Exploring an Alternative Management Approach to Shift the Paradigm in Community-Based Water Resource Management in Barind Tract- A Case Study in Godagari and Tanore, Rajshahi.

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Date: 25-01-2025

ICCCAD
International Centre for Climate Change and Development

ACKNOWLEDGEMENT

This study would not have been possible without the generous support and encouragement of several individuals and organizations. First and foremost, I express my heartfelt gratitude to the International Centre for Climate Change and Development (ICCCAD), Dhaka, for providing the funding and guidance necessary to undertake this research. Their unwavering support has been instrumental in shaping the study.

I am deeply indebted to the local people of Tanore and Godagari, whose invaluable insights, cooperation, and active participation enriched the findings of this study. Their willingness to share their experiences and knowledge provided a crucial foundation for addressing the water management challenges in their communities.

Special thanks go to the personnel of the Barind Multipurpose Development Authority (BMDA) for their assistance and for sharing critical information and technical expertise. A heartfelt acknowledgment is also extended to *Tanveer Hossain Rhine* and *Mehjabin Jahangir Rafjin* for their invaluable assistance in data collection. Their dedication and efforts were essential to the success of this research. Their collaboration was vital in gaining a comprehensive understanding of the water management systems in the Barind Tract.

Lastly, I am profoundly grateful to Almighty Allah for granting me the strength, perseverance, and guidance to complete this work. His blessings and mercy have been my greatest source of motivation throughout this journey.

Sincerely

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ABSTRACT

This study investigates the challenges and opportunities of community-based water resource management in the Barind Tract, focusing on Godagari and Tanore upazilas of Rajshahi, Bangladesh. The region faces severe water scarcity due to declining groundwater levels, unsustainable irrigation practices, inadequate governance, and the compounding impacts of climate change. A comprehensive methodology was adopted, integrating remote sensing analysis, participatory rural appraisal (PRA) techniques, and systematic literature reviews to explore sustainable management strategies tailored to the region's socio-ecological needs.

Key findings reveal significant changes in land use, with wetlands shrinking due to manmade interventions, such as canal construction and agricultural expansion, and the absence of effective governance mechanisms. Community feedback highlights the critical role of traditional water bodies and the challenges posed by over-reliance on groundwater. The study emphasizes the urgent need for integrated water resource management (IWRM) approaches that incorporate ecological preservation, local knowledge, and participatory decision-making.

The study proposes several actionable recommendations, including promoting rainwater harvesting, introducing water-efficient irrigation techniques like Alternate Wetting and Drying (AWD), and adopting artificial groundwater recharge methods. Strengthening institutional frameworks and enhancing stakeholder collaboration are emphasized to improve governance and ensure equitable resource distribution. Additionally, the study advocates for a holistic policy shift to prioritize the sustainable use of wetlands and groundwater while encouraging community ownership of water management initiatives. By aligning local perspectives with ecological and technological advancements, this research provides a replicable model for addressing water scarcity in arid and semi-arid regions globally.

Keywords: Barind Tract; Water Scarcity; Water Governance; Community Engagement; Climate Change Impacts

ABREVIATIONS

AWD: Alternate Wetting and Drying

BMDA: Barind Multipurpose Development Authority

CBD: Central Business District

DSS: Decision Support System

DTWSI: Deep Tube-Well Water Supply Installations

FGD: Focus Group Discussion

GIS: Geographic Information System

IWRM: Integrated Water Resources Management

KII: Key Informant Interviews

MLC: Maximum Likelihood Classification

NGO: Non-Governmental Organization

NWPo: National Water Policy

PRA: Participatory Rural Appraisal

ROC: Relative Operating Characteristics

SSI: Semi-Structured Interview

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Chapter 1. Introduction

This chapter introduces the context of the study, outlining the water scarcity issues in the Barind Tract, the significance of effective water management, and the rationale for exploring alternative approaches. It also highlights the research objectives and the structure of the study, setting the stage for a comprehensive investigation into sustainable water resource management in this challenging yet critical region.

1.1 Background of the Study

The developing difficulties that are related to water scarcity in semi-arid climates are exemplified by the Barind Tract, which is situated in the northwestern part of Bangladesh. When it comes to water resources, this region, which is well-known for its peculiar topographical and climatic characteristics, has long suffered from insufficient water supplies (Rashid, Islam, & Sultan-Ul-Islam, 2019). In recent years, the situation has gotten even more grave as a result of the combined effects of climate change, methods to extract and use water that are not sustainable for water management, and the growing demand for water across a variety of sectors (Kamruzzaman & Huq, 2020). The Barind Tract, with its one-of-a-kind socio-environmental context, will serve as an important case study for gaining an understanding of water scarcity in vulnerable places and developing strategies to solve it.

Existing difficulties in the Barind Tract have been made significantly more difficult by climate change. The vulnerability of the region to water shortages has been enhanced as a result of rising temperatures, unpredictable patterns of rainfall, and extended dry seasons (Hossain, Bari, & Miah, 2021). The annual average rainfall in this region is significantly lower than the national mean, and the majority of this precipitation concentrates during the monsoon season. As a result, the region experiences extended dry periods that put a burden on the available water supplies. Because of this climatic mismatch, there has been an increase in the region's reliance on groundwater extraction, particularly for agricultural irrigation, which is the primary economic activity in the region. According to (Kamruzzaman & Huq, 2020), more than 80 percent of the groundwater that is collected from the Barind Tract is used for agricultural purposes, which leaves very few resources available for domestic consumption and the preservation of essential ecosystems on the ground. As a consequence of this, groundwater tables are fast diminishing, which is causing yields from tube wells to decrease and increasing salt in water sources, which further exacerbates the issue.

The majority of the water management initiatives in the region have been piecemeal, fragmented, and reactive in nature. This is even though the impact of the problem is significant. To ease the current water shortages, efforts headed by the government have been implemented, such as the development of deep tube wells and irrigation channels (Khan, 2021). However, these activities have not adequately addressed the underlying causes of the problem. These interventions frequently lack a holistic and long-term vision, and they fail to take into account the ecological dynamics of the region as well as the requirements of the communities that are located there. Additionally, top-down approaches to water management have suppressed the views of those individuals who are most impacted by water scarcity, particularly smallholder farmers and marginalized communities (Md Saiful Islam, Hossain, & Sikder, 2019). This has led to the marginalization of these individuals. When these interventions are carried out without the participation of the community, they frequently turn out to be unsustainable in the long run, leaving the region susceptible to repeated water problems.

In addition, the water shortage in the Barind Tract is a reflection of the larger national difficulties that are associated with the management of water resources. Because Bangladesh is one of the countries with the highest population density in the world, the country's scarce water resources are under a great deal of strain (M. R. Islam, Jahan, Rahaman, & Mazumder, 2020). A considerable amount of the country's freshwater withdrawals is used inefficiently due to the usage of antiquated irrigation methods and constraints in infrastructure. The agriculture sector alone is responsible for more than 70 percent of the country's freshwater withdrawals. Because seasonal droughts and the unequal distribution of water resources further exacerbate these difficulties, water scarcity has become an urgent concern for sustainable development (Sujan, Hasan, & Hossain, 2023).

