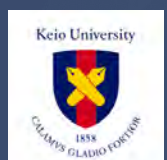


Socio-hydrological
perspective of climate
change adaptation in
large riverine islands:
Comparative study
from India, Bangladesh,
and Vietnam



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Project Leader and Contact Details: Dr Pankaj Kumar, Institute for Global Environmental Strategies (IGES), 2108-11 Kamiyamaguchi, Hayama, Kanagawa, Japan 240-0115

Collaborators and Contact Details:

- Dr Md. Nasif Ahsan, Economics Discipline, Khulna University-9208, Bangladesh
- Dr Abhijit Mukherjee, Indian Institute of Technology, Kharagpur, Kharagpur, West Bengal, India 721302
- Dr Nguyen Hong Quan, Center of Water Management and Climate Change (WACC), Vietnam National University - Ho Chi Minh city (VNU - HCM), 01 Str. 6, VNU campus, Quarter 6, Linh Trung, Thu Duc Dist., Ho Chi Minh city, Vietnam
- Dr Ram Avtar, Hokkaido University, Kita-10 Nishi-5 Kita-ku, Sapporo, Japan 060-0810
- Dr Rajarshi Dasgupta, Institute for Global Environmental Strategies (IGES), 2108-11 Kamiyamaguchi, Hayama, Kanagawa, Japan 240-0115
- Dr. Rajib Shaw, Graduate School of Media and Governance, Keio University, Shonan Fujisawa Campus, 5322 Endo Fujisawa, Kanagawa 252-0882, Japan

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1. Summary

Rapid global changes cumulatively affected local water bodies, resulting in unfavorable hydrological, ecological, and environmental changes in major river systems. Particularly, communities in the isolated riverine islands are worse affected due to their poor adaptive capacities, which is well documented in the contemporary literature. The focal point for the vulnerability of these people lies in the water resources (drinking water availability, agricultural water quality, salt-water intrusion, flooding etc.) and the future interaction between human and water systems. With above background, socio-hydrology can be very relevant approach for enhancing social adaptive capacity as well as for developing resilient water environment. This proposed work strives to explore how nexus of human–water relations can be applied to improve adaptive measures to maintain the hydrological cycle along with managing local water needs and human well-being. Socio-hydrological models will be used to quantify the feedback between water resources and society at multiple scales to expedite stakeholder participation for sustainable management. Study area selected for this research were *Sagar (Ganges River, India)*, *Dakshin Bedkashi (Padma River, Bangladesh)* and *Con Dao Island (Mekong River, Vietnam)* (Figure 1).

