INITIATIVE ON Asian Mega-Deltas

CGIAR

Water-Salinity Dynamics and Stakeholder Perceptions of a Polder in Coastal Bangladesh: A Socio-hydrological Perspective

Mahesh Jampani, Md. Raqubul Hasib, Syed Adil Mizan, Nesaruddin Md, Manoranjan K Mondal, Dipaka Ranjan Sena, Rubayat Alam, Deepa Joshi and Karthikeyan Matheswaran

December 2024

Introduction

Asian Mega Deltas (AMD) are critical agroecological regions that support millions of livelihoods and serve as essential food baskets. However, they are increasingly facing significant challenges such as water scarcity, flood risks, and ecological degradation (Chan et al., 2024). The sustainability of these deltas is vital for regional food security and global agricultural stability, as the well-being of communities within these areas directly impacts food availability beyond their borders (Nicholls et al., 2016). These deltaic landscapes are particularly vulnerable to the increasing effects of climate change, including extreme weather events, cyclones, rising sea levels, increased soil and water salinity, and land subsidence (Walton et al., 2024). The threat posed by climate change exacerbates existing challenges, leading to severe social and economic repercussions. If left unaddressed, these climatic trends will further burden the already vulnerable populations in these regions, worsening food insecurity, deepening poverty, and intensifying hunger. These results in a vicious cycle of declining food security, increased destitution, and rising malnutrition, emphasizing the urgent need for proactive interventions to protect the future of these vital landscapes.

The CGIAR has launched the AMD initiative to address these pressing issues and create resilient, productive, and inclusive deltas capable of withstanding climatic and environmental stresses while maintaining their socio-ecological integrity. Achieving this goal requires efficiently scaling transformative technologies and practices at community, national, and regional levels. As part of this initiative, localized hydrological models in two key deltas - the Ganges and the Mekong were developed to facilitate informed decision-making and enhance water resilience in these critical regions.

Ganges-Brahmaputra Delta in Bangladesh

In Bangladesh, the poldering of floodplains in the Ganges-Brahmaputra delta aims to enhance agricultural productivity on fertile land while mitigating vulnerabilities to flood inundation, coastal erosion, and salinity intrusion (Bruins et al., 1998). The poldered areas are predominantly low-lying islands formed from alluvial sediment deposits. Out of over 2.8 million hectares in the coastal zone, about 1.2 million hectares have been converted into polders. Previously, there were 139 polders in southern Bangladesh; now, the number of polders has rearranged to 162 across the Gangetic-Brahmaputra delta and Chattogram hill tract region, encompassing a diverse geographical landscape. This ecosystem supports the livelihoods and food security of more than eight million people, highlighting its importance. However, with increasing anthropogenic and climate pressures in recent decades, Intensive human activities have disrupted the polder systems and the hydrological processes of the floodplains, leading to significant challenges. The geomorphological evolution of river channels and floodplains has been altered, resulting in waterlogging and drainage congestion within the polder system. Rising sea levels, tidal surges, and increasing salinity intrusion exacerbate these challenges.

During the monsoon season, abundant rainfall and river inflows facilitate crop production; however, waterlogging can persist in certain areas and adversely impact wet and dry-season agriculture. During the dry season, soil and water salinity emerges as a pressing issue, undermining the productivity of polder systems. During tidal surges in the dry season (when river water salinity remains very high), saltwater intrusion from the sea pollutes soil and water sources, negatively affecting crop growth and overall agricultural yields. Additionally, inadequate drainage hinders the adoption of improved agricultural technologies, resulting in low productivity in the wet season. In the dry season, soil and water salinity increases, and most crops suffer from salt stress, leading to stunted growth and lower-quality produce. Furthermore, saline water intrusion jeopardizes local drinking water supplies, posing a risk to human health.

Addressing the productivity gaps in these polder systems requires effective management of water and salt concentrations. Farmers often lack efficient management strategies to cope with salinity conditions before the monsoon season, which can complicate the initiation of agricultural activities (Mondal et al., 2022). The interplay between riverine and coastal natural processes further complicates maintaining optimal water levels in the polder ecosystem for agricultural purposes while catering to aquaculture needs. The International Water Management Institute (IWMI) has engaged in various stakeholder discussions, both internal (including AMD initiatives) and external, and field activities and hydrological modeling to comprehend ongoing activities in the Ganges-Brahmaputra delta to develop efficient management strategies that can enhance sustainable water and agricultural management.

