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Socio-Hydrological Pathways to Water–Food Resilience: Integrating Climate, Wetlands, Governance, and Conflict–Cooperation Dynamics

Ankit Balvanshi[1], K.V. Jayakumar[2], V.R. Desai[3]

[1]Postdoctoral Researcher, Department of Civil & Infrastructure Engineering, Indian Institute of Technology Dharwad, India.
[2]Visiting Professor cum Outreach Advisor, Department of Civil and Infrastructure Engineering, Indian Institute of Technology, Dharwad, India.
[3]Professor & Director, Indian Institute of Technology Dharwad, India.

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Corresponding author Ankit Balvanshi
Email: ra.ankitbalvanshi@iitdh.ac.in

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Abstract

The two-way feedback between societies and water systems is investigated using the socio-hydrology framework. This study evaluates how climate change and wetlands governance, as well as feedbacks, generate socio-hydrological pathways in the human–water system. The paper draws comparative lessons from six contrasting basins: Ganga–Brahmaputra, Kuttanad and Bundelkhand within India, and the Mississippi, Murray–Darling and Rhine outside of it to highlight how floods, droughts, wetland degradation and responses of institutions produce diverse adaptation and maladaptation trajectories. Results of this analysis indicate that, alongside hydroclimatic variability, resilience outcomes also result from governance structures, institutional path dependence, unequal access to water, and conflict–cooperation dynamics shaping water allocation and long-term vulnerability. Wetlands, playing an important role as ecological buffers, are under-represented in socio-hydrological studies despite their significance for agricultural sustainability, ecological resilience, and water security. The review has identified four major gaps in the existing approaches: limited incorporation of cultural and institutional dynamics, weak characterisation of ecological thresholds, weak integration of multi-level governance, and neglect of hydro-political and conflict–cooperation processes. In this regard, we present an expanded socio-hydrological framework that can link hydrological science to governance analysis, remote sensing and dynamic modelling in order to further understand resilience pathways of wetland-dependent and agri-food systems under climate change.

Keywords: Agriculture, Climate change, Socio-hydrology, Water resources, Wetlands

Introduction

Human activities are capable of altering hydrological processes, ultimately threatening the stability of food and water systems across the globe. Increased frequency of hydroclimatic extreme events, resulting in floods and droughts, not only hampers agricultural production but also degrades wetland systems that provide crucial ecosystem services and buffering capacity. The pressures tend to be most severe in developing regions. There, demographic transitions, urban growth, and institutional hindrances combine with environmental pressures to produce complicated human–water risks. In such contexts, water stress is not just a biophysical issue but also a governance and political challenge caused by uneven access, contested institutions, and competing social priorities (Pande and Sivapalan, 2017; Ross and Chang, 2020; Prakash et al., 2025). The rise of the concept of the water-driven society has brought greater relevance to the socio-hydrology framework, which studies two-way feedbacks between society and water (Sivapalan et al., 2012).

In contrast to conventional hydrology, social hydrology studies coupled human-water systems in which hydrological processes co-evolve with social behaviour, institutions, infrastructure, and decision-making. Recent scholarship goes further by arguing that socio-hydrological analysis should go beyond behavioural response and risk perception to governance structures and power relations, justice, and hydrosocial relations (Ross and Chang, 2020; Basel et al., 2022; Ricart et al., 2025). Wetlands and agricultural landscapes are a priority because of climatic variability, but also because of institutional path dependence, allocation regimes, and uneven access to water and ecosystem benefits. These shape resilience outcomes. New research from South Asia has illustrated that socio-hydrological frameworks are good for understanding issues of climate uncertainty, adaptive governance and regional vulnerability in rapidly changing water systems (Prakash et al., 2025).

Worldwide, socio-hydrological research has shown how feedbacks between floods, droughts, infrastructure and social memory can produce adaptive and maladaptive trajectories. More recent research has built on these insights to cover resilience, groundwater governance and multilevel water management (Wei et al., 2022; Wang and Huang, 2025). The literature increasingly points out that water interaction often involves cooperation and contestation at the same time, especially in transboundary and institutionally fragmented settings. As can be seen in the case of Wei et al. (2022), conflict and cooperation in river basins emerge from the interplay of hydrological variability, social motives, and power relations, not scarcity alone. A related hydrosocial research accentuates stakeholders' roles, institutional legitimacy and power asymmetries as significant factors influencing water governance outcomes (Ricart et al., 2025). In India, the Ganga–Brahmaputra, Bundelkhand and wetland–agriculture systems such as Kuttanad that are impacted by hydrological stress, poor governance, livelihood insecurity, and social differentiation are home to the problems.