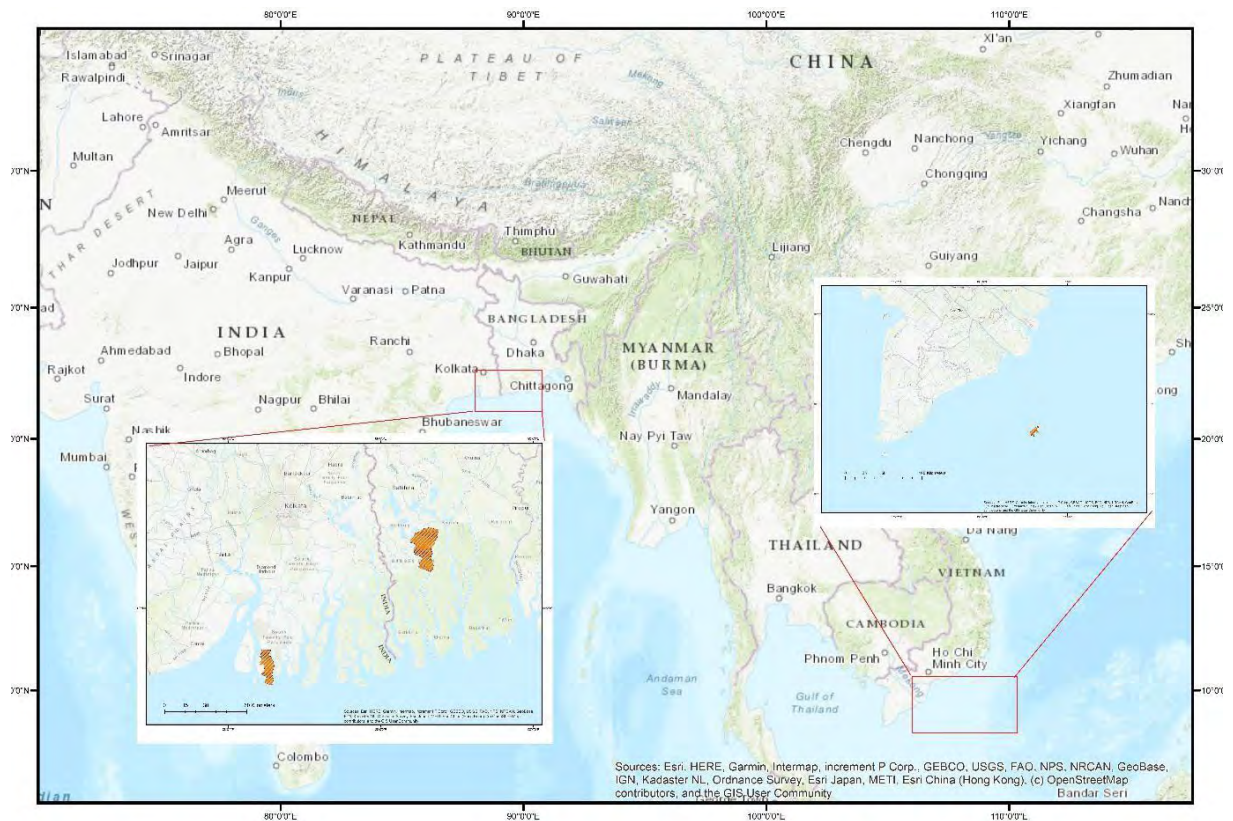


Figure 1. Study area map

In the last three years, our team did fantastic work. We have tried to identify the unsolved issues related to the current state of the environment (reporting first of such kind), in isolated riverine islands of Bangladesh, India, and Vietnam (Figure 2). For the Sundarban delta region (both Bangladesh and India), even the information about the state of the environment on water pollution was missing. We did work on it and published few papers on water pollution. Later we have analyzed how water insecurity in terms of quality and quantity impacts the region's socio-economic status (Figure 3).