The concept of Integrated Water Resources Management (IWRM) has arisen as an internationally recognized way to tackle water management concerns comprehensively. This approach has gained widespread recognition globally. In the context of water resource management, integrated water resource management (IWRM) emphasizes the necessity of balancing social, economic, and environmental factors (M. Islam, Kashem, Momtaz, & Hasan, 2023). Participatory techniques, in which all stakeholders, from policymakers to local communities, are involved in the decision-making process, are advocated for by this organization. The deployment of IWRM in the Barind Tract, on the other hand, has been restricted and fragmented (M. R. Islam et al., 2020). The ecological significance of wetland areas and other natural water bodies, which play an essential part in preserving hydrological equilibrium, is sometimes overlooked by the initiatives that are already in place. In addition, they do not take into account the socio-economic realities of the people that are located in the area, such as their dependence on agriculture and their susceptibility to water shortages that are caused by climate change (M. Islam et al., 2023; Md Shafiqul Islam, 2019).

Given these circumstances, the purpose of this study is to provide alternate approaches to the problems that have been encountered in the management of water in the Barind Tract. The purpose of this project is to build a paradigm for managing water resources that is more inclusive and sustainable, going beyond the traditional top-down approaches that have been used in the past. At the same time as it recognizes that efficient water management must link human demands with environmental sustainability, it emphasizes the incorporation of community perspectives and ecological issues into the planning process. The purpose of this study is to identify solutions that are both practical and actionable. That is accomplished by concentrating on the specific difficulties that are encountered by the communities in Godagari and Tanore, which are two regions within the Barind Tract that are particularly afflicted by water scarcity.

The primary goal of this study is to establish alternative water management techniques that address both the immediate and long-term demands of the region. As such, the research will focus on developing these solutions. This entails conducting a thorough analysis of the existing state of water supply, the difficulties that are being experienced by the communities in the area, and the ecological value of wetlands and other bodies of water. The purpose of the study is to suggest novel techniques that improve the efficiency with which water is used, encourage the sustainable utilization of groundwater resources, and integrate both traditional and contemporary methods of water management to achieve these goals. By matching these tactics with the concepts of integrated water resource management (IWRM), the research aims to establish a model that may be replicated for solving water scarcity in situations that are also similar.

In addition to addressing the ecological and technical components of water management, the study emphasizes the significance of encouraging community engagement and ownership in water management projects. This is in addition to addressing the technical aspects of water management. Ultimately, the purpose of this research is to contribute to the larger conversation about the sustainable management of water resources in Bangladesh and beyond. Through the provision of a thorough understanding of the challenges and potential in the Barind Tract, the study intends to inform policy and practice, thereby paving the way for a future that is more resilient and water-secure for the region.

1.2 Objectives of the Study

The primary aim of this research is to provide alternative strategies to address water management challenges in the Barind Tract, particularly in the Godagari and Tanore upazilas, with a focus on sustainable practices and community engagement. To achieve this aim, the study is guided by the following specific objectives:

- To assess the current status of water availability in Godagari and Tanore and identify the specific challenges faced by the community.
- To explore sustainable water management strategies that account for the ecological importance of wetlands while meeting the community's needs.

1.3 Justification of the Study

An extensive water management challenge is being faced by the Barind Tract of Bangladesh. This challenge is being made worse by the complex interaction of environmental deterioration, excessive groundwater exploitation, and socio-economic vulnerability. Even though several studies have been conducted to investigate water scarcity in this region, the bulk of these studies have focused exclusively on technical concerns or have had only a minimum amount of community input. When it comes to the formulation of management plans that are both effective and sustainable, such approaches typically fail to take into account the fundamental value of local knowledge, attitudes, and behaviors. Due to this gap, a strategy that is both more comprehensive and inclusive must be implemented immediately.

This study is differentiated by the fact that it incorporates community involvement thoroughly throughout the entirety of the research process. The purpose of this study is to authentically reflect the complex realities of water management challenges faced by those who are most impacted by them. Local stakeholders, such as farmers, community leaders, and marginalized groups, are involved in their participation. The utilization of participatory methodologies ensures that the voices of the community are not only acknowledged but also actively affect the solutions that are being proposed. This approach fosters a sense of ownership and accountability among local stakeholders, which ultimately increases the likelihood that the strategy will be successfully implemented.

The study is justified not only by the fact that it is centered on participation, but also by the fact that it analyzes and evaluates existing policies and practices thoroughly. The purpose of this evaluation is to build a solid foundation for evaluating the effectiveness of the water management techniques that are currently in place, while simultaneously identifying areas of weakness and potential for improvement. In this study, an alternative management framework is developed by combining insights from local perspectives with broader academic and policy contexts. Additionally, the study integrates traditional knowledge with contemporary methodologies and principles of integrated water resources management (IWRM).

The combination of extensive community participation and a thorough evaluation places the research in a position that is unparalleled in its ability to address the intricate water management concerns that are present in the Barind Tract. While simultaneously intending to contribute to a more comprehensive conversation about participatory water resource management in semi-arid regions, it strives to provide answers that apply to the local situation and are specific to the local situation. The research is both comprehensive and all-encompassing, which ensures that it will be relevant and has the potential to have an impact on the Barind Tract as well as other regions across the world that are struggling with water scarcity challenges.

1.4 Scope and Limitations

Addressing the significant water management difficulties that the Barind Tract is currently facing is the primary objective of this study, with a special emphasis on the Godagari and Tanore upazilas as the primary areas of investigation. The purpose of this study is to investigate the complex interaction between ecological, social, and technical elements that are contributing to the current water shortage in the region. The objective is to assess the availability of groundwater and the patterns of its utilization, intending to shine a light on the degree of depletion and inefficiencies in water utilization. Additionally, the study aims to identify the issues that are special to the community, such as socio-economic vulnerabilities and restricted access to water. The research highlights the significance of including local stakeholders to guarantee that the solutions are both realistic and inclusive. This is accomplished through the utilization of participatory approaches. The ultimate goal of the research is to present alternative solutions that incorporate traditional traditions, contemporary technologies, and the concepts of Integrated Water Resources Management (IWRM). Additionally, the research intends to make policy recommendations to improve water resource management frameworks. In addition to addressing the water problems that are now occurring in the Barind Tract, the purpose of this study is to serve as a model for other semi-arid locations throughout the world that also have comparable problems.

On the other hand, the process of carrying out this research was not devoid of difficulties for anything. As a result of the political instability that occurred in Bangladesh during the months of July and August, which was a period that was distinguished by tensions that made it impossible to gather essential data, there was a considerable limitation. It was difficult for government officials to participate in interviews or offer information since they were frequently focused on the circumstances of the political atmosphere. The absence of cooperation made it difficult to obtain vital data and information regarding the water management system that was already in place. In addition, the limited availability of resources restricted the magnitude of the fieldwork, which in turn hindered the ability to carry out more comprehensive surveys or more in-depth ecological investigations.