Despite these developments, important gaps remain. Socio-hydrological models are first criticized for omitting cultural value, informal institutions, and socially differentiated vulnerability. Second, wetland collapse, groundwater over-extraction, and irreversible ecological damage, all of which are threshold-type dynamics, are still under-incorporated in resilience evaluation. Another point is that many literatures continue to privilege biophysical feedbacks over hydro-political ones and conflict-cooperation dynamics, as well as questions of justice and legitimacy in water governance (Basel et al., 2022; Grasham et al., 2022; Taylor et al., 2026). The restrictions outlined above are particularly important for conducting reviews of wetlands and agro-hydrological systems, where the long-term sustainability of the practices depends both on ecological robustness and a socially equitable governance regime. Consequently, the study proposes an integrative review that considers socio-hydrological pathways to water-food resilience and the role that climatic variables, wetlands, governance and conflict-cooperation play in it. An improved approach for concurrent human-water systems is to be established through adaptive and maladaptive trajectories from six different basins. These basins are Ganga–Brahmaputra, Kuttanad, Bundelkhand, Mississippi, Murray–Darling, and Rhine. Further, the approach will involve a better socio-hydrology, which talks about governance, power, and resilience.

Conceptual and Analytical Basis of Socio-Hydrological Pathways

Socio-hydrology is a growing and increasingly recognized field which seeks to explain coupled human-water systems. Socio-hydrology differs from traditional hydrology. The latter often treats society as a 'forcing' impacting water systems. Socio-hydrology, instead, places human behaviour, institutions, cultural responses and governance processes within the water system. This change is particularly important in the Anthropocene, which refers to the period in which human activity is deemed to have a significant impact on climate and the environment. Climate, land-use changes, environmental stress and institutional arrangements interact across scales related to water and food resilience, among other disciplines. So, socio-hydrological pathways are seen as an interplay of environmental change, social response and institutional action, which can produce outcomes of adaptation or maladaptation. Everyone impacted by hydrological extremes, including wetland degradation, droughts, floods and groundwater stress. However, they do not happen in isolation. Furthermore, their impacts are mediated through feedback among policy choices, infrastructure development, social memory, ecological thresholds, access to water and so on. Consequently, resilience in the human-water system depends not only on bio-physical conditions, but also on governance structures, institutional path dependence, and the ability of societies to respond to change in fair and adaptive ways.

This paper's conceptual framework (Fig. 1) integrates climate change, society, wetlands and water systems to identify the key pathways that determine water–food resilience. The framework, which builds on existing socio-hydrological models, places hydrological extremes within broader socio-ecological contexts and highlights the relevance of governance, feedbacks, thresholds, and resilience trade-offs. In the context of the newly considered scope of this review, socio-hydrological systems are not only shaped by power relations but are also about competing interests and conflict–cooperation dynamics that shape and are shaping water access, allocation and long-term resilience outcomes.

Hence, the analytical basis of this review is organized into four dimensions that are interrelated. Section on climate change and water systems, i.e. the interaction of hydroclimatic variability generating vulnerability as well as adaptive response. The next section examines how institutions, policy interventions and governance structures determine resilience or maladaptation, which in turn feeds back to society and governance. This section talks about wetlands and ecosystem resilience. It examines ecological buffering, pathways of degradation, and consequences for agricultural systems. The further section discusses more broadly socio-hydrological feedbacks, i.e. interaction of social memory, institutional set-up, ecological threshold, and long-term adaptation trajectories. The conceptual, analytical basis of the socio-hydrological pathways must be multiscale, dynamic, and deeply embedded in the ecological and social system.

