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Climate Change and Water Security in South Asia: A Qualitative Study of Vulnerability, Adaptation Strategies, and Community Responses

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Abstract

The effects of climate change have made water insecurity a greater challenge in South Asia, by affecting hydrological cycles, raising environmental risks and driving up underlying socio-economic vulnerabilities. Some research has been conducted on the effects of climate change on the hydrology and environment, but this research had been limited and focused on a community-based perspective, including lived experience, local climate change challenges and adaptation. This study explored the societal and hydrological interactions between climate change, water security, adaptation options and institutional reactions in water vulnerable regions of South Asia in a community based approach. Qualitative multi case study approach through semi-structured interviews, focus group discussions, field observations and document analysis with community members, farmers, water users, water and climate experts and policy makers. Thematic analysis revealed five closely related sub-themes related to water insecurity; climate induced water insecurity, community based adaptation, institutional constraints, social vulnerability and integrated socio-hydrological governance. The results show that water insecurity is not just the direct result of climatic variability but is a result of the synergistic effect of climatic variability, livelihood dependency, household practices and governance. The study highlighted the importance of formal adaptation process and need for community involvement. This study not only links the hydrological process to social realities, but also helps deepen the understanding of socio-hydrology and defines the context-sensitive climate adaptation strategy which is inclusive and equitable.

Keywords: Adaptation process, Climate fluctuation, Hydrological process, Livelihood, Vulnerabilities.

1. Introduction

Water security and climate change were a direct link in sustainable development particularly in the South Asian region as the increased climate variability and climate fluctuation are threatening water security in the region, in addition to the lack of infrastructure

(Baig *et al*., 2025). The consequences of these environmental changes on the livelihoods, economic stability and community resilience of human societies were grave and the mitigation of water-related crises is a key priority in order to realize long-term regional development (Han *et al*., 2024). The challenge of water insecurity was more complex and complicated, apart from changes brought about by climate change, environmental degradation, population pressures and institutional problems. The issues were interconnected and needed to be understood when formulating strategies towards sustainable and equitable water governance. There previous studies related to climate change, water security and socio-hydrological systems and highlighted that environmental change and rapid urbanization and sub-optimal water resource management can be a major driver of the changes in hydrological variability under climate change. So there had been a lot of focus on physical and environmental aspects while the social aspects of water insecurity have received less attention (Rehman *et al.*, 2024; Rokonuzzaman *et al*., 2023). The recent study indicated that it is necessary to include community voices in water governance. The adaptive processes and coping mechanisms that can be observed in specific socio-ecological contexts had been shown but are still unrepresentatively captured in the dominant research literature on climate and water (Newman *et al.*, 2024). But the socio-hydrological approaches attempted to address this disconnect by considering human behavior, institutional frameworks and the impacts of climate change on the environment to enhance understanding of the dynamics of water insecurity (Ahmad *et al*., 2018; Prakash *et al*., 2025).

However, in South Asia, there is a lack of insights on the local communities' perception, experiences, and coping to increased water insecurity in their socio-ecological contexts (Newman *et al.*, 2024). This research focused mostly on the climate modelling, hydrological assessment and institutional responses but lacks attention to the climate related water related problems in the community, Agricultural practices and traditional water management practices, Interactions between households and environmental degradation and governance systems. There was need for research that helped to close the gap between scientific knowledge about water changes due to climate change and knowledge and adaptive capacity of communities. This study was brought together the three elements of local knowledge, human behavior and climate related water hazards to create a community centered socio-hydrological perspective to understand the complex relationship between communities and water insecurity (Prakash *et al*., 2025).

The use of scientific analysis together with the voice of the people in the study helped to shape inclusive and localized water management frameworks. The aim of this study was to understand the adaptation strategies of the community to climate change, water insecurity and to develop integrated socio-hydrological perception of human environment interaction in the south Asian region.

- To discuss the opinions regarding the impacts of the climate change on water security in South Asia countries.
- To interpret and understand the ways in which water issues are expressed within the community, and the relationship between water-use and community environmental degradation by households.
- To record local coping mechanisms and traditional water management practices in order to determine local adaptation strategies.
- To review institutional responses, governance and potential for integrating approaches with community and state led approaches.