Because the timeline of the study corresponded with the cyclical nature of water shortage and agricultural operations, seasonal dynamics also presented issues. This made it difficult to capture the entire diversity of water supply and utilization patterns. Literacy obstacles, cultural sensitivities, and the competing objectives of these communities made it difficult to engage marginalized communities, even though participatory efforts were made. Geographically speaking, the scope of the study was restricted to Godagari and Tanore, which, even though they offer interesting insights, might not be able to fully reflect the Barind Tract as a whole. Furthermore, there were gaps in ecological data, notably about the state and relevance of wetland areas, which made it difficult to make comprehensive conclusions regarding the role that wetland areas play in the management of water sustainably.

The study demonstrates a significant attempt to comprehend and handle the water management concerns that are present in the Barind Tract, despite the limitations that have been mentioned. At the same time as it highlights the myriad of issues that are associated with resource management, it also provides a roadmap for future research and treatments in comparable situations.

1.5 Research Framework

The research framework for this study is structured to systematically address the challenges of water management in the Barind Tract by integrating community perspectives and evidence-based analysis. The objectives are designed to assess the current water availability and identify community-specific challenges, explore sustainable management strategies that align ecological preservation with local needs, and propose alternative approaches to address water scarcity.

Guided by research questions, such as the state of water availability, the role of community participation, and the potential for innovative strategies, the study is underpinned by hypotheses that emphasize the significance of participatory methods and systematic evaluations. This framework ensures a holistic approach to developing practical and sustainable solutions for water management issues in the region.

Table 1: Overall Framework of the Study

Research Objectives	Research Questions	Research Hypothesis
To assess the current status of water availability in Godagari and Tanore and identify specific challenges faced by the community.	What are the current levels of water availability in Godagari and Tanore? What specific challenges do local communities face in accessing and managing water resources?	The community in Godagari and Tanore faces significant water management challenges, including declining groundwater levels, inefficient infrastructure, and inadequate policy implementation.

To explore sustainable water management strategies that account for the ecological importance of wetlands while meeting the community's needs.	How can water management strategies balance ecological preservation with the needs of the local community? What role can community participation play in developing these strategies?	Community-based water management approaches are more likely to balance ecological preservation with local needs and enhance the long-term sustainability of water resources.
To provide alternative strategies for addressing water scarcity issues by integrating local perspectives with systematic reviews.	What alternative approaches can address water scarcity in the Barind Tract? How can systematic reviews and participatory methods inform better water management solutions?	Integrating community knowledge with systematic evaluations of current practices will result in more effective and locally adaptable water management strategies.

Chapter 2. Theoretical Framework and Literature Review

2.1 Theoretical Framework

Water resource management has emerged as a critical global concern, necessitating an integrated and multidimensional theoretical approach. This study is grounded in two primary theoretical frameworks: Integrated Water Resources Management (IWRM) and Participatory Development Theory, both of which emphasize the necessity of collaboration, sustainability, and local community involvement in addressing water-related challenges.

2.1.1 Integrated Water Resources Management (IWRM)

The IWRM framework serves as a guiding principle for managing water resources in a holistic and coordinated manner. This approach advocates for the equitable allocation of water to balance social, economic, and environmental needs while ensuring long-term sustainability (M. Islam et al., 2023). The core tenets of IWRM emphasize integrating policies, engaging stakeholders, and incorporating cross-sectoral strategies to optimize water usage. For the Barind Tract, where water scarcity is a persistent challenge, IWRM offers a structured method to identify inefficiencies in infrastructure, assess groundwater depletion, and develop actionable plans that prioritize resource sustainability.

2.1.2 Participatory Development Theory

Participatory Development Theory underscores the importance of including local communities in decision-making processes to ensure sustainable outcomes. This theory advocates for a bottom-up approach, allowing community members to actively contribute their knowledge and experiences to policy formation and project implementation. In the Barind Tract, where top-down water management approaches have historically failed to address local challenges comprehensively, participatory development provides an alternative pathway to empower communities, enhance trust, and create context-specific solutions.

2.1.3 Definitions of Key Terms

Water Resource Management: A systematic process of planning, developing, and managing water resources to meet the demands of society while preserving the environment. This involves integrating multiple sectors, policies, and stakeholders to ensure balanced resource allocation.

Groundwater Depletion: The reduction in the volume of water stored underground due to excessive extraction, often leading to ecological and socio-economic challenges. It is a critical issue in arid and semi-arid regions like the Barind Tract.

Sustainability: The ability to meet present needs without compromising the capacity of future generations to meet their own. This concept serves as a guiding principle for water resource management to ensure long-term viability.

Stakeholder Engagement: The active participation of individuals, groups, or organizations with a vested interest in water management processes and outcomes. Effective engagement enhances trust and ensures diverse perspectives in decision-making.

Wetland Conservation: The practice of protecting and managing wetlands to maintain their ecological integrity and functions. Wetlands provide essential ecosystem services, such as flood control and biodiversity support, making their conservation critical in water-scarce regions.

Community Participation: Involvement of local communities in decision-making and implementation processes to ensure inclusive and effective water management solutions. This approach strengthens ownership and aligns management strategies with local needs.

Bottom-Up Approach: A planning or management strategy that originates at the grassroots level, emphasizing local input and control. It contrasts with top-down methods by fostering community empowerment and accountability.

Ecosystem Services: Benefits that humans derive from ecosystems, such as clean water, biodiversity, and climate regulation. Recognizing these services helps prioritize ecological health in water management strategies.

Systematic Review: A methodical synthesis of existing research to identify patterns, gaps, and actionable insights. This process provides a comprehensive understanding of water management practices and informs evidence-based recommendations.

GIS (Geographic Information Systems): A technological tool for mapping and analyzing spatial data to support water management and planning. GIS is instrumental in identifying high-risk areas and optimizing resource allocation.

Policy Implementation: The execution of strategies and regulations designed to manage water resources effectively. Challenges in policy implementation, such as lack of enforcement or political barriers, often hinder sustainable outcomes.

Adaptive Management: A dynamic approach to water resource management that emphasizes flexibility and learning from outcomes to refine strategies over time. This method is particularly useful in addressing complex and changing environmental challenges.

By integrating these frameworks and defining key terms, the study establishes a robust foundation for exploring water management challenges in Godagari and Tanore, aiming to balance technical efficiency with socio-ecological considerations through active community involvement.