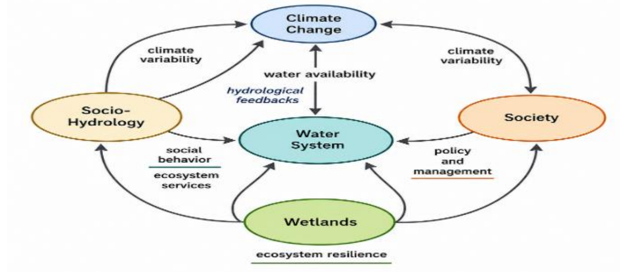

Fig. 1 Conceptual framework of socio-hydrological pathways linking climate change, society, wetlands, and water systems

Climate Change and Water Systems

The most direct impact of climate change on water systems occurs through hydroclimatic variability in rainfall, temperature and evapotranspiration (Kundzewicz et al., 2018). Worldwide socio-hydrological studies show that climate extremes do not occur in isolation. Instead, these extremes generate cascading feedbacks that shape long-term vulnerability, social response and adaptation trajectories (Di Baldassarre et al., 2019). In this regard, climate change is not just an external hydrological disturbance but one that interacts with human decisions, ecological systems, and institutional responses to affect water–food resilience. In India, the Bundelkhand region exemplifies how prolonged droughts and drought-like scenarios lead to groundwater recharge, soil degradation, and out-migration; thus, reinforcing long-term socio-hydrological vulnerability (Rani, 2025; Jain et al., 2025). Similarly, when it comes to the Ganga–Brahmaputra floodplains, climate variability performs a dual function as floods generate negative agricultural impact and immediate social disruption, but also enhance the resilience of wetlands along with replenishing ecological functions (Bhuyan and Deka, 2024). The contrasting cases illustrate how climate extremes not only modify the hydrological baseline but also invoke social responses, including water reservoir expansion, crop diversification, livelihood adjustment and migration.

Other socio-hydrological settings show similar trends around the world. The prolonged events of drought and climate change in the Murray–Darling Basin revealed vulnerability in the water allocation system as it concentrates water for commercial uses, marginalising smallholders and weakening social resilience (Grafton et al., 2019). In the Rhine Basin, adaptive flood management reduced threat but at the same time created increasing reliance on engineered infrastructure, which increases the chance of maladaptive outcomes over time (Di Baldassarre et al., 2018). These illustrations highlight an important insight from socio-hydrology: while responses to climate shocks may enhance resilience in the short-term, they may also create new dependencies, trade-offs and vulnerabilities in the longer term. An increasing amount of literature points to the need to capture threshold dynamics, including irreversible groundwater depletion, wetland collapse and delayed ecological responses in socio-hydrological models (Kreibich et al., 2025). Several existing studies continue to be strongly biophysical in orientation, and as a result fail to fully take into account the cultural, institutional and governance dimensions through which climate-water interactions are experienced and managed (Buytaert, 2016; Borah et al., 2022). Addressing these shortcomings is crucial if socio-hydrology is to emerge as a powerful mechanism for understanding adaptation and maladaptation pathways under climate change in wetland– and agricultural water systems.

Society and Governance Feedbacks

The primary interface between society and water systems takes place through policies (and governance arrangements and institutional arrangements) that mediate climate and hydrological variability. Governance is increasingly considered a principal driver of resilience or maladaptation in socio-hydrology because it influences preparation, response, and recovery to hydroclimatic extremes (Pahl-Wostl, 2019). Nevertheless, governance is more than a mere administrative context to hydrological change, reflecting institutional priorities, the unequal access to resources, and competing social interests that matter for how water is governed, accumulated and contested. Because of this, socio-hydrological pathways are shaped not only by environmental stress but also by the quality of the institutions, the inclusiveness of decision-making and governance systems that foster cooperation or reinforce vulnerability.

In India, governance responses often produce contradictory outcomes. Flood protection embankments in the Brahmaputra basin decreased flood exposure in the short term. However, they stopped the natural sediment movement and wetland dynamics. As a result, they caused ecological degradation and increased long-term vulnerability (Chakraborty et al., 2024). Canal irrigation and groundwater subsidies in semi-arid regions such as Bundelkhand and Punjab enhanced food production in the short term. But they also led to over-extraction of groundwater, declining baseflows and increasing dependence on unsustainable practices (Shah, 2021). All these examples show where policy-driven interventions inadvertently reinforce risk pathways. Governance results are rarely neutral, the studies show. While certain users or sectors profit from infrastructure and subsidies, long-term socio-hydrological costs tend to be offloaded onto ecosystems, smallholders or downstream users.