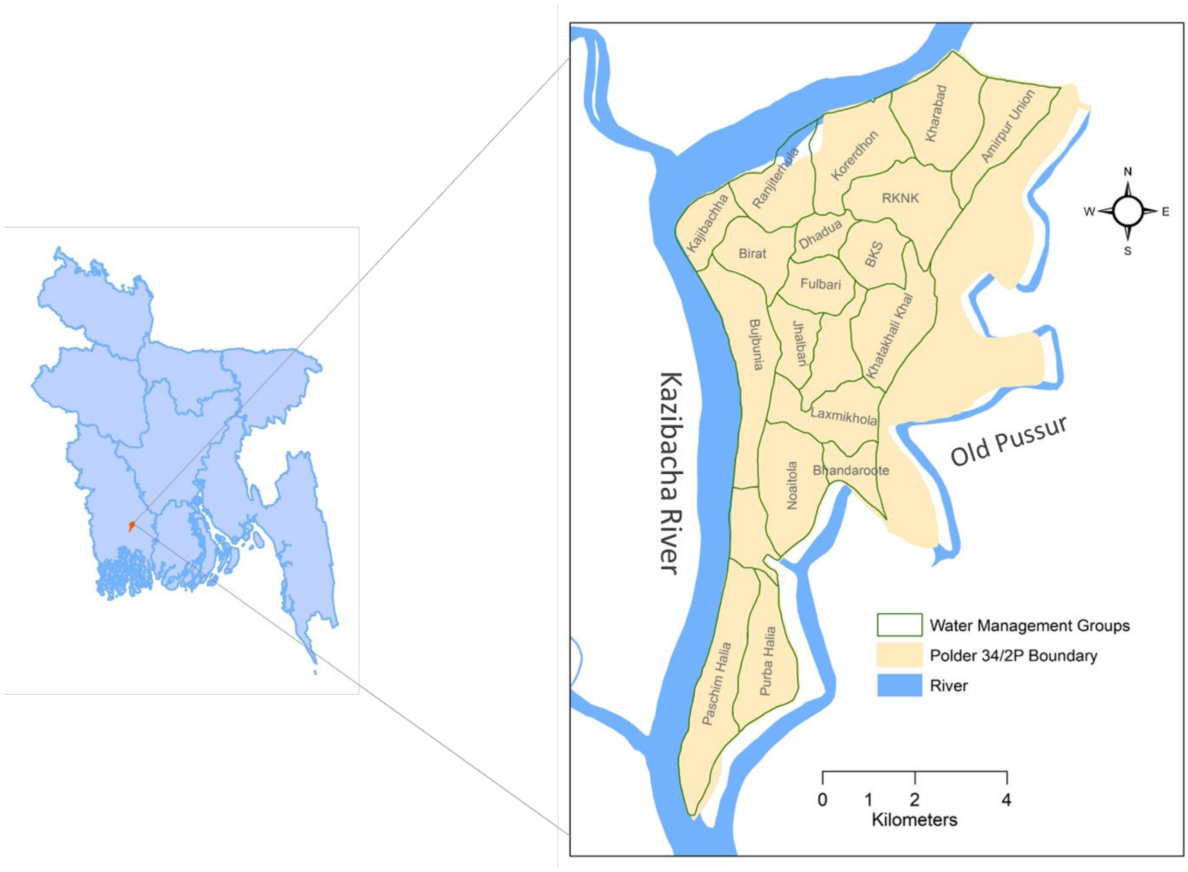

Figure 1. Location map of the polder 34/2P with Water Management Group (WMG) boundaries.