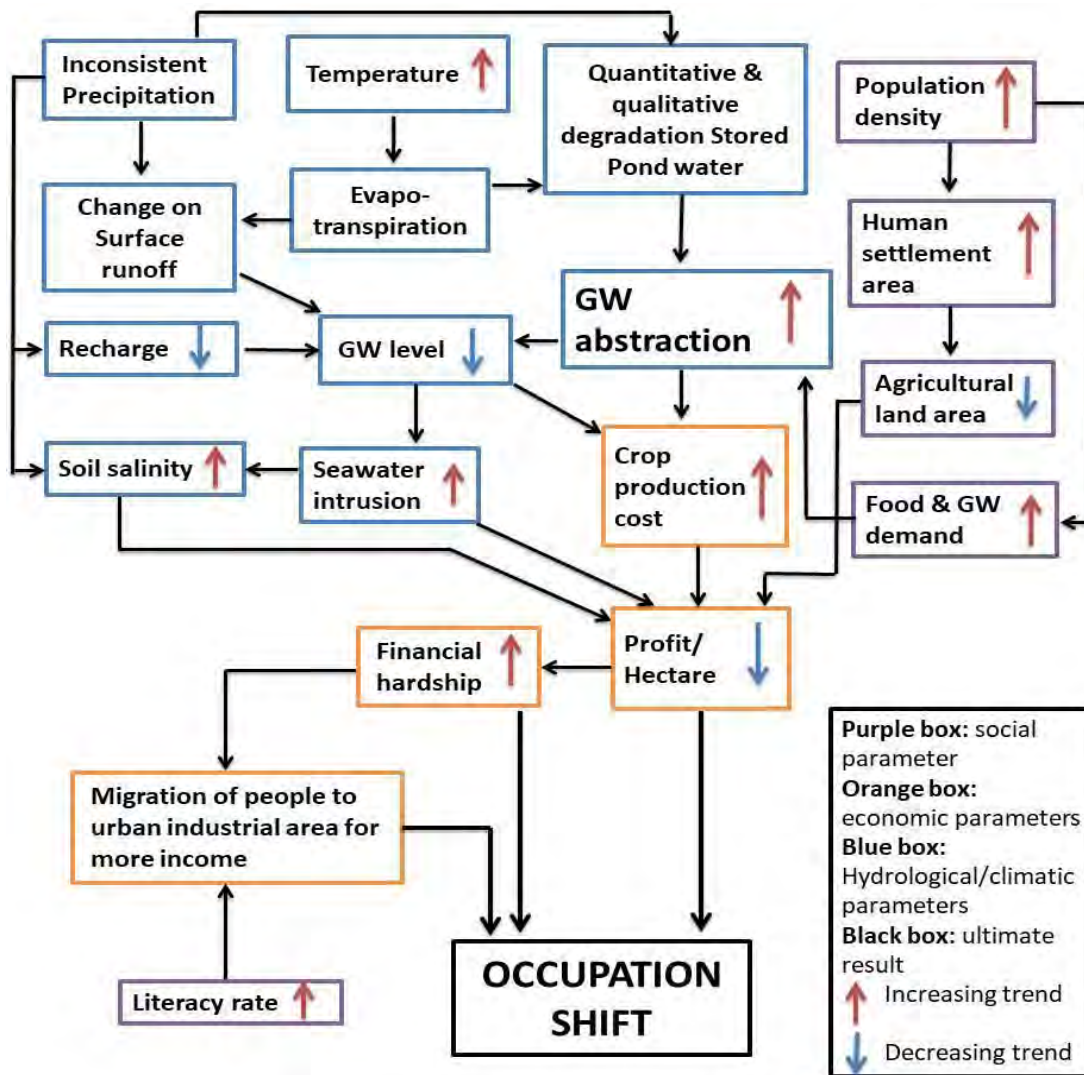


Figure 2: Conceptual diagram of hydro-socioeconomic interdependence (based on analysis) in the study area.

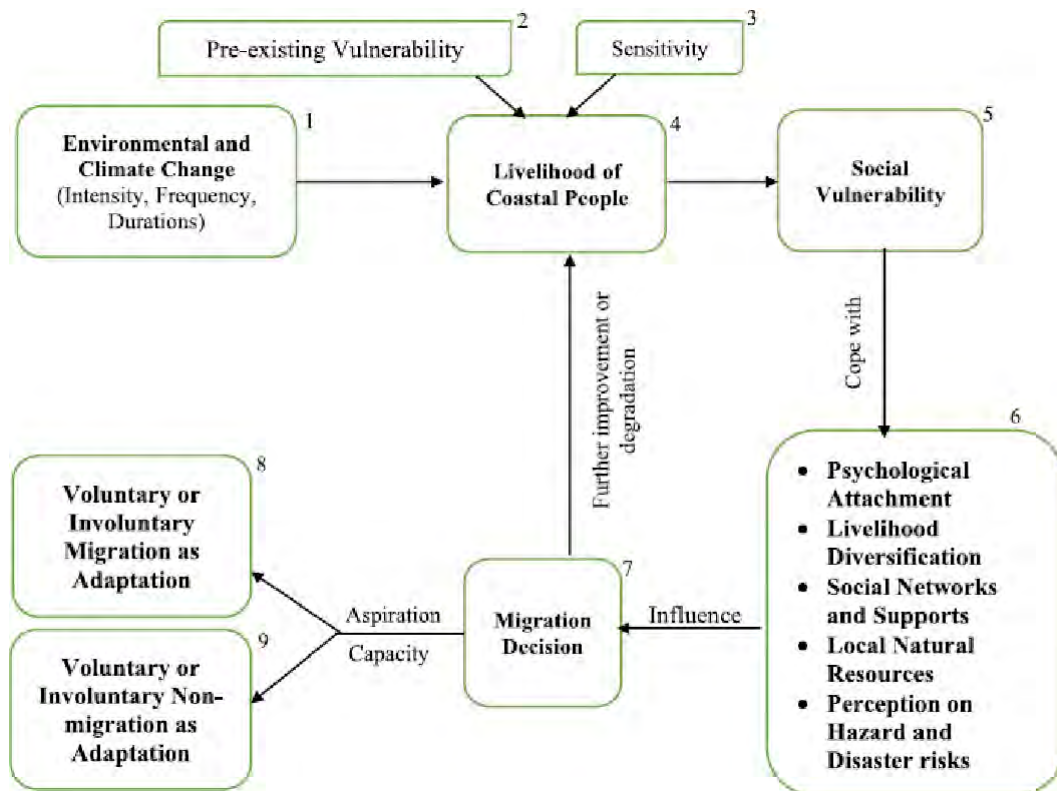


Figure 3 Summary showing the major determinants of voluntary environmental non-migration decision