Similar governance challenges are evident at the global level. An example of a market-based water allocation that generated economic efficiencies but reduced the agency of smallholder farmers, exacerbating social inequities and resilience, is the Murray–Darling Basin (Grafton et al., 2019). In the Mississippi Basin, large, artificial levee systems may have limited flood risk within protected areas, but they have increased vulnerability further downstream. This is because levees cut a river off from its floodplain (Di Baldassarre et al., 2018). In both scenarios, the governance structures influenced adaptive capacity as well as creating maladaptation traps. On the whole, such case studies demonstrate that in becoming good water users, governments tend to shed their roles and responsibilities as water suppliers. Usually, water governance entails the interplay between cooperation and contestation.

By embedding social memory, risk perception and institutional inertia in hydrological analysis, tools can be provided for analyzing these feedbacks (Sivapalan et al., 2012). The most recent developments employ agent-based models to further capture how household decisions interact with policy regimes, and system-dynamics approaches to simulate governance trade-offs under uncertainty (Wang et al., 2025). Governance continues to be underrepresented in many socio-hydrological models that still emphasise physical feedbacks and oversimplify cultural, political and institutional processes (BUYTAERT, 2016). In India, the constraint matters a lot owing to rapid urbanization, federal–state water disputes and the duality of formal-informal institutions which engender layered governance contexts. The resilience here is conditioned not only by water stress but also by negotiation, institutional path dependence and unequal access to water.

To advance socio-hydrology, there is a need to develop an analytical focus. This development involves the governance issue. The issue will further expand from being technical management to a dynamic process. The dynamic process has varied interactions. These include institutions, trade-offs, power relations and conflict–cooperation outcomes. If these dimensions are omitted, socio-hydrological analysis may underestimate the role of socio-political processes in water-food resilience as much as hydrological uncertainty. A framework that is more socially grounded and politically aware must be developed to understand resilience trajectories for wetland and agrohydrological systems.

Wetlands and Ecosystem Resilience

Wetlands play an important role in socio-hydrological systems as they regulate hydrological extremes and sustain biodiversity and agricultural livelihoods. Wetlands provide floodwater storage, groundwater recharge, local microclimate moderation, and essential ecosystem functions, acting as a natural buffer enhancing ecosystem-based resilience (Davidson et al. 2018). Tropical forests rank as the most biologically diverse terrestrial ecosystems on our planet. Simultaneously, they are one of the most degraded ecosystems in the world. The loss of tropical forests is due to land conversion, urban expansion, and climate change (Ramsar Convention 2022). Wetlands are critical to socio-hydrology, given changes in wetland condition influence ecological integrity, water security, food production and the adaptive capacity of human communities.

Wetlands are vital building blocks of many wetland–agriculture systems in India whose resilience is dependent on hydrology, land use and governance interactions. The Kuttanad wetlands, a rice and wetland cultivation area below sea level, are recognized for their global significance. Still, it has been increasingly vulnerable to floods as well as sea level rise due to land reclamation, urban encroachment and saline water intrusion. The hydropower development and land encroachment in Loktak Lake, Manipur, a Ramsar site of considerable socio-ecological significance, have been adversely affecting its viability as a means of livelihood and ecological support system (Ningombam et al., 2019). The East Kolkata Wetlands, facing huge pressure from urbanization and weak enforcement of governance mechanisms, are critical for wastewater-based agriculture and aquaculture (Ghosh et al., 2020). When wetlands are degraded, it is not only because water disappears from them. This process also involves policies, institutions, and how we use resources, which can be hydrological.

Similar trends can be seen globally. Wetland degradation in the Murray–Darling wetlands in Australia and the Mississippi delta in the USA has led to the erosion of the long-term resilience and ecological buffering capacity and threatens food and livelihood security (Finlayson et al., 2017). In the Rhine Basin, governance did adapt to nature. Floodplain restoration has helped reconnect rivers to wetlands and improve their ecological resilience. However, this only happened due to much governing coordination across many administrative levels (Kern et al., 2019). Wetlands are not just passive landscape features, according to these cases. They are part of the resilience pathways. Also, they are what determines whether water systems absorb disturbance, recover from shocks, etc.

Even though wetlands are important, they are still lacking in many socio-hydrological models. Existing frameworks focus primarily on water demand, land-use change, and infrastructure, neglecting key ecological thresholds like salinity intrusion, biodiversity loss, and irreversible wetland collapse (McMillan et al., 2016). Because of this absence, socio-hydrology cannot capture longer-term resilience dynamics in agro-hydrological systems where the decline of wetlands feeds back into agricultural water stress, livelihood insecurity and ecosystem instability. Full inclusion of wetlands in socio-hydrological analysis requires taking a remote sensing, hydrological modelling, and participatory governance approach. For example, satellite-based land-use and land-cover monitoring can quantify wetland shrinkage, while system-dynamics approaches can simulate how wetland degradation interacts with water allocation, agricultural stress, and institutional response. Embedding these ecological processes into socio-hydrology is essential for understanding the water–food–ecosystem nexus under climate change and for developing more robust pathways to long-term resilience.