2.2 Challenges and Integrated Approaches in Water Resource Management in Bangladesh

With a focus on the socio-economic, environmental, and political complexities shaped by the Farakka Barrage's impact on the Char Ashariadaha region of Rajshahi, Md. Azizur Rahman's dissertation "Challenges and Issues of Water Management in Bangladesh: An Anthropological Study" offers a thorough examination of water management issues in Bangladesh through an anthropological lens. The report draws attention to important problems that worsen water shortages, agricultural decline, and socioeconomic instability, including transboundary water disputes, climate-induced water stress, and inadequate governance. In-depth interviews, participant observations, and key informant talks are among the anthropological techniques used in this study to examine how the Farakka Barrage's decreased water flow affects river-based livelihoods, necessitates occupational changes, and exacerbates socioeconomic disparities. In addition, the dissertation examines the institutional and stakeholder dynamics affecting water governance and assesses national and international water management policies, such as the Ganges Water Treaty of 1996. It demonstrates how local power systems impede sustainable water management through unequal resource distribution and political nepotism. The report urges policy reform and a multidisciplinary, participatory strategy including community stakeholders to guarantee socioeconomic resilience, environmental preservation, and fair water distribution in Bangladesh's water-scarce areas. This thorough research emphasizes how urgent it is to improve local government, settle international water-sharing conflicts, and implement integrated water resource management plans (Rahman, 2021).

The study "Development of a Decision Support System (DSS) for Integrated Water Resources Management in Bangladesh" emphasizes how important it is to have a DSS to handle the country's intricate water management issues, which are exacerbated by its dense population, monsoon climate, and river systems. Although it is crucial, national programs rarely use a nexus strategy to integrate water security with energy, climate, and agriculture policies. Although the Institute of Water Modeling (IWM) offers useful hydrological data, it is still difficult to turn this data into useful insights. The DSS's forecasting capabilities can be improved by using sophisticated predictive models, such as coupled river-coast flood models and machine learning-based flood risk assessments. Incorporating green infrastructure into urban water management can help control runoff and lower climate concerns. Participatory decision-making and community involvement are essential to sustainable water management. There are still several important gaps, though, such as utilizing cutting-edge technology like AI and remote sensing, combining local knowledge, enhancing climate adaption models, and integrating nexus concepts. The DSS will be more effective if these gaps are filled by empirical research, participatory frameworks, and technical advancements, promoting climate resilience and sustainable water management in Bangladesh (Zaman, Rahman, & Khan, 2009).

A.H.M. Kausher's paper "Water Resources Management in Bangladesh: Past, Present and Future" offers a thorough historical analysis of water management techniques in Bangladesh that span the ancient, medieval, colonial, and contemporary eras. It emphasizes early inventions like tank systems and overflow irrigation, which developed into state-run water management during British domination and then into participatory methods following independence. Large-scale drainage and flood control projects, groundwater irrigation, and integrated water resources management (IWRM) are examples of contemporary water management activities. The government's emphasis on sustainable practices, stakeholder involvement, and socio-environmental assessments is reflected in the development of policies such as the National Water Policy (1999), National Water Management Plan (2004), and participatory water management guidelines. Floods, droughts, riverbank erosion, water pollution, and arsenic contamination are some of the current issues brought on by climate change. The necessity of resilient, adaptive management that incorporates interagency collaboration, community involvement, and climate adaption is emphasized in the article. It ends by highlighting the Bangladesh Delta Plan 2100's future priorities, which include climate resilience, water governance, and the efficient use of scarce water resources through technological innovation and democratic decision-making (Kausher, 2017).

In their 2013 study "Integrated Water Resource Management for Mega City: A Case Study of Dhaka City, Bangladesh," Nasir Hossain and Khalid Md. Bahauddin critically analyzes the city's growing water scarcity issues, which are fueled by population development, urbanization, and poor infrastructure. Despite Dhaka's physical advantages—ample rainfall and proximity to important rivers—unsustainable groundwater exploitation, pollution, and a lack of infrastructure cause the city's water supply to fall short of demand. The study highlights how important Integrated Water Resource Management (IWRM) is to solving the interconnected problems of flooding, pollution, water scarcity, and governance. It suggests rainwater collection, wastewater reuse, groundwater and surface water use balance, efficient pricing, and strict adherence to pollution control regulations. Better governance, stakeholder participation, and decentralization are among the institutional improvements that are emphasized as being essential to the implementation of IWRM. To improve water management capability, the writers also emphasize the necessity of public awareness and human resource development. Socioeconomic, biophysical, institutional, and water quality issues are identified as critical for sustainable management in the research's conceptual framework for IWRM. The paper envisions IWRM as a catalyst for socio-economic development and environmental sustainability in Dhaka by integrating alternative water supply options and enhancing resource efficiency. It suggests that other densely populated megacities facing comparable challenges could also benefit from this approach (Agarwal et al., 2000).

With an emphasis on the relationship between water resources, governance, and livelihoods, Matthew Chadwick and Anjan Datta's work, "Water Resource Management in Bangladesh: A Policy Review," explores the development of water management policies in Bangladesh. With a focus on the transition from agricultural water usage dominance to multi-sectoral considerations, the study charts the historical trajectory from pre-independence infrastructure initiatives to modern tactics. Early initiatives, such as the East Pakistan Water and Power Development Authority, prioritized irrigation, drainage, and flood control, frequently utilizing extensive engineering solutions. However, calls for reform were sparked by the shortcomings of these structural techniques, such as maintenance issues and their effects on the environment and society. The National Water Plan (NWP) and its successor, the National Water Policy (NWPo), are reviewed in this study. Both emphasize integrated water management, sustainability, and participatory techniques. In addition to addressing inter-sectoral disputes and promoting equitable water access, especially for marginalized communities, policies like the 1999 NWPo seek to strike a balance between ecological conservation and economic development. One of the major turning points was the Flood Action Plan (FAP), which brought Bangladesh's flood problems to the attention of the world but was criticized for being implemented in a top-down manner. The study also examines the institutional environment, highlighting the functions of institutions such as the Water Resources Planning Organization (WARPO) and the Bangladesh Water Development Board (BWDB). It points out areas where policies are not being implemented effectively, like inadequate community involvement and conflicting jurisdictional duties. The study envisions a more inclusive and cohesive policy framework by coordinating water resource management with national objectives such as food security and poverty reduction. It emphasizes, therefore, that accomplishing these calls for removing long-standing institutional obstacles, maintaining policy coherence, and encouraging a culture of local participation in decision-making. Although great progress has been made, the assessment believes that ongoing reforms, stakeholder involvement, and tackling new issues including water shortage and climate change are necessary for sustainable water management in Bangladesh (Chadwick & Datta, 2003).

Mohammad Rafiul Azam Khan's study, "Sustainability Management for Groundwater Irrigation in the Barind Tract of Bangladesh", examines the sustainability of groundwater (GW) irrigation in the Barind Tract of Bangladesh. In the context of decreasing surface water availability and GW levels, this PhD thesis assesses GW management strategies in an area that mostly relies on irrigation for the production of boro rice. The study uses both qualitative and quantitative techniques, such as focus groups, key informant interviews, and surveys, to learn about farmers' perspectives and the functions of governmental organizations findings include a lack of knowledge of irrigation efficiency strategies such as Alternate Wetting and Drying (AWD), high GW extraction caused by traditional boro farming, and a lack of institutional coordination and law enforcement. According to the report, stronger governance, enhanced irrigation infrastructure, and artificial recharge are essential tactics for attaining sustainability. To guarantee fair and sustainable use of water resources in the Barind Tract, it emphasizes the necessity of an Integrated Water Resources Management (IWRM) strategy that incorporates multi-stakeholder participation, regulatory changes, and farmer education (Khan, 2021).