Then for Bangladesh we further analyzed how this water scarcity and hydro-meteorological hazards is sharing the occupation shift with (migration and voluntary non-migration issues). We published three very high impact factors papers on these issues (Water Policy, Journal of Regional Environmental Changes, Journal of Global Environmental Changes). This is first such kind of this study in this region, very relevant for scientific communities as well as decision makers. These non-migrants enjoyed higher socioeconomic and sociopsychological advantages and availed more local support from different government and non-government organizations than involuntary non-migrants. Again, mutual assistance, connection with social groups, natural resource access, sense of secured livelihood, stable societal atmosphere, and participation in decision-making in society appeared to build their higher degree of social capital compared to involuntary non-migrants. The conceptual diagram showing the summary of the mechanism behind is shown in figure 3.

We have also calculated the risk and vulnerability analysis due to climate change on the Indian study site as a case study to showcase the “answers for what-if” and needs to manage for water resources and human well-being for decision makers. The result summary is shown in figure 4.

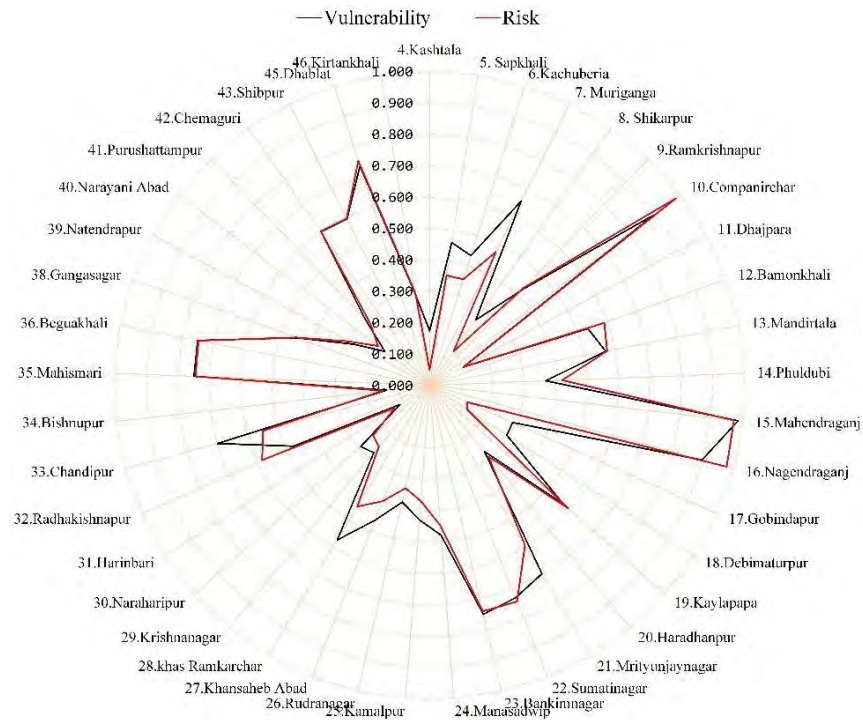


Figure 4. Mouza-level relative ranking of risk and vulnerability for Sagar Island.