Socio-Hydrology and Feedback Loops

The feedback between human decisions and water systems regulates long-term socio-hydrological resilience as understood in socio-hydrology. In contrast to conventional models that focus on linear cause-and-effect relationships, socio-hydrological approaches involve conceptualising bidirectional interactions where social memory, risk perception, cultural values and institutional responses shape hydrological outcomes, while the hydrological change shapes social behaviour and decision-making in response (Sivapalan et al., 2012; Pande and Sivapalan, 2017). This view is essential to understanding why similar climate or hydro events cause different adaptations or maladaptations in different places and times.

This feedback is illustrated clearly by Indian history. In Rajasthan, recurrent droughts promoted the evolution of indigenous tank systems as adaptive water management technologies. The expansion of tube wells and groundwater pumping in later years led to the cultivation of high-water-use crops, making the groundwater situation more vulnerable as well as accelerating depletion (Shah, 2021). As a socio-hydrological regime shift, adaptive practices become maladaptive dependencies when governance and institutions fail to limit extraction. These instances show that feedback loops are not only hydrological or economic but also moulded by institutions, social choices, and patterns of resource use over the longer term.

In every part of the world, feedback loops are both used in a positive way and as a negative one as well. Water markets in the Murray–Darling Basin initially afforded flexibility during drought, but they ended up entrenching inequities and eroding the resilience of smallholder farmers (Grafton et al., 2019). Flood-control infrastructure investments in the Rhine Basin reduced flood risk but also increased confidence and settlement in floodplains, leading to increased potential catastrophic loss for extreme events (Di Baldassarre et al., 2018). Path dependence is a signature characteristic of socio-hydrological systems. Once societies are locked into specific technological, policy, or institutional pathways, maladaptation soon becomes irreversible.

Recent advances have stressed the significance of nonlinear feedback and threshold effects. Agent-based socio-hydrological models show how individual decisions and actions can lead to adaptations such as migration, land-use change, agricultural transformation or wetland degradation (Wang et al., 2025). Models based on system dynamics provide further insight into how risk may be concealed for a time by delayed feedback, for example, the gap between groundwater depletion and drop in crop yields. Kreibich et al. (2025) use such models to demonstrate how the realisation of risk may be postponed until we reach certain ecological or social thresholds. These approaches are useful because they clarify how resilience can seem stable in the short-term even if systemic vulnerability builds up underneath.

Advances notwithstanding, cultural, institutional and governance feedback is limitedly represented so far. The Indian economy, with respect to water management, is not simply a product of economic calculations and physical shortage. Rather, it is influenced by factors such as religion, caste relations, informal institutions and varying access to resources by different social groups. Feedback in systems is not only biophysical; they are also social and political in nature. If these dimensions are not included, socio-hydrology will only be able to partially explain resilience and vulnerability. To advance the field, we need to move away from the analysis of water systems in isolation, toward more holistic socio-ecological feedback frameworks that explicitly capture adaptation, maladaptation, institutional path dependence, and the long-term consequences of human–water interactions.

Conclusions

This review indicates that socio-hydrology provides a powerful lens for the interacting forces of climate change, wetlands, governance, and society in shaping water-food resilience. Floods and droughts do not act alone. That is the conclusion drawn from evidence from the six basins. It is the impact of floods and droughts that is mediated by land use, institutions, and governance responses. All these could produce adaptation or maladaptation. Wetlands are important features that can combat ecological degradation, but are themselves vulnerable and underrepresented in socio-hydrological analysis. The study states that robustness cannot be solely due to biophysical feedbacks. Four different known factors play a role in determining the long-term outcomes of coupled human-water systems. These are governance quality, institutional path dependence, unequal access to water, and conflict-cooperation dynamics. This is particularly the case in wetland-reliant and agro-ecological settings, where ecological stress collides with social vulnerability and governance fragmentation. To sum up, the paper identifies four main gaps: limited consideration of cultural and institutional dynamics and insufficient representation of ecological thresholds, weak integration of multi-level governance, as well as lack of hydro-political and conflict–cooperation processes. To manage these gaps more effectively, we need more integrated socio-hydrological approaches using hydrological science, governance analysis, remote sensing and dynamic modelling. This framework is vital for wetland sustainability, adaptive water governance, and improved water-food resilience under the impact of climate change.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethics Approval

This study does not involve humans, animals, or biological materials. If applicable, ethical approval details must be provided.