Muhammad Badrul Hasan and Gazi Alif Laila's study, "Investigating the Potential of the Community Management Plus Model for Governing Community Drinking Water Systems in Barind Tract of Bangladesh: A Case Study of Deep Tube-Well Water Supply Installations," examines how well the Community Management Plus (CM+) model works to oversee community drinking water systems in Bangladesh's drought-prone Barind Tract. The study tackles the ongoing problem of a shortage of clean drinking water, which is made worse by groundwater depletion, climate change, and poor water system governance. With a focus on enabling conditions for the implementation of the CM+ model, the research assesses factors influencing user collective action and collaboration with public agencies through a case study of Deep Tube-Well Water Supply Installations (DTWSI). Through the use of surveys, interviews, and stakeholder workshops, the study pinpoints important elements that are essential to encouraging collective action, including small group size, interdependency, affordability, willingness to pay, locally designed regulations, and public agency assistance. Additionally, it emphasizes how important trust, openness, dedication, and participatory decision-making are to successful cooperation between community members and organizations such as the Barind Multipurpose Development Authority (BMDA). The results show how crucial local participation and integrated governance frameworks are to the long-term management of community drinking water systems. To improve water governance in areas with limited resources, the study ends by suggesting legislative changes, increased institutional capability, and increased stakeholder involvement (M. B. Hasan & Laila, 2023).

M. Shahjahan Mondal in his research article titled "Groundwater Resources in the Hard-to-Reach Areas of Bangladesh: Constraints for Drinking Water Supply and Strategies for Sustainable Use" examines the difficulties and possible solutions for managing groundwater resources in Bangladesh's remote and socioeconomically underdeveloped areas. The study examines a variety of physiographic environments, such as hills, the Barind Tract, haors, chars, and coastal regions. Each of these environments has its own set of groundwater problems, including over-extraction, iron, manganese, salinity, and arsenic poisoning. The study emphasizes the physical and chemical limitations influencing groundwater accessibility and sustainability by using a thorough analysis of secondary data and primary analyses of groundwater quality, recharge rates, and usage. It demonstrates that although groundwater recharge is not a major problem in the majority of areas, quality degradation—caused by elements such as microbiological pollution, arsenic, and saline intrusion—poses a serious risk to the supply of safe drinking water. Evidence of groundwater mining worsens resource depletion in some places, such as the Barind Tract and some mountainous areas, underscoring the necessity of regulatory action. The study also evaluates the sustainability and efficacy of current water supply systems and mitigation techniques, such as managed aquifer recharge, desalination, piped water supply, and rainwater collection. It emphasizes the significance of an integrated management strategy that incorporates strong institutional frameworks, stakeholder participation, local water-use practices, and policy coherence. To guarantee fair and sustainable access to groundwater resources in these remote locations, the study ultimately promotes adaptive governance, strict monitoring, and the development of varied and context-specific water solutions (Mondal, 2015).

Chapter 3. Study Area Profile: Tanore and Godagari Upazilas in Rajshahi

This chapter provides an overview of the geographical, environmental, and socio-economic conditions in Tanore and Godagari upazilas in Rajshahi Division, Bangladesh. It highlights the region's climate, water scarcity, and the challenges posed by groundwater depletion, which impact agricultural productivity. The chapter also discusses existing water management practices, such as the re-excavation of beels, and the adoption of climate-resilient farming techniques to cope with droughts. Additionally, it covers the role of government and NGO support in promoting sustainable agriculture and water management strategies in the region.

3.1 Geographical and Environmental Context

3.1.1 Location and Geographical Features:

- Godagari: Godagari is located in the Rajshahi Division of Bangladesh, covering 475.26 square kilometers. It is situated between latitudes 24°21' and 24°36' N and longitudes 88°17' and 88°33' E, with the Padma River to the south and neighboring upazilas, including Tanore, to the north.
- Tanore: Spanning 295.40 square kilometers, Tanore is located between latitudes 24°29' and 24°43' N and longitudes 88°24' and 88°38' E. It is bordered by Niamatpur and Manda Upazilas in the north and Godagari and Paba Upazilas in the south (Shahrear, Al Amin, Waliullah, Hasan, & Hasan).

3.1.2 Climate and Rainfall Patterns:

Both upazilas experience a tropical climate with high temperatures ranging from 8°C to 44°C. The average annual rainfall is between 1250 mm and 2000 mm, which is below the national average for Bangladesh. Rainfall is concentrated in the monsoon months of June to October, leaving the region vulnerable to drought during the dry season, as less than 20% of rainfall occurs outside this period (Haque & Hossain; M. R. Hasan, Nuruzzaman, & Mamun, 2019).

3.2 Hydrological Conditions:

The region lies within the Barind Tract, an area characterized by a shallow aquifer system, where groundwater levels have been declining due to over-exploitation for irrigation. Groundwater extraction through deep tube wells (DTWs) is the primary method of irrigation, but the aquifer's capacity is limited, and natural recharge is insufficient, exacerbating the region's vulnerability to drought(A. Islam, 2020).

3.3 Demographics and Socio-Economic Overview

3.3.1 Population Characteristics:

- **Godagari**: With a population of 330,924 (166,260 males and 164,664 females), Godagari has a population density of 696 persons per square kilometer. It is divided into 9 unions, 316 mauzas, and 396 villages, with an average household size of 4.57 persons.
- **Tanore**: Tanore has a population of 191,330 (94,041 males and 97,289 females), with a population density of 648 persons per square kilometer. The upazila consists of 7 unions, 157 mauzas, and 169 villages, with an average household size of 4.03 persons. (Person & Rahman)

3.3.2 Education and Literacy Rates:

- **Godagari**: The literacy rate is 46.3% overall, with 46% for males and 46.6% for females.
- **Tanore**: The literacy rate in Tanore is 48.8% overall, with 51.1% for males and 46.7% for females. The literacy levels in both upazilas indicate a significant need for educational development, particularly in rural areas. (Person & Rahman)

3.4 Agricultural Practices and Economy

Agriculture is the backbone of both upazilas' economies, with paddy, wheat, jute, sugarcane, turmeric, oilseeds, onions, garlic, and fruits such as mango, jackfruit, and banana being the primary crops. However, several traditional crops like linseed, sesame, and mustard have become nearly extinct. The region's agricultural economy is heavily reliant on water resources, and any disruption to these resources directly impacts livelihoods.