The study helped to support water and climate security as it increased the understanding of the lived experience and responses of communities to water related challenges associated with climate change. It integrated local knowledge and a participatory framework that increased stakeholders' involvement to build resilient and equitable socio-hydrological systems (Bassi *et al*., 2025). The study informed water governance policy makers to create adaptive water governance strategies to connect institutional and community-based approaches that ensured that climate science is translated into a practical, place-based decision support tool for adaptation to climate change, given the vulnerabilities of the populations that it serves (Adla *et al*., 2023).

2. Review of Literature

The interactions among hydrological variability, socio-economic vulnerability, infrastructure limitations and adaptive governance systems had been increasingly focused on in studies of climate change and water security. In the South Asia region particularly in the watershed of Indo-Gangetic Plains and the Himalayas, scientific studies on the impact of climate change on the water resources (quantity, quality, access) on human livelihoods and ecological sustainability have been launched. The last few years had seen the importance of water security not just in terms of access to water resources but as the capability to enable equitable access, ecological integrity and resilience to environmental uncertainty, as described by Paul *et al*. (2025). This question had been approached from several angles such as political ecology, socio-hydrology, human security, and governance models, to examine the role that social structures, institutional frameworks, and power dynamics play in water distribution and management (Müller *et al.*, 2023). Moreover, it was pointed out that weak institution and poor sanitation and drinking water service heighten the vulnerability of the community to water hazards (Baig *et al*., 2025).

The main thrust of current research is therefore increasingly on solutions that address social, governance and environmental aspects of water security. The concept of a water crisis had been shifting from an environmental sense to a more sociotechnical sense in the theoretical realm. Interrelationships between elements and the complexity of the system allowed for the explanation of the failure of complex systems of many interdependent elements which was explained by the Normal Accident Theory. This would imply that a water infrastructure (forming a water system) could be vulnerable to very harsh climatic conditions.

The High-Reliability Organization (HRO) philosophy is the other way around that show how to operate complex systems without failing by making good organizational arrangements with other institutions preparing for failure and changing the system's management. Overall the theoretical approaches have confirmed that the drivers of water crises are not necessarily the natural hazards but governance failures and lack of integrated institutions and decision-making processes also play a role. The Hydro Social Cycle theory builds on the concept of social construction of the water system by suggesting that the water system is socially constructed in the interaction between ecological processes, political structures and human activities. This view posited water resource injustices not only are due to water scarcity, but also to social and institutional injustices. Likewise, the Water System Justice dimension underscored the increased social inequalities and institutional vulnerability due to hydrological change in the era of climate change among marginalized populations (Gupta *et al*., 2025). These theoretical perspectives encourage thinking about water insecurity on the one hand at the level of environmental processes and on the other hand at the human systems level.

A number of empirical research projects focused on the different pathways to achieve ‘water resilience’ and to lessen the vulnerabilities from climate change. Rain water harvesting has proven effective at a smaller scale and community-based management of watersheds has proven effective in the reduction of the effects of drought in rural areas of Rajasthan and Bangladesh. Furthermore, studies have indicated that besides governance programs, technological innovations can improve the resiliency of irrigation systems with detailed datasets available yet in many parts of South Asia (SA) this is not true (Hajirad *et al*., 2026). Other research has focused on the significance of hybrid infrastructure systems combining social and engineered solutions. These approaches had proven to produce more adaptive and equitable results than centralized water management systems which frequently do not meet the needs of the local communities (Wutich, 2025). The recent socio-hydrological studies have also shown that the actions of humans, institutional decision-making and governance mechanisms play an important role in water resilience in the region, thereby further complicating the uncertainties in the climate which further increased the uncertainty about the climate (Prakash *et al.*, 2025). It had also been observed that many of the modelling-based approaches fail to address the importance of the informal governance system and traditional ecological knowledge (TEK) which are also crucial factors of local water management (Zhang *et al*., 2026). Previous

research indicated that there are some overarching trends that had similar views and agreed that all these factors contributed to the growing problem of water insecurity, climate change, infrastructure constraints and governance issues. In addition, it was widely recognized that using the community and adaptive governance approaches are crucial to the development of sustainable water management strategies. However, several studies adopted different methodological approach and focused of the research. Socio-hydrological and political ecology approaches tend to be more on human behavior, institutional structures, and social inequalities whereas hydrological and model-based studies tend to focus on physical processes and climate impacts and predictions of the system as a whole. Although the use of modeling had been shown to benefit the understanding of climate variability and uncertainties for future water risks, it failed to adequately deal with local knowledge systems and informal adaptation mechanisms. Local experience and coping strategies, however, were documented in community-based studies without necessarily having a detailed quantitative assessment of hydrological changes.

