the first one. Given the importance of the Yellow River basin, the authors may want to illustrate this basin in the title of this paper. Currently, the title is "Hydroeconomic Optimization of Water Management: Dealing with Scarcity at the Basin Scale" reads like a review paper.

Reply: We appreciate your suggestion for the title. To more clearly reflect the geographical focus and significance of our study, we have revised the title of the paper to "Hydroeconomic Optimization of Water Management in the Yellow River Basin: Dealing with Scarcity."

Thirdly, "Hydroeconomic Optimization" is not a new subject in the field of water resources. One concern is that the objectives/constraints considered are far from real-world issues. Given that the model cover the years from 1996 to 2015, can the authors collect some real-world data to showcase that the findings are consistent with things happened in the past?

Reply: Thank you for your valuable comment. We fully agree that hydroeconomic optimization is an established field in water resources research, with active ongoing efforts devoted to it. However, we respectfully note that the objectives and constraints in our model are closely aligned with real-world management practices and institutional realities in the Yellow River Basin:

(1) The use of Positive Mathematical Programming method enables the model to reproduce observed agricultural water use and land allocation responses under different water availability conditions.
(2) The operation of major reservoirs in the model follows key operation rules used in the real world, including considerations for ice flood control, sediment flushing, and storage curves, reflecting operational rules being implemented by the managing agencies including the Yellow River Conservancy Commission (YRCC).
(3) The model incorporates key policy instruments, most notably the *1987 Water Allocation Scheme*, which specifies provincial limits for consumptive use of water diverted from the Yellow River or its tributaries, thus directly constraining interprovincial allocations.
(4) Ecological replenishment is represented as a mandatory constraint ensuring minimum flows for designated ecological zones, consistent with the basin's environmental management requirements in the real world.

Regarding the use of the 1996–2015 hydrological data series, our hydroeconomic optimization model follows a planning-model framework, consistent with widely used

basin-scale models such as the California Value Integrated Network (CALVIN) model (Draper et al., 2003; Harou et al., 2009), as well as the official planning practices of the YRCC (YRCC, 2015), where 2020 and 2030 were selected for water demand and supply planning. These approaches typically fix a recent representative planning year or period as the baseline for evaluation. The period of 1996–2015 was chosen because it represents the most recent and reliable continuous hydrological dataset available for the YRB.

Using a multi-year series instead of a single hydrologic year allows the model to capture the large interannual variability of the Yellow River and provides a more robust representation of hydrologic conditions. Moreover, the Longyangxia Reservoir in the very upstream of the YRB has multi-year regulating capacity. Using continuous multi-year data enables the model to realistically explore cross-year regulation and storage behavior, which would not be possible under a single-year implementation.

Finally, to demonstrate the model's consistency with real-world outcomes, we have added a table of goodness-of-fit metrics in the supplementary material comparing modeled results with observed data for major stations, reservoir end-of-year storage, and agricultural water use. These evaluations are based on Percent Bias (PBIAS) and Normalized Root Mean Square Error (NRMSE). The results show that the deviations between modeled and observed values are within an acceptable range (PBIAS ± 10%; NRMSE 10–30%), indicating that the model adequately reproduces the basin's hydrological behavior and allocation patterns.

Reference:

[1] Draper, A. J., Jenkins, M. W., Kirby, K. W., Lund, J. R., and Howitt, R. E.: Economic-Engineering Optimization for California Water Management, J Water Resour Plan Manag, 129, 155–164, https://doi.org/10.1061/(asce)0733-9496(2003)129:3(155), 2003.

[2] Harou, J. J., Pulido-Velazquez, M., Rosenberg, D. E., Medellín-Azuara, J., Lund, J. R., and Howitt, R. E.: Hydro-economic models: Concepts, design, applications, and future prospects, J Hydrol (Amst), 375, 627–643, https://doi.org/10.1016/j.jhydrol.2009.06.037, 2009.

[3] YRCC: Executive Summary of the Yellow River Basin Comprehensive Planning 2012-2030 (in Chinese), http://yrcc.gov.cn/zwzc/ghjh/202312/t20231220_365017.html, 2015.