2. Objectives

Considering the high vulnerability, isolation and poor adaptive capacity of the communities from riverine islands against the extreme weather events, proposed work strives to explore the nexus of human–water relation and how it can be applied to maintain local hydrological cycle. Socio-hydrological models will be used to quantify the feedbacks between water and society at multiple scales with aim to expedite and mainstream stakeholder participation for managing water resources. More precisely this work will try to achieve following objectives: (i) Identify the key factors/parameters/indicators to quantify the impact of environmental changes hydro-meteorological disasters and extreme weather conditions and its impacts on socio-economic, ecological status (in terms of income, life, health, migration etc.) in the study area, (ii) Quantify the stocktaking of societal measures taken for mitigation and adaptation during the past disaster events for water resource management. Also, this study will identify the gaps in facilitating better adaption or mitigation strategies for water resource management, (iii) Use of socio-hydrological to do the scenario based future prediction about the nexus between water-climate-economy-human well-being- food. (iv) Finally, pathway analysis for co-designing different adaptive countermeasures based on socio-hydrological simulation. Here, model will consider the biophysical sciences and in particular societal responses to and

influence on extreme hydrological events. For bio-physical components, mainly structural measures like Wastewater Treatment Plants, retention ponds etc., will be considered. For societal components, different variables like socio-political attributes, indigenous knowledge, culture, crop types, water consumption patterns, practices and monitoring efforts to be made to reach the regional/ national targets in line with the sustainable development goals (SDGs) (i.e. goal 6) will be considered, (v) finally, best practices for co-designing the effective management/adaptation strategies for water resource as well as harmonizing it with human well-being will be show cased to all the people/organization concern for water resources management.

3. Outputs, Outcomes and Impacts

Outputs	Outcomes	Impacts
<p>First of all, we have evaluated the status quo of water resources in the data scarce regions (first of such kind in Bangladesh). Then, to deduce the ground reality and try to understand the interlinkages between human and water system in all three study sites, we have applied socio-hydrological models and tried to find the adaptation and mitigation measures needed for both managing water resources and human well-being. In this process, we have published all research outputs in 14 high impact factors peer reviewed journal articles (attached as Appendix 1-14), one book chapters and one conference proceeding as mentioned below.</p>	<ul style="list-style-type: none"> - Conducted household survey, key informant interviews, stakeholders' workshop, field survey to gather primary data. - State of art technologies like remote sensing, GIS, IWRM models, agent-based modelling, etc., were used to assess the current situation as well as to predict the future situation of this interlinkages between water-occupation-health-climate-food 	<ul style="list-style-type: none"> - This project assessed the Nexus between water-health-climate-economy from water as an entry point, first of its kind of research work in these data scarce regions - Stakeholders workshop and validation workshops were conducted to make policy makers, academics, researchers, farmers association, were made aware about the nexus between water-food-health-economy-climate with the help of figures and graphs, which is easy to understand the complex issues. Also we used retrofitting models, hence all the

		<p>stakeholders has option to give their feedback at different stages of model development, calibration, validation, simulations because of its retrogressive in nature.</p> <ul style="list-style-type: none"> - Vulnerability and risk assessment to climate change in Sagar island, India - Capacity development was done young researchers from all three countries about socio-hydrological models -
<p>1. Kumar, P*., Avtar, R., Dasgupta, R., Johnson, B.A., Mukherjee, A., Ahsan, M.N., Nguyen, D.C.H., Nguyen, H.Q., Shaw, R. Mishra, B.K. (2020) Socio-hydrology: a key approach for adaptation to water scarcity and achieving human well-being in large riverine islands. Progress in Disaster Science, 8, 100134. Elsevier Publication.</p>		
<p>2. Paudel, S., Kumar, P*., Dasgupta, R., Johnson, B.A., Avtar, R., Shaw, R., Mishra, B.K., Kanbara, S. (2021) Nexus between water security framework and public health: A comprehensive scientific review. Water, 13, 1365,</p>		

doi.org/10.3390/w13101365. MDPI (IF- 3.530)		
3. Halder, S., Kumar, P* , Das, K., Dasgupta, R., Mukherjee, A. (2021) Socio-hydrological approach to explore groundwater-human wellbeing nexus: Case study from Sundarbans, India. Water, 13, 1635. MDPI, (IF- 3.530)		
4. Nguyen, D.C.H., Tang, LT., Nguyen, D.C., Le, T.C., Kumar, P. , Dasgupta, R., Nguyen, H.Q. (2021) Enhancing water supply resilience in the tropical island via socio-hydrological approach: a case study in Con Dao Island, Vietnam. Water, 13, 2573. MDPI (IF- 3.530)		
5. Kadir, A., Ahmed, Z., Uddin, M.M., Xie, Z., Kumar, P* . (2021) Integrated approach to quantify the impact of land use and land cover changes on water quality of Surma River, Sylhet, Bangladesh. Water, 14, 17, https://doi.org/10.3390/w14010017 . MDPI (IF- 3.530)		
6. Acharjee, A., Ahmed, Z., Kumar, P* , Alam, R., Rahman, M.S., Gandara, J.S. (2022) Assessment of the ecological risk from heavy metals in the surface sediment of River Surma, Bangladesh: Coupled approach of Monte Carlo simulation and		