Though there was extensive research that looks at the impact of climate change, water governance and adaptation but a number of important gaps exist. There were only a few studies that offer an understanding of local communities' perceptions and experiences, and responses to water insecurity as affected by climate change in their socio-ecological contexts. The socio-hydrological models are becoming more interested in socio-hydrological processes and decision-making by institutions but many models are not adequately considering the social-hydrological governance systems, indigenous knowledge systems and practices of community-based adaptation. In spite of all the efforts in South Asia both in physical climate assessment and social vulnerability studies there are still many efforts that are isolated. There was also a lack of inter-disciplinary research that combined the various aspects of community and experience, hydrological changes, adaptive practices and governance issues with a coherent approach. In addition to environmental processes there was an absence of community centered understanding of water insecurity from the literature review which took the local knowledge, community processes and institutions and how they respond to water insecurity into account.

3. Methodology

The study adopted a qualitative research design to analyze how water insecurity, water governance responses, community vulnerabilities and water adaptation strategies resulting from climate change impact water security in South Asia. Qualitative method was chosen because of its key strength in seeking a deep understanding of social realities, experiences and perceptions related to climate-water challenges (Creswell & Poth, 2018). Though quantitative research method was more popular for quantifying climatic and hydrological shifts the qualitative research methods enriched the ways in which the study's affected communities experienced, interpreted and responded to climatic and hydrological insecurity. Multiple case studies were used to investigate the different context of climate-water vulnerabilities in South Asia because it enabled the study of real-life environments of problems related to contemporary environmental issues and provided detailed information on complex social and institutional processes (Yin, 2018).

The study was conducted in some Climate Vulnerable Regions of South Asia. The site of the region was determined based on the vulnerability of the area to climate change-related impacts on water such as changes in precipitation, flooding, drought, groundwater depletion, melting glaciers and salinity intrusion (IPCC, 2022). Several climate-water vulnerability contexts were taken into account in the research. Bangladesh is facing coastal water scarcity and salinity problem due to sea level rise and extreme weather events. The scarcity of water and drought has created a water security issue in Northern India. Climate variability has impacted water availability and water sustainability in the agricultural sector in Pakistan. The geomorphic effects of the rain water and glacier changes in Nepal. These locations included a mix of ecological and socioeconomic environments across a range of water insecurity under climate change in South Asia. The respondents comprised people and actors that have experienced the impacts of water insecurity because of climate change in their everyday lives and actors who are engaged in the

management and adaptation of water. Community-level participants included farmers whose production relied on rainfall and those who rely on irrigation. Households in the coastal areas were facing water scarcity and salinity specially the fisher communities. That water related problems were encountered by the rural population. Institutional participants included People from the community who are volunteers with water quality groups, Local administrative representtatives, Climate experts from agro clusters and Environmental and water resource professionals. The multi-stakeholder approach shaped the institutional responses and the experiences at the community level in relation to climate change and water governance. The purposive sampling technique was adopted for the study because they needed to have participants who had the necessary knowledge and first-hand experience of the issue of water insecurity due to climate change. This sampling technique was appropriate for this study as it is in qualitative research where information rich participants who can give detailed explanations about the research phenomenon is needed (Patton, 2015). The study participants were selected based on some criteria like they were located in a community that is at risk to climate change at home and at work and had first-hand experience of water insecurity. They made an adaptation to climate change and water management related decision. Further participants were sought using snowball sampling particularly with those who were not easy to reach such as those who were institutional stakeholders or experts. Total–50 participants were included in the study. Data saturation was used to determine the final sample size with the addition of further data collection no longer adding new themes or significant information (Guest *et al*., 2006; Takalloo and Ariaee, 2024)).