Methodological Approach

The research focuses on Polder 34/2P, located near Khulna city in southwest Bangladesh, to comprehensively assess the socio-hydrological dynamics (Jampani et al., 2023) (Figure 1). We integrated both biophysical and socioeconomic analysis through a variety of primary and secondary data sources that explain the complexities of polder dynamics:

- Hydrological data for evaluating the spatiotemporal water flow conditions in the polder;
- Water quality information to understand the seasonal salinity dynamics affecting the polder agriculture and livelihood of the communities;
- Groundwater and surface water samples were collected over a one-year hydrological cycle to understand local water availability and salinity dynamics comprehensively;
- Groundwater data is used to assess pumping conditions and aquifer heterogeneity to gain insights into groundwater availability and quality;
- Government stakeholder inputs through workshops to capture insights on regional dynamics and integrated hydrological modeling;
- A socio-hydrology survey was conducted among farmers within the 16 Water Management Groups (WMGs) of the polder to gather perspectives on livelihoods and socioeconomic conditions.

We used this integrated approach to analyze the polder's heterogeneity and the social dynamics, which influence key factors such as water balance, saline water intrusion, and crop production.

Water and salinity dynamics

Farmers in the polders rely heavily on the river system in the region, which feeds water into the polders through sluice gates to the canal networks in the polder. Two crops are grown per year in the region. During the monsoon season, most farmers utilize rainfall and river water, drawing water into the polder through sluice gates for rice cultivation. Diversified cropping is practiced in the dry season; a few farmers depend on surface or canal water and/or rely on groundwater sourced from electric pumps primarily for rice cultivation, and others either keep the land fallow or cultivate rabi crops by utilizing residual soil water and rainfall. The majority of groundwater pumping occurs in the northern parts of polder 34/2P, while farmers in the southern areas tend to depend more on surface water. The groundwater system consists of three aquifers: a shallow aquifer, which is often saline and occasionally used for irrigation; a second aquifer, which supplies most water for rice irrigation; and a deeper freshwater aquifer, which is primarily designated for domestic use and drinking purposes.

Salinity is a significant limiting factor that influences agricultural conditions and the seasonal usage of water in the polder. A conundrum is also associated with paddy rice farming, which requires non-saline water, whereas aquaculture (shrimp and fish farming) thrives in saline conditions. Salinity levels in the Rupsa River range from 1 to 19 parts per thousand (ppt), influenced by monsoon rainfall, upstream discharge, tidal variations, and extreme climate events (Figure 2). Field experiments suggest that salinity over 2 ppt could affect rice yields; however, the suitability of high-salinity waters for irrigation depends on different biophysical conditions (Minhas and Qadir, 2024). Typically, river salinity peaks during the summer months of April and May and is at its lowest during monsoon from July to December. Additionally, surface water salinity in the polder canals fluctuates between 2 to 8 ppt, while groundwater salinity ranges from 0.5 to 3 ppt throughout a hydrological year. Groundwater salinity varies according to the aquifer type, with the shallow aquifer generally exhibiting higher salinity values, while the deeper aquifer maintains salinity levels below 1 ppt year-round.