<p>multi-component statistical analysis. <i>Water</i>, 14, 180. MDPI (IF- 3.530)</p>		
<p>7. Ahsan, M.N., Khatun, F., Kumar, P*, Dasgupta, R., Johnson, B.A., Shaw, R. (2021) Promise, premise, and reality: The case of voluntary environmental non-migration despite climate risks in coastal Bangladesh. <i>Regional Environmental Change</i>, 22,1. https://doi.org/10.1007/s41748-021-00274-x. Springer Publications. (IF- 3.678)</p>		
<p>8. Singh, V.G., Singh, S.K., Kumar, N., Kumar, P., Gupta, P.K., Singh, P.K., Gašparović, M., Ray, R.L., Saito, O. (2022) Water accounting using satellite products and water accounting plus framework in a semi-arid Betwa river basin. <i>Water</i>. MDPI (IF- 3.530)</p>		
<p>9. Minh, H.V.T., Lavane, K., Ty, T.V., Downes, N.K., Hong, T.T.K., Kumar, P.* (2022) Evaluation of the impact of drought and saline water intrusion on rice yields in the Mekong delta, Vietnam. <i>Water</i>, 14, 3499. MDPI (IF- 3.530).</p>		
<p>10. Ahsan, M.N., Khatun, F., Islam, M.S., Hossain, M.S., Mou, B.H., Kumar, P. (2022) Assessment of household-level adaptation strategies to water stress in southwestern coastal</p>		

<p>Bangladesh: a counter-factual analysis. <i>Water Policy</i>, 24, 9, 1516. Taylor and Francis, (IF-1.733)</p>		
<p>11. Debnath, J., Meraj, G., Pan, N.D., Chand, K., Debbarma, S., Sahariah, D., Gualtieri, C., Kanga, S., Singh, S.K., Farooq, M., Sahu, N., Kumar, P.* (2022) Integrated remote sensing and field-based approach to assess the temporal evolution and future projection of meanders: A case study on River Manu in North-eastern India. <i>PLOS One</i>, 17(7): e0271190. (IF- 3.758)</p>		
<p>12. Nujaira, H., Prasad, A.K., Kumar, P., Yunus, A.P., Kharrazi, A., Gupta, L.N., Kurniawan, T.A., Sajjad, H., Avtar, R. (2022) Quantifying spatio-temporal variation in aquaculture production areas in Satkhira, Bangladesh using geospatial and social survey. <i>PLOS One</i>, 17 (12), e0278042. (IF- 3.758)</p>		
<p>13. Bera, A., Kanga, S., Meraj, G., Farooq, M., Singh, S.K., Sahu, N., Kumar, P.* (2022) Vulnerability and risk assessment to climate change in Sagar island, India. <i>Water</i>, 14, 823. MDPI (IF- 3.530)</p>		
<p>14. Khatun, F., Ahsan, M, N., Afrin, S., Warner, J., Ahsan, R., Mallick, B., Kumar, P. (2022) Environmental non-migration as adaptation in hazard-prone</p>		

<p>areas: evidence from coastal Bangladesh. Global Environmental Change, 77, 102610. Elsevier Publication. (IF- 11.16)</p>		
<p>15. Book chapter - Kumar, P., Dasgupta, R., Avtar, R. (2022) Chapter 14- Socio-hydrology: a holistic approach to address water-human nexus in large riverine islands from India, Bangladesh and Vietnam. In Riverine Systems: Understanding the Hydrological, Hydrosocial and Hydro-heritage Dynamics. Springer publications, pp. 253-266, 10.1007/978-3-030-87067-6_14.</p>		
<p>16. Conference paper- Kumar, P., Socio-hydrology: An Integrated Approach to Address Intrinsically Linked Issues of Water Resource Management and Human Well-being” presented in 39th IAHR World Congress organized by the International Association for Hydro-Environment Engineering and Research (IAHR) in Granada, Spain (19-24 June 2022)</p>		

4. Key facts/figures

- An easy to understand ground reality for water scarcity and its cascading effects on health, economy, migration, human well-being is presented for all three study sites in India, Bangladesh and Vietnam (first of its kind) (got published in peer reviewed journal article).