The qualitative data was collected in two sets namely primary qualitative data and secondary qualitative data. Primary Data obtained from the Community members, Farmers, Water users, Government officials, NGO representatives and Climate & Water experts. The primary data were used to gain insights into Concern over water availability, Perceived climate impacts, Adaptation practices and Water governance challenges. Secondary data was collected from IPCC reports, Government climate policies, planning to address water management at national level, NGO publications and Peer-reviewed academic studies. These documents were analyzed to get an understanding of the wider policy context and institutional responses in relation to climate change and water security. The semi-structured interviews, focus group discussions and document analysis were employed in the study that involved the community, policy makers, experts and representatives from NGOs. This enabled flexibility to explore participant's experiences and the research aims were maintained along the way (Creswell & Poth, 2018). The primary attention of the interviews was on Changes in climate, Climate-related water challenges, Impacts on livelihoods, Existing adaptation practices, Issues and supports of institution. Six Focus Group Discussions were conducted with community members to hear their voices and perceptions of the water insecurity faced by them as a result of climate change that helped Community-level adaptation practices, the social impacts and vulnerabilities caused by water insecurity, Local knowledge systems and Challenges to effective adaptation. This approach proved to be helpful as they provided an opportunity to share common experiences and come up with group interpretations of climate-related issues (Morgan, 1997). Policy documents and climate adaptation reports and water management strategies were reviewed to discuss the institutional response to water security. Observation was also made to the field to gain insights into the local water characteristics, infrastructure and adaptation measures within the communities. The documents were used to analyze the experiences and link them with an overarching climate governance framework (Bowen, 2009).

The research instruments included Semi-structured interview guides, Discussion about the focus group questions and answers, Field observation checklists, Document review frameworks. The development of the instruments was based on the research goals and literature review of climate change and water security. The interviews were audio-recorded, transcribed and then thematically analyzed using an emergent theme analysis approach following six steps (Braun and Clarke, 2006). The process of analysis consisted of six stages included Knowledge of the procedure of analyzing interview transcripts and field notes, Deve-

lopment of basic codes, recognizing themes that are emerging, Themes checking and editing, Identifying and labelling themes and Drawing inferences and making judgements. Thematic categories included Climate-induced water insecurity, Community vulnerability, Livelihood impacts, Adaptation strategies, Institutional challenges, and Water governance gaps.

The research adhered to build ethical standards. The respondent received full study information, explaining why it was being carried out and what they needed to do along with information on the use of their data. A written informed consent was obtained from all participants prior to any participation (Beauchamp & Childress, 2019; L. Cohen *et al*., n.d.) .All information was kept confidential during the study and in personal data anonymization. Participants received the freedom to withdraw from the study at any time with no penalty and their consent was based on the assumption of a willingness for voluntary participation(Beauchamp & Childress, 2019).

4. Results

Five interconnected themes resulted from the thematic analysis which reflect the lived experience, interpretation and coping with water insecurity in vulnerable communities in South Asia as a result of climate change. The themes were the following: climate change and growing water supply insecurity, differences in the social vulnerability and impacts, community based adaptation and local knowledge systems, institutional constraints and governance issues, and integrated socio-hydrological water management. The results showed that water insecurity was not only felt as a result of water shortages but was also a dynamic interplay of environmental change, socio-economic conditions, household practices and institutional structures. The result aligned with the current perspective on water security which focuses on water availability but encompasses water accessibility, resilience, equity and adaptive capacity aspects (Grey & Sadoff, 2007; Zeitoun *et al*., 2016).

The participants identified that there were substantial changes in local water systems that were linked to the changing climatic conditions. The effects of climate change on rainfall and the occurrence of extreme weather events, the length of dry seasons and the lack of reliability of traditional water sources were reported by participants in various settings in South Asia. The freshwater security was seriously threatened by salinity intrusion in the coastal region where it is more likely to be affected by sea-level rise and cyclonic events. Rise in salinity could have impacts on drinking water availability, agricultural productivity and on household water management practices. The experiences were connected to the general science evidence related to sea-level rise, freshwater stress in coastal South Asia, due to sea level rise and rainfall interaction and absence of water infrastructure (IPCC, 2022). Likewise, farmers said they were increasingly relying on groundwater because of the erraticism of rainfall and lack of water on the surface. This extra pressure on groundwater resources in addition to the other long-term water sustainability challenges. The results showed that water insecurity had now become a reality, due to climate change. The community also had to deal with problems of water shortages in cases of extreme scarcity and water forecasting and utilization in water management.