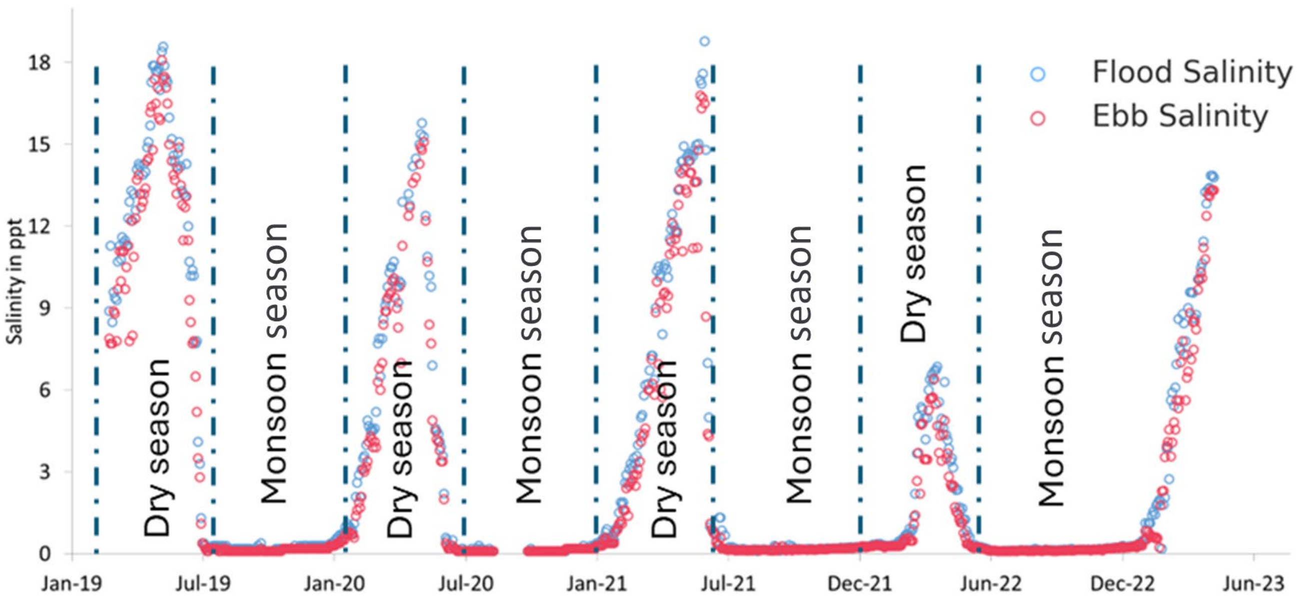

Figure 2. Temporal dynamics of Flood and Ebb Salinity (2019 to 2023) in Rupsa (Kazibacha) River upstream of the study polder 34/2P.

Socio-hydrological System and Perceptions

Farmers' survey results reveal that the majority of the agricultural land in the polder is under paddy rice cultivation, and groundwater is a vital resource, with over 60% relying on it for domestic use and drinking purposes (Figure 3). During the primary growing season, approximately 90% of respondents depend on monsoon rainfall, while the remainder utilize canal water. Agricultural practices vary significantly across the 34/2p polder in the secondary growing season. Farmers in the north primarily rely on groundwater for irrigation, while those in the middle and south depend on residual soil water and canal water or do not cultivate a second crop. About 25% of farmers use canal-stored water for irrigation in the secondary or dry season. This percentage could rise if fresh water could be consistently supplied through the canal system.

Farmers have reported a perceived increase in surface water salinity over the last decade, with 77% noting this change (Figure 3). Interestingly, 92% of respondents indicated that groundwater remains non-saline, which can be attributed to the use of a second aquifer for irrigation and the third or deeper aquifer for domestic and drinking water needs has contributed to this perception, alongside a possible increase in salinity tolerance among the local population. Investment costs for secondary season crops are notably higher than for primary crops, mainly due to the diesel and electricity costs for irrigation. Many stakeholders express that salinity poses a significant challenge, limiting their agricultural output to one or two crops instead of three. This limitation highlights the intricate relationships within the socio-hydrological system and reflects the evolving perceptions and concerns of the community regarding water resources and agricultural sustainability.