References

Adla, S., Pande, S., Vico, G., Vora, S., Alam, M. F. and Basel, B. 2023. Place for Sociohydrology in Sustainable and Climate-Resilient Agriculture: Review and Ways Forward. Cambridge Prisms: Water, 1: e13. https://doi.org/10.1017/wat.2023.16.

Basel, B., Hoogesteger, J. and Hellegers, P. 2022. Promise and paradox: A critical sociohydrological perspective on small-scale managed aquifer recharge. Frontiers in Water, 4: 1002721.

Bhuyan, M. J. and Deka, N. 2024. Understanding Human–Water Nexus in a Floodplain District of the Brahmaputra Valley, India: An Integration of Socio-Hydrological and Rural Hydrological Approaches. Science of the Total Environment, 907: 167637.

Borah, R., Das, S. and Sharma, P. 2022. Hydrological Extremes and Socio-Hydrological Risks in Northeast India: A Basin-Level Analysis. Environmental Monitoring and Assessment, 194: 657. https://doi.org/10.1007/s10661-022-10478-3.

Buytaert, W. 2016. Socio-Hydrology: Towards a More Integrated Understanding of People and Water. WIREs Water, 3(3): 327–338. https://doi.org/10.1002/wat2.1131.

Chakraborty, S., Chatterjee, A. and Kumar, P. 2024. Urban Water Ecosystems in Africa and Asia: Challenges and Opportunities for Conservation and Restoration. Springer, Singapore.

Davidson, N. C., Fluet-Chouinard, E. and Finlayson, C. M. 2018. Global Extent and Distribution of Wetlands: Trends and Issues. Marine and Freshwater Research, 69(4): 620–627. https://doi.org/10.1071/MF17019.

Di Baldassarre, G., et al. 2019. Floods and Societies: The Socio-Hydrology of Floods. Nature Reviews Earth & Environment, 1: 76–89. https://doi.org/10.1038/s43017-019-0002-9.

Di Baldassarre, G., Viglione, A., Carr, G., Kuil, L., Salinas, J. L. and Blöschl, G. 2018. Socio-Hydrology: Scientific Challenges in Addressing the Complex Human–Water System. Water Resources Research, 54(4): 3019–3035. https://doi.org/10.1002/2017WR020866.

Finlayson, C. M., Arthington, A. H., Pittock, J. and Schuyt, K. D. 2017. Freshwater Wetlands, Climate Change and Water Management: Policy and Scientific Challenges. Climatic Change, 144(2): 273–284. https://doi.org/10.1007/s10584-017-1945-6.

Ghosh, D., Mandal, A. and Bhatta, R. 2020. Sustaining East Kolkata Wetlands: Socio-Hydrological Perspectives on Wastewater Use and Urban Pressure. Environmental Management, 65(2): 205–218. https://doi.org/10.1007/s00267-019-01241-7.

Grafton, R. Q., Williams, J., Perry, C. J., Molle, F., Ringler, C., Steduto, P., Udall, B., Wheeler, S. A., Wang, Y., Garrick, D. and Allen, R. G. 2019. The Paradox of Irrigation Efficiency. Science, 361(6404): 748–750. https://doi.org/10.1126/science.aat9314.

Grasham, C. F., Charles, K. J. and Abdi, T. G. 2022. (Re-)orienting the concept of water risk to better understand inequities in water security. Frontiers in Water, 3; 799515.

Jain, M., Awasthi, S., Singh, P. and Mondal, S. 2025. Hydroclimatic Extremes and Socio-Hydrological Responses in Semi-Arid India. Frontiers in Water, 7: 1442107. https://doi.org/10.3389/frwa.2025.1442107.

Kern, K., Gresch, M. and Blöchliger, H. 2019. Floodplain Restoration and Multi-Level Governance in the Rhine Basin. Water

International, 44(4): 409–424. https://doi.org/10.1080/02508060.2019.1593668.