- Scenario based quantitative analysis was done to predict the nexus issues with water as an entry point was done in all three areas, where we have also discussed different adaptation and mitigation measures for holistic management of water resources and human well-being. All findings were published in three high impact factors journal articles.
- Vulnerability and risk assessment to climate change in Sagar island, India. The finding is very much policy relevant as it will help to design different adaptation and mitigation measures in these areas. The methodology was also described in such a detailed way, which can be replicated in any data scarce region. (got published in peer reviewed journal article)
- For Bangladesh region, even the information on current status of water was lacking, so we have assessed the water pollution for the first time in this area.
- We have also assessed the trend of change in agriculture and aquaculture pattern. Since aquaculture is one of the main sources of income in this area but because of environmental changes, the aquaculture is getting affected. We have quantified spatio-temporal variation in aquaculture production areas in Satkhira, Bangladesh using geospatial and social survey and published in high impact factor journal.
- Also, we have assessed the relation between water scarcity and human migration in this area first of such policy relevant research work got published in three high impact factors journal articles like Journal of Global Environmental Changes, Regional Environmental Changes, Water Policy.

5. Publications

Peer reviewed journal articles (*- Corresponding author)

1. **Kumar, P*.**, Avtar, R., Dasgupta, R., Johnson, B.A., Mukherjee, A., Ahsan, M.N., Nguyen, D.C.H., Nguyen, H.Q., Shaw, R., & Mishra, B.K. (2020) Socio-hydrology: a key approach for adaptation to water scarcity and achieving human well-being in large riverine islands. Progress in Disaster Science, 8, 100134. Elsevier Publication.
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Book Chapter

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Vietnam. In *Riverine Systems: Understanding the Hydrological, Hydrosocial and Hydro-heritage Dynamics*. Springer publications, pp. 253-266, [10.1007/978-3-030-87067-6_14](https://doi.org/10.1007/978-3-030-87067-6_14).

Conference Paper

16. **Kumar, P.***(2022) Socio-hydrology: An Integrated Approach to Address Intrinsically Linked Issues of Water Resource Management and Human Well-being” presented in 39th IAHR World Congress organized by the International Association for Hydro-Environment Engineering and Research (IAHR) in Granada, Spain (19-24 June 2022)

6. Media reports, videos and other digital content

Our journal paper on common framework on socio-hydrological approach for achieving water resource management and human well-being got high attention not only from academia but from government bodies in different countries in Asia.

Our journal article on water scarcity and migration issues caught attention from both local as well as central government in Bangladesh and other Asian countries as well. Now we are venturing for different collaborations to scale up this research activities.

7. Pull quotes

“Socio-hydrological an integrated transdisciplinary research approach, which has the tremendous potential to deduce the interlinkages between water system and human well-being, considering all other key drivers of environmental changes especially in Asian region where such empirical research works are still very much lacking”.

8. Acknowledgments

We express our gratitude to Institute for Global Environmental Strategies (IGES) for providing in-kind funds for giving logistic arrangements for the smooth conduct of this project activities. This research work cannot be achieved without a tremendous support and active participation from all our collaborators and their institutes Khulna University (Bangladesh), Indian Institute of Technology, Kharagpur (India), Vietnam National University Ho Chi Minh City (Vietnam), Hokkaido University (Japan), Keio University (Japan) for carrying all the tasks (Field works, data analysis, report/paper writing etc.) to achieve all the aforementioned objectives in a timely manner. We are also grateful to all the local government organizations like water resource board, fisheries board, department of statistics, etc., to share the available observed data, maps etc. Finally, our sincere thanks to local farmer’s association, community representative, local residents for their valuable time and willingness to share their experience during conducting the questionnaire surveys.

9. Appendices

Appendix. 1-14 - All peer reviewed journal articles published.