3.5 Drought Vulnerability and Water Scarcity

3.5.1 Frequency and Impact of Droughts

The region experiences frequent droughts, including both meteorological and agricultural droughts, with significant hydrological droughts occurring in 1972, 1975, 1979, 1982, 1986, 1989, 1992, 1994, 2003, 2005, 2009, and 2010. These droughts cause widespread crop failures, especially in dry seasons when rainfall is minimal, leading to severe economic consequences for the predominantly agrarian population.

3.5.2 Groundwater Depletion

Over-exploitation of groundwater is a major concern in the Barind Tract. The region's reliance on deep tube wells (DTWs) for irrigation has caused the groundwater table to drop significantly. Between 2005 and 2022, the groundwater level in Tanore declined by 8 meters. The shallow aquifer is unable to naturally recharge due to the thick clay layer that impedes infiltration, further exacerbating the issue.

3.6 Water Management and Irrigation Dependency

Both upazilas depend heavily on groundwater for irrigation, especially during the dry season when surface water is scarce. The Barind Multipurpose Development Authority (BMDA) has been instrumental in installing over 15,000 deep tube wells to support agricultural irrigation. However, the overuse of these water resources has resulted in an unsustainable rate of groundwater depletion.

3.7 Coping Mechanisms and Mitigation Strategies

3.7.1 Groundwater Management and Irrigation Practices

Efforts have been made to optimize the use of groundwater by improving irrigation systems. The installation of deep tube wells and shallow tube wells by the BMDA has allowed farmers to irrigate crops and increase cropping intensity. However, the rapid depletion of groundwater calls for sustainable water management strategies, including limiting groundwater extraction and promoting water conservation.

3.7.2 Surface Water Conservation Initiatives

The re-excavation of beels (wetland areas) is an existing feature in Tanore and the surrounding upazilas, playing a vital role in improving surface water availability. Beel Kumari in Tanore, for example, serves as a natural reservoir that conserves rainwater and surface water during the monsoon, helping to reduce the region's reliance on groundwater. Similarly, beels like Jobai Beel and Hugla Damas Beel are integral parts of the local water management system, contributing to water storage and supporting agricultural activities, particularly during the dry season. These wetlands are essential in maintaining a sustainable water supply for the area.

3.7.3 Climate-Resilient Agricultural Practices

In response to recurring droughts, farmers are adopting more drought-resistant crops such as maize, pulses, and oilseeds, while continuing to cultivate rice, which remains the mainstay crop. Government and NGO programs promote the use of water-efficient irrigation techniques, soil conservation practices, and crop diversification to reduce the region’s vulnerability to droughts.

3.7.4 Government and NGO Support

Both government and non-government organizations have been involved in providing support to local farmers, especially during drought years. This includes providing access to improved irrigation systems, crop insurance, and climate-resilient agricultural techniques. Such efforts aim to strengthen the region's resilience to climate variability and water scarcity.

Tanore and Godagari Upazilas in Rajshahi are among the most drought-prone areas in Bangladesh. The combined challenges of frequent droughts, declining groundwater levels, and over-dependence on irrigation have put immense pressure on the region’s agricultural productivity. While significant efforts are being made to address water scarcity through surface water conservation, better groundwater management, and climate-resilient farming practices, the region requires continued intervention to ensure sustainable water use and agricultural practices. The future of Tanore and Godagari's agriculture depends on comprehensive and adaptive strategies to manage water resources, promote efficient irrigation, and enhance climate resilience to secure the livelihoods of their population.

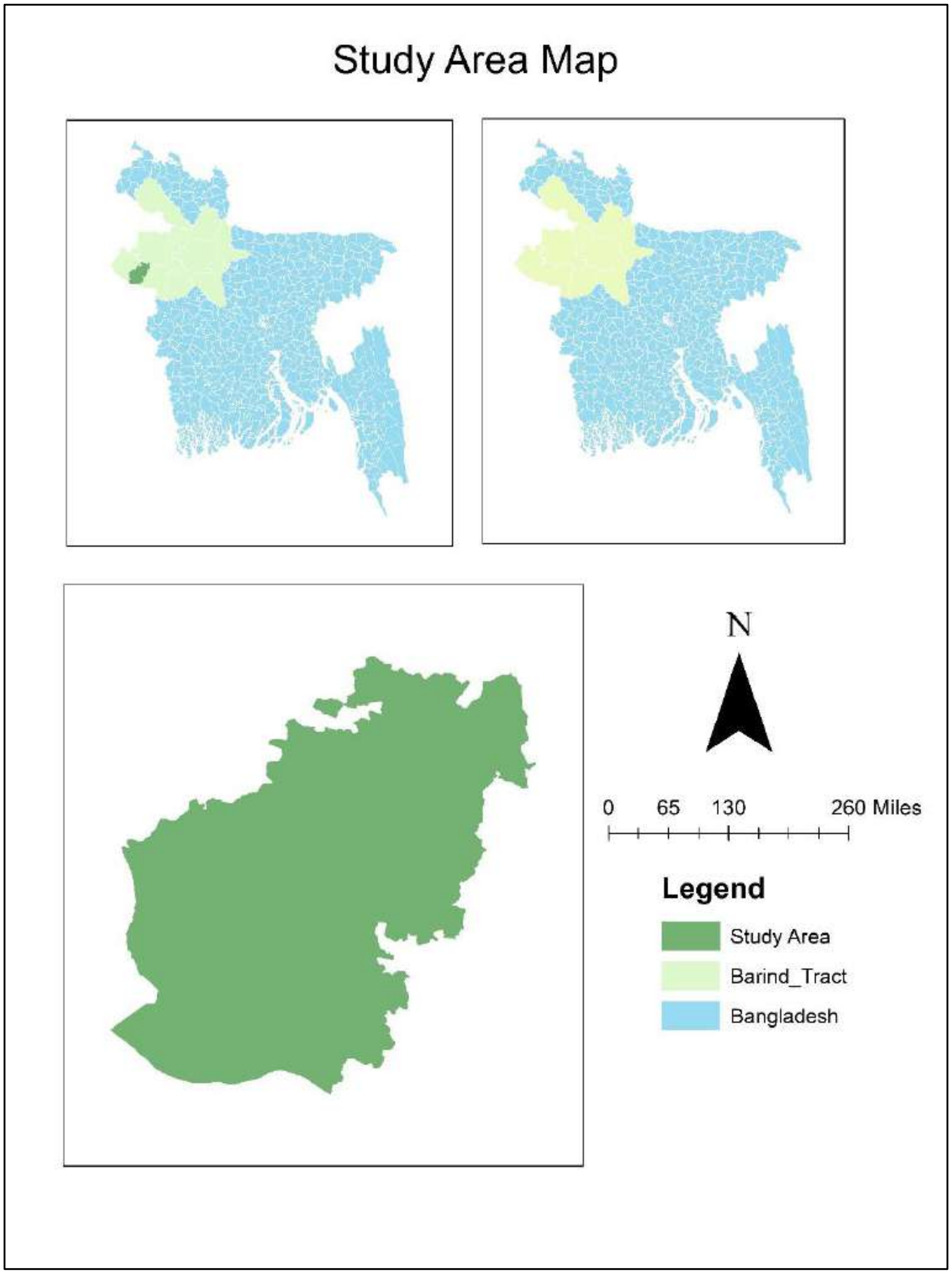


Figure 1: Study Area Map

Source: Prepared by Authors, 2024

Chapter 4. Methodology of the Study

The methodology used in this study is specifically tailored to address the challenges and possibilities of community-based water resource management in the Barind Tract region. It takes a comprehensive and inclusive approach, integrating geospatial analysis and local engagement, to guarantee that the offered solutions are not only technically solid but also socially acceptable. The process consists of various primary components: preliminary assessment both with in situ visit and with remote sensing technology, community engagement, and stakeholder consultation, survey, literature review and data collection, exploration of alternative water sources, data analysis, and synthesis.