The results showed that social groups were differently impacted by climate induced water insecurity based on their livelihood dependency, economic situation and adaptive capacity. Households engaged in non-natural resource activities were generally less vulnerable than small farmers, or fishing communities and households in the rural areas. The impacts of reduced water availability on agriculture decision making, household income and food security and migration were reported by the participants. The availability of irrigation was an issue of particular concern as was the increasing cost of production to farmers in the traditional farming system. It was also observed that women were disproportionately affected as they are the ones who fetch water for the whole household, particularly during scarcity of water. It provides evidence that Water insecurity due to climate change is linked to prevailing social inequalities. The findings support the water justice perspective that climate change does not make things equally vulnerable, but reinforces existing inequalities in terms of access, resources and institutional recognition (Boelens *et al*., 2018). The findings are also consistent with the previous studies that have shown the relationship between social and

environmental exposure and climate vulnerability identification (Adger, 2006). This study confirmed that community-based adaptation measures are important to help solve water-related problems associated with climate change. The participants discussed different practices in their region such as rain water harvesting, traditional water storage, crop adjustments, other livelihoods and community based resource sharing.

Several years of interactions with the environment were believed to result in the vulnerable communities having the adaptive knowledge and this was identified. It was not only communities that were passive victims of climate change but they also adapted their actions and use of resources to the uncertainty. The findings also showed that these adaptation approaches were seldom institutionalized, and were not integrated into established adaptation programmes. Participants identified that to some degree and in many cases more attention was paid to the technical aspect of the process rather than the importance of local knowledge systems. The outcome builds on increasing socio-hydrological research that recognizes the need to take human action, cultural practices and institutions into account in the study of the resilience of water systems (Sivapalan & Blöschl, 2015). This is also supported by previous studies that have shown that indigenous knowledge, especially community based practices (CBPs) have not been addressed in traditional climate adaptation strategies (TAS). Meanwhile, there is a need to consider indigenous knowledge and CBPs for the effective implementation of TAS. (Reid, 2016)

The study found that there was a considerable gap between the formal water governance systems and reality at the community level. Water resource management and climate adaptation programs were in place in both government and development organization sectors, but participants reported on some limitations in the implementation, accessibility and participation. There were three governance issues that emerged.

Fragmented Institutional Coordination

The participants identified multiple institutional responsibilities for water that lowers the effectiveness of water policies and made it difficult to respond to the fast evolving water risks related to climate change.

Limited Community Participation

This water insecurity had significant consequences on communities, but not consistently was there a community voice in water adaptation planning and decision making.

Policy needs and local needs that don't align

Most interventions were generic and aimed at the ecological context, livelihood systems and traditional practices were not considered. These results complement previous studies that have focused on the need for a multi-layered adaptive governance system that is able to link up science, institutions and communities (Folke *et al*., 2005).

5. Discussion

This paper focused on water insecurity as a socio-hydrological problem. In this paper, the socio-hydrological challenge of water insecurity was addressed. The study contributed to the ongoing climate-water research that has shown that water insecurity in South Asia does not just happen as a result of climatic changes but as a result of interactions between the environmental processes and social systems. The previous study was mostly on the aspect of climate modeling, hydrological evaluation and physical water availability. These approaches, how-ever, lack a good understanding of community experience and the response to water issues.

The findings added to the existing studies by providing proof that social conditions, livelihood structures and institutional arrangements play an intermediary role between the impacts of climate change and the impact on food security. Therefore, water insecurity needs to be considered as a consequence of the effects of the climate on water systems but also as a consequence of the relationship, management and coping of society with water systems. This was align with the hydro social cycle perspective which sees water as a physical resource and a socially constructed set of political, economic and cultural connections (Linton & Budds, 2014). This study recognized and highlighted local knowledge and community agency in climate adaptation, one of the key findings. Results indicated that solutions developed by the communities were community-specific as they were imagining the environmental changes. But such practices stayed on

the fringe of formal adaptation frameworks. There was always a battle between the two kinds of resilience in a community and the institutional planning for climate change. Prior research carried out had also shown that the adaptation strategies are more effective if the local communities are part of the decision making process and if local knowledge is used in the governance process (Ensor & Berger, 2009). It was important to change the approach to climate adaptation planning from one of experts to a method that can involve community knowledge.