Kreibich, H., Di Baldassarre, G., Merz, B., Vorogushyn, S. and Blöschl, G. 2025. Socio-Hydrology: Past, Present, and Future. Hydrological Sciences Journal, 70(1): 1–19. https://doi.org/10.1080/02626667.2025.2405612.

Kundzewicz, Z. W., Krysanova, V., Dankers, R., Hirabayashi, Y., Kanae, S., Hattermann, F. F. and Huang, S. 2018. Differences in Flood Hazard Projections in Europe – Their Causes and Consequences for Decision Making. Hydrological Sciences Journal, 63(7): 964–979. https://doi.org/10.1080/02626667.2018.1446211.

McMillan, H., Montanari, A. and Cudennec, C. 2016. Panta Rhei 2013–2015: Global Perspectives on Hydrology, Society and Change. Hydrological Sciences Journal, 61(7): 1174–1191. https://doi.org/10.1080/02626667.2016.1159308.

Ningombam, S. S., Khuman, P. C. and Singh, E. J. 2019. Socio-Hydrological Impacts of Hydropower Development on Loktak Lake, Manipur, India. Lakes & Reservoirs: Research and Management, 24(2): 120–133. https://doi.org/10.1111/lre.12263.

Pahl-Wostl, C. 2019. The Role of Governance Modes and Meta-Governance in the Transformation towards Sustainable Water Governance. Environmental Science & Policy, 91: 6–16. https://doi.org/10.1016/j.envsci.2018.10.008.

Pande, S. and Sivapalan, M. 2017. Progress in Socio-Hydrology: A Meta-Analysis of Challenges and Opportunities. Wiley Interdisciplinary Reviews: Water, 4(4): e1193. https://doi.org/10.1002/wat2.1193.

Prakash, A., George, R. and Barua, A. 2025. Socio-hydrological frameworks for adaptive governance: addressing climate uncertainty in South Asia. Frontiers in Water, 7:1556820.

Ramsar Convention on Wetlands. 2022. Global Wetland Outlook: State of the World's Wetlands and Their Services to People. Ramsar Secretariat, Gland, Switzerland.

Rani, S. 2025. Land and Water Nexus: Exploring the Interplay of Resources in South Asia. In Land and Water Nexus in South Asia: Exploring the Interplay of Resources, Springer, Singapore, 1–20. https://doi.org/10.1007/978-3-031-87429-1_1.

Ricart, S., Villar-Navascués, R., Squitieri, F., Neri, M., Hernández-Hernández, M., Toth, E. and Rico-Amorós, A. M. 2025. How to reinforce governance in water–tourism nexus research? Updating the hydrosocial cycle to loop into stakeholders' roles, interactions, and power dynamics. Environmental Research Letters, 20(3):034021. https://doi.org/10.1088/1748-9326/adb447

Ross, A. and Chang, H. 2020. Socio-hydrology with hydrosocial theory: two sides of the same coin? Hydrological Sciences Journal, 65(9): 1443–1457.

Shah, S. H. 2021. How Is Water Security Conceptualized and Practiced for Rural Livelihoods in the Global South? A Systematic Scoping Review. Water Policy, 23(5): 1129–1147. https://doi.org/10.2166/wp.2021.184.

Sivapalan, M., Savenije, H. H. G. and Blöschl, G. 2012. Socio-Hydrology: A New Science of People and Water. Hydrological Processes, 26(8): 1270–1276. https://doi.org/10.1002/hyp.8426.

Taylor, K. S., Poelina, A., Moggridge, B. J., Currell, M., Jackson, S., Jackson, S. E., Pollino, C. A., Ross, A. and Werner, A. D. 2026. Integrating hydrogeology and water justice for more effective and equitable groundwater planning. Hydrogeology Journal, 34. https://doi.org/10.1007/s10040-025-02997-x

Wang, Y., Zhao, Y., Hu, Q., Qi, J. J., Lv, Z. and Liu, J. 2025. Enhancing Water Resources Management: Integrating Critical Zone Science and Complex Systems for River Basin Ecohydrological Processes. Environmental Research Letters, 20(2): 025003. https://doi.org/10.1088/1748-9326/adc750.

Wei, Y., Wei, J., Li, G., Wu, S., Yu, D. and Sivapalan, M. 2022. A socio-hydrological framework for understanding conflict and cooperation with respect to transboundary rivers. Hydrology and Earth System Sciences, 26: 2131–2149.