4.1 Problem Identification

In the Barind tract area, water scarcity is getting higher. The Barind Tract receives low rainfall, averaging around 1,200–1,500 mm annually, with most of it occurring during the monsoon season. Changing rainfall patterns due to climate change have worsened the situation, with longer dry periods and reduced monsoon intensity. This research aims to investigate the main driving factor of water scarcity in the Barind tract, analyze the existing watershed management practices, and propose sustainable solutions tailored to the region's socio-economic and environmental needs. This study focuses on watershed management problems and methods to manage the available wetlands.

4.2 Defining Study Area and Objective

To fulfill this research's aim, Godagari and Tanore are selected for research purposes to analyze the watershed management of the barind tract and the objective is formulated to mitigate the problem of the existing area.

4.3 Data Collection

For data collection, primary data is collected by physical survey and PRA tools. The secondary data is collected from research articles. A group of people are selected as participants for Focus Group Discussion in both of our study areas. They drew the map and diagrams according to their willingness, perception, and needs. The PRA tools such as Focus group discussion, Key Informant Information (KII), Semi-structured Interview (SSI), Ven diagram, Seasonal Diagram, spider web Diagram, and TimeLine are used for collecting the data from the participants through their active participation. Each tool is used for certain purposes. The purposes of using tools that are used for this study are given below and reporting and recommendations. Each of these stages is discussed in depth below.

4.3.1 Identifying Change in Surface Waterbody Over the Years

The methodology for this study begins with identifying existing surface water bodies using remote sensing techniques, a critical step to understanding water resource distribution and availability in the study area. To achieve this, satellite imagery is processed and analyzed using supervised classification methods, with an application of the Maximum Likelihood Classification (MLC) technique. This approach ensures accurate identification and classification of various land cover types, including water bodies, vegetation, bare land, and built-up areas, based on spectral signatures.

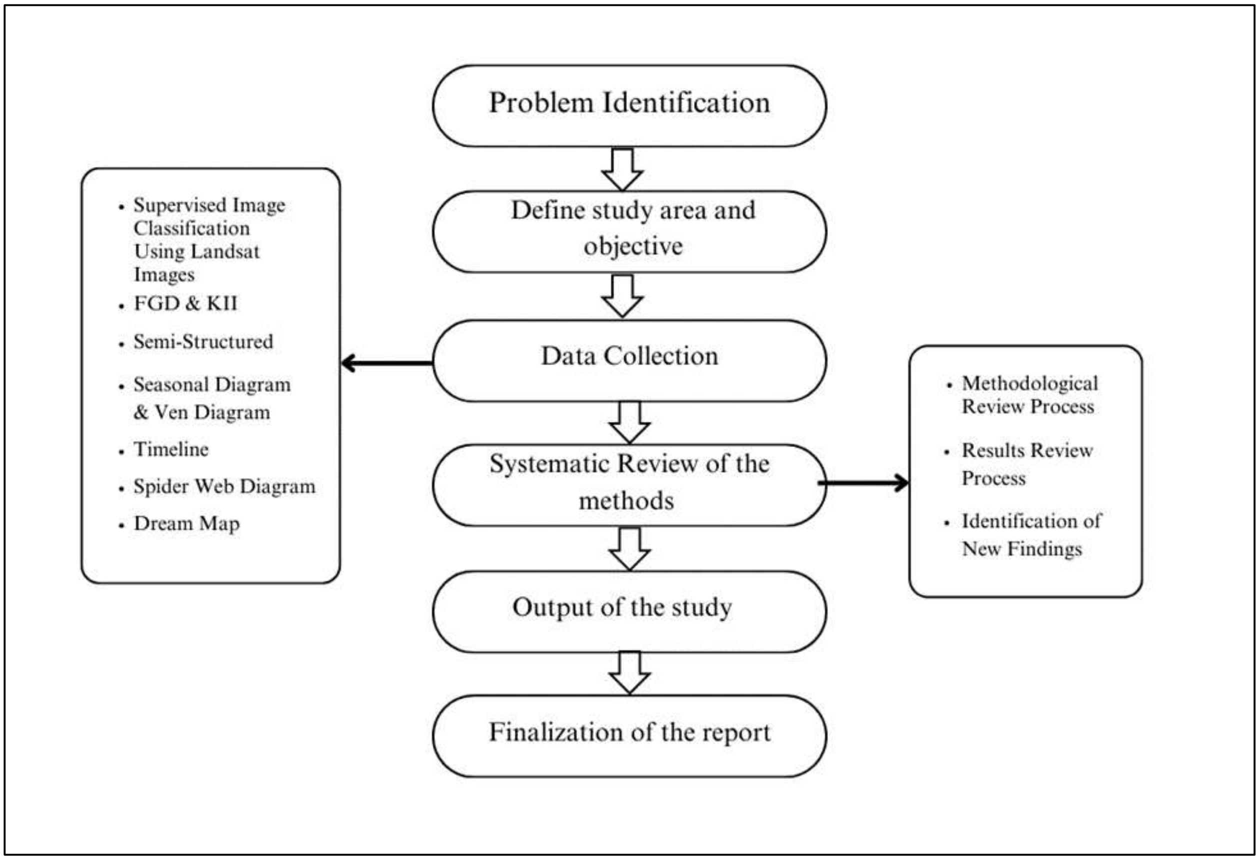


Figure 2: The whole methodological framework of this research

4.3.2 Remote Sensing and Supervised Classification

The method begins with acquiring a Landsat image from the USGS Earth Explorer. These images, captured during cloud-free periods, contain the spectral bands required for land classification. The study uses supervised classification approaches to train the classification model on ground truth data. Field surveys are used to acquire ground truth data, which involves identifying and recording specific land cover categories using GPS coordinates. This data is used as a reference for understanding spectral properties in satellite imagery.

The Maximum Likelihood Classification (MLC) strategy was used since it is one of the most dependable supervised classification methods. MLC assumes that the data for each class in each band follows a normal distribution and calculates the probability that a given pixel belongs to that class. Each pixel is subsequently assigned to the class with the highest probability, resulting in extremely accurate land cover classification. This technology allows for the precise mapping of various land cover types, such as forests, urban areas, and bodies of water, using their distinct spectral signatures. Researchers and policymakers can make more informed decisions about land use planning, environmental conservation, and natural resource management if they can correctly identify and categorize land cover types. Overall, using MLC in conjunction with GPS data is an effective method for assessing and comprehending land cover patterns and changes over time.