The research discovered that an institutional constraint was a major problem for sustainable water security. Governance is a critical piece of the puzzle in addressing climate-water issues alone, in addition to technological solutions and infrastructure. Based on the results it was concluded that good water governance requires more integration of institutions, participatory decision-making, identification of local adaptation practices, Social vulnerability assessments in relation to climate planning. This further supported the idea that water problems are not only a result of environmental risks but also of institutional decay and bad governance (Pahl-Wostl 2009).

Theoretically the study contributed to the body of knowledge in two ways. It contributed to the development of the socio hydrological strategies by drawing on empirical knowledge of how water insecurity is experienced in the communities. This study was an integration of environmental processes and social vulnerability since the previous studies have dealt only with the social or environmental dimension. The key findings of the study were to combine the hydrological changes, community practices and experiences, adaptation and governance issues into a single analytical frame, thus meeting a gap in the literature. The outputs were highly policy relevant in practice. Policies acknowledged the communities as knowledge-carrying agents and active partners in the process of climate resilience building.

6. Conclusion

The study focused on the complex relation between Climate Change (CC) and the socio-hydrological study of water insecurity in the South Asian countries by tackling environmental change, community experiences, water adaptation and socio-institutional processes. The findings revealed that climatic variability and water scarcity are the drivers of water insecurity but that changes in the hydrological regime, socio-economic vulnerabilities, livelihood dependence, household practices and institutional structures are also drivers of water insecurity. Water insecurity was identified in five dimensions among vulnerable communities and some of these dimensions can be mutually reinforcing like vulnerability due to climate change in water availability, social vulnerability, community-based adaptation, indigenous knowledge systems, and institutional limitations and need for integrated socio-hydrological governance.

The findings suggested that there are different vulnerabilities and adaptive capacities among social groups with the smallholder farmers and fishing communities and rural households more vulnerable due to dependence on climate sensitive resources. One of the main characteristics of this research is the notion that communities are not only victims of climate change but also as agents of climate change. The study findings revealed that local communities can learn from their knowledge and adaptive measures like rain water harvesting, traditional water reservoir, livelihood diversification, etc. and sharing of resources. However, these local practices were well integrated in the formal process of climate adaptation and water management. The study also indicated that the water governance problems remain- institutional disorganization and low level of community participation and co-ordination.

The solutions to water interventions were taken beyond the technical aspects and moved to the management of water security where scientific knowledge is used, institutions have capacity and local experiences are involved in participatory and adaptive governance processes. Theoretically, this research impacted socio-hydrological literature by creating one framework to integrate and incorporate environmental processes, social vulnerability, community agency, adaptation practices and governance processes. A very important constraint of the previous studies focusing on physical water systems or the social dimension alone was taken into account in this contribution. The results highlighted the need to view adaptation to

climate change as a social and institutional process not a mere technological solution in practice. The key water governance strategies should be community based where communities are holders of knowledge and active participants to build resilience. Developing more inclusive and resilient water related strategies for the future with institutional cooperation involving local water knowledge in water policy etc. is needed for the South Asian countries.

7. Author Contributions

M.A.A.R.: Conceptualization, project administration, supervision, and critical review of the manuscript and A.S.: Methodology, investigation, data collection, data analysis, and interpretation of findings and M.S.: Investigation, data collection, literature review, and interpretation of findings and R.C.M.: Literature review, data collection, qualitative analysis, and manuscript preparation and J.B.M.: Data collection, data management, literature search, and manuscript editing and All authors contributed to the development and preparation of the manuscript, critically reviewed the manuscript for important intellectual content, approved the final version, and agreed to be accountable for all aspects of the work.

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9. Conflicts of Interest

The authors confirm that there are no conflicts of interest, whether financial, academic, professional, or personal, associated with this study. No external interest has influenced the research process, analysis, interpretation, or presentation of the findings.

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