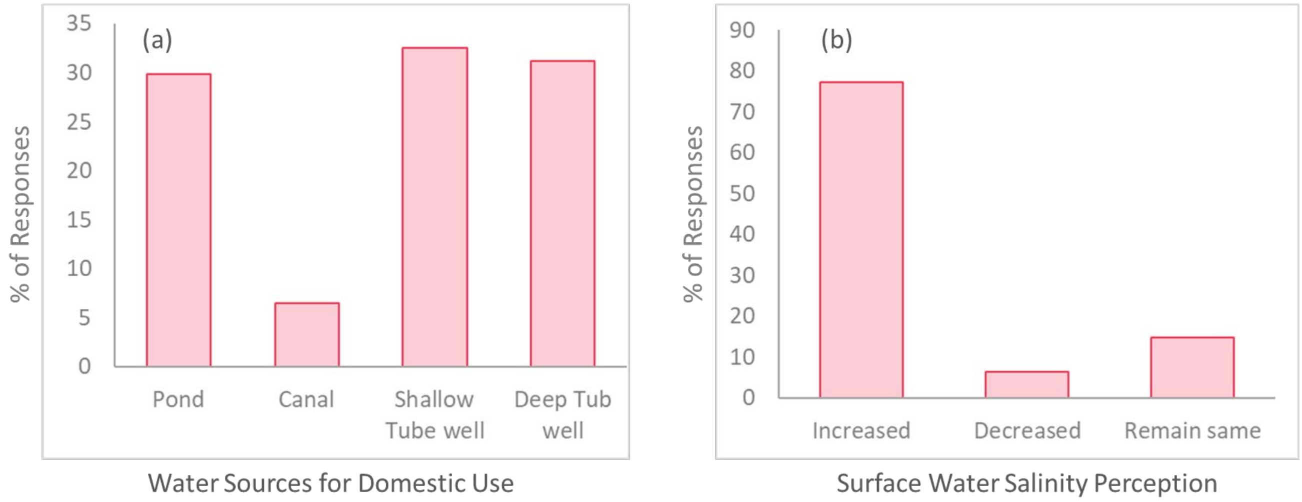

Figure 3. Farmer survey perceptions on (a) water sources in use for domestic use and (b) overall surface water salinity perception in polder 34/2P.

The Way Forward for Polder Management

Farmers in the polder are acutely aware of the salinity challenges they face, which limit their irrigation options and agricultural productivity. Monsoon patterns, tidal effects, and climate extremes further compound the variability of salinity levels, posing challenges to sustainable water management. Addressing these issues requires a comprehensive, co-development approach to managing water and salinity through a socio-hydrological lens.

Key recommendations from the study for moving forward include:

1. *Enhanced Data Collection and Integration:*
   - Collaborate with local partners to gather primary and secondary data on irrigation practices, groundwater levels, and water quality;
   - Integrate and analyze diverse datasets to understand interactions between sociological and hydrological systems in the polder.
2. *Development of Integrated Models:*
   - Establish robust hydrological models incorporating biophysical and socio-hydrological factors to simulate water flow regimes, irrigation return flows, and saltwater intrusion dynamics of individual polder systems;
   - Analyze interactions between human activities and natural processes to predict the impacts of climate variability and anthropogenic pressures.
3. *Scenario Analysis and Decision Support:*
   - Create diverse scenarios to simulate the effects of different management interventions on salinity and water availability within the polders;
   - Use these scenarios to inform sustainable agricultural practices and water management strategies, balancing the needs of both aquaculture and crop production.
4. *Capacity Building and Stakeholder Engagement:*
   - Conduct workshops and training sessions for farmers and local water management groups to enhance their understanding of salinity management and sustainable practices;

    - Foster partnerships with government agencies, research institutions, and local communities to co-develop and implement solutions.
5. *Policy Development and Institutional Support:*
    - Advocate for evidence-based policies that address the unique challenges of polder systems, including salinity intrusion and waterlogging;
    - Strengthen institutional frameworks to support coordinated water and salinity management across sectors.
6. *Technology Adoption and Scaling:*
    - Promote the adoption of innovative technologies such as AI/ML-based forecasting systems, low-cost water-saving technologies, salinity-tolerant crop varieties, and efficient drainage systems;
    - Facilitate the scaling of transformative practices and technologies to ensure their widespread impact.

By integrating these strategies, the polder system can become more resilient to climate change and anthropogenic pressures. This comprehensive approach will enhance agricultural productivity, improve livelihoods, and ensure the long-term sustainability of the delta system. Effective collaboration among farmers, government agencies, and researchers is critical to achieving these goals and fostering a resilient and inclusive future for the Ganges Delta.

References

Bruins, R. J. F., Shuming, C., Shijian, C., Mitsch, W. J. (1998). Ecological engineering strategies to reduce flooding damage to wetland crops in central China. Paper presented at ICEE 96—International Conference on Ecological Engineering, Beijing, China, 7–11 October 1996.1. Ecological Engineering, 11(1), 231–259. https://doi.org/10.1016/S0925-8574(98)00068-8

Chan, F. K. S., Paszkowski, A., Wang, Z., Lu, X., Mitchell, G., Tran, D. D., Warner, J., Li, J., Chen, Y. D., Li, N. Pal, I. (2024). Building resilience in Asian mega-deltas. Nature Reviews Earth & Environment, pp.1-16.

Jampani, M., Sena, D. R., Matheswaran, K. (2023). Framework for advancing water resource sustainability and climate resilience through local-scale hydrological modeling in the Ganges Delta. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Asian Mega-Deltas. 8p.

Minhas, P. S., Qadir, M. (2024). Irrigation Sustainability with Saline and Alkali Waters. Springer Singapore.

Mondal, M. K., Yadav, S., Baidya, B., Khan, Z. H., Sutradhar, A., Humphreys, E., Kamal, F. A., Jagadish, S. V. K. (2022). Evaluation of gravity-led and energy-fed drainage for sustaining food security in the polders of the coastal zone of Bangladesh. Irrigation and Drainage 71, 86–99. https://doi.org/10.1002/ird.2698

Nicholls, R. J., Hutton, C. W., Lázár, A. N., Allan, A., Adger, W. N., Adams, H., Wolf, J., Rahman, M., Salehin, M. (2016). Integrated assessment of social and environmental sustainability dynamics in the Ganges-Brahmaputra-Meghna delta, Bangladesh. Estuarine, Coastal and Shelf Science, Sustainability of Future Coasts and Estuaries 183, 370–381. https://doi.org/10.1016/j.ecss.2016.08.017

Walton, R. E., Salgado, J., Bisht, T., Large, A. R., Henderson, A. C., Renaud, F. G., Hensengerth, O., Van, P. T., Cremin, E., Murshed, S. B. and Chowdhury, A. I. A. (2024). Building resilience in South and Southeast Asian mega-deltas. In Resilience and Riverine Landscapes (pp. 425-444). Elsevier.

Authors
Mahesh Jampani, International Water Management Institute (IWMI), Colombo, Sri Lanka
Md. Raqubul Hasib, Institute of Water Modelling (IWM), Dhaka, Bangladesh
Syed Adil Mizan, International Water Management Institute (IWMI), New Delhi, India
Nesaruddin Md, Institute of Water Modelling (IWM), Dhaka, Bangladesh
Manoranjan K Mondal, International Rice Research Institute (IRRI), Dhaka, Bangladesh
Dipaka Ranjan Sena, International Water Management Institute (IWMI), New Delhi, India
Rubayat Alam, Institute of Water Modelling (IWM), Dhaka, Bangladesh
Deepa Joshi, International Water Management Institute (IWMI), Colombo, Sri Lanka
Karthikeyan Matheswaran, International Water Management Institute (IWMI), Colombo, Sri Lanka

Acknowledgments

This work was carried out under the CGIAR Initiative on Asian Mega-Deltas, which is grateful for the support of CGIAR Trust Fund contributors (www.cgiar.org/funders). The authors gratefully acknowledge the stakeholders in Bangladesh who provided time and inputs into this study.

CGIAR Initiative on Asian Mega-Deltas

The CGIAR Initiative on Asian Mega-Deltas aims to create resilient, inclusive, and productive deltas that maintain socio-ecological integrity, adapt to climatic and other stressors, and support human prosperity and wellbeing by removing systemic barriers to the scaling of transformative technologies and practices in the community, national and regional levels. https://www.cgiar.org/initiative/asian-mega-deltas/

Citation: Jampani, M.; Hasib, Md. R.; Mizan, S. A.; Nesaruddin, Md.; Mondal, M. K.; Sena, D. R.; Alam, R.; Joshi, D.; Matheswaran, K. 2024. *Water-salinity dynamics and stakeholder perceptions of a polder in coastal Bangladesh: a socio-hydrological perspective*. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Asian Mega-Deltas. 7p.

Cover photo: Groundwater Irrigation well near Khulna polder 34/2P and surrounding paddy fields (photo: Dr. Mahesh Jampani)

Mahesh Jampani, International Water Management Institute (IWMI), Colombo, Sri Lanka (m.jampani@cgiar.org)
Karthikeyan Matheswaran, International Water Management Institute (IWMI), Colombo, Sri Lanka (k.matheswaran@cgiar.org)

INITIATIVE ON
Asian Mega-Deltas
CGIAR