4.3.3 Initial Classification of Land Cover

Upon completion of the classification model training, the satellite imagery is analyzed to categorize the research area into four primary land cover types: build-up area, vegetation, bare land, and water body. This preliminary classification offers a comprehensive understanding of land cover distribution and assists in assessing the spatial extent of surface water resources. The classification process allocates pixels to one of four categories based on their spectral reflectance values.

Particular emphasis is placed on differentiating water bodies from other land cover classifications. Water bodies generally display low reflectance in the near-infrared (NIR) spectrum and elevated reflectivity in the visible blue spectrum. The distinctive spectral properties are employed to precisely identify and categorize aquatic environments.

4.3.4 Reclassification for Water Body Analysis

After the preliminary categorization, the land cover data undergoes reclassification to concentrate exclusively on surface water bodies. The four land cover categories are consolidated into two classes: "Water Body" and "Others." This reclassification streamlines the analysis by segregating water bodies from other land cover types. The reclassified data is subsequently checked against the ground truth data to verify precision. Validation measures, including the kappa coefficient and overall accuracy, are computed to evaluate the dependability of the classification. These measures assess the degree of alignment between the reclassified data and the real water bodies present on the ground. The kappa coefficient quantifies the concordance between classified data and ground truth, whereas total accuracy offers a comprehensive evaluation of classification precision. By validating the classed data, researchers may ensure the precision of their study and make educated judgments based on the findings. This stage is essential for guaranteeing the reliability and validity of the land cover classification for subsequent studies and applications.

4.3.5 GIS Integration and Analysis

A Geographic Information System (GIS) is used to incorporate the classified data for additional spatial analysis. The water bodies are mapped and quantified using GIS, providing a geographical overview of their extent and distribution. Finding the overall area covered by bodies of water, determining their connectedness, and gauging their proximity to populated areas and farmland are all part of this process. Surface water resource accessibility and availability can be better planned for with the help of GIS analysis, which is crucial for community water management. Policymakers can safeguard water sources from pollution and guarantee that all citizens have access to safe drinking water by gaining a better grasp of the geographical connections between bodies of water and human settlements. In addition, GIS is used to pinpoint the exact locations that require water management interventions like infrastructure development or restoration of watersheds the most. In sum, the study area's water resource management can be better planned and executed with the use of reclassified data.

4.4 Preliminary Assessment

The study proceeded with a thorough preliminary evaluation after the study area was remotely sensed to set a baseline for understanding the water resource difficulties in the Barind Tract, particularly in the Godagari and Tanore regions of Rajshahi. The procedure begins with a thorough literature review. Water resource management in regions prone to drought is the focus of this literature review, which aims to compile significant studies, theories, and research on the subject. This review focuses on studies that shed light on community-based water management strategies, but it also includes studies from around the world. Recent research has focused on hydrological stress, the societal and economic effects of water shortage, and the efficacy of current water management strategies. Academic journals indexed by Scopus and Web of Science, government papers, non-governmental organization (NGO) reports, and case studies from comparable ecological environments make up the review's sources.

The literature review places heavy emphasis on investigating under-documented traditional water-saving practices that may be common in the area. To further comprehend the study area's specific needs, this study also examines the policies and initiatives that international organizations and the government of Bangladesh have launched. Using secondary data from credible sources including the Barind Multipurpose Development Authority (BMDA), local government offices, and non-governmental organizations (NGOs), a baseline assessment is also carried out alongside the literature study.

4.5 Systematic Literature Review and Comparative Analysis

The study examines successful water management initiatives in regions with similar climatic and socio-economic conditions. These case studies are used to identify best practices, innovative approaches, and lessons that can be adapted to the Barind Tract. Emphasis is placed on solutions that are cost-effective, scalable, and environmentally sustainable. A key component of the methodology is the systematic review of existing literature and case studies, which provides a comprehensive understanding of potential water resource management solutions and their applicability to the Barind Tract. This approach involves an in-depth examination of peer-reviewed journal articles, technical reports, policy documents, and case studies from both regional and global contexts. The systematic review is structured around clearly defined research questions aimed at identifying effective strategies for water resource management in arid and semi-arid regions. These questions focus on identifying innovative approaches to water conservation, alternative sources of water, sustainable extraction methods, and community-based management practices.

To ensure thoroughness, the review uses explicit inclusion and exclusion criteria. Priority is given to studies that address regions with similar climatic and socio-economic conditions as the Barind Tract, such as those characterized by seasonal rainfall variability, high dependence on agriculture, and limited water availability. Studies documenting successful interventions, challenges encountered, and long-term impacts are particularly emphasized to draw meaningful insights. The review process also includes a critical appraisal of the methodologies and findings of the selected studies. Factors such as sample size, data reliability, and replicability of results are considered to assess the quality and applicability of the research. Additionally, attention is given to innovative technologies, traditional water management practices, and community-driven approaches that have demonstrated success in similar settings.

By synthesizing the findings, the systematic review highlights key themes and best practices relevant to the Barind Tract. These include insights into the scalability of different interventions, their cost-effectiveness, and the socio-cultural factors influencing their adoption. The review also identifies gaps in the existing literature and areas where further research is needed, guiding the study's subsequent stages.

4.5.1 Methodological Review Process

The design of the study, the methods for gathering and analyzing data, and the theoretical frameworks used were the main topics of the methodological review. Research design types like field studies, case study approaches, and participatory research were specifically mentioned in the papers that were reviewed. Where appropriate, sampling methods like simple sampling, random sampling, or census-based research were highlighted. Alongside data analysis methods like statistical modeling, financial benchmarking, and thematic analysis, data collection methods like surveys, interviews, focus groups, and document reviews were noted. This stage made sure that the methodological procedures were appropriately documented and placed in context.

4.5.2 Results Review Process

Based on the scientific data presented, the main conclusions from each paper were extracted for the results section review. The findings were divided into main themes, including the effectiveness of water resource management, system operation, governance difficulties, and social dynamics in community-based models. Common problems, like the sustainability of water systems and the function of local governance, were discovered through comparative analysis across various studies. To deepen the analysis, quantitative information was incorporated where it was available, such as system functionality rates or financial sustainability indicators.

4.5.3 Identification of New Findings

Finding contributions that increased knowledge in the field of study was the main focus of the extraction of new findings. This included critiques of long-standing paradigms like the Community-Based Management (CBM) model, new frameworks for climate adaptation, and advancements in community-based management models. Highlighted were studies that offered innovative solutions such as hybrid models combining community and state involvement, decentralized management structures, and rainwater harvesting integration

4.6 Community Engagement and Stakeholder Consultation

To ensure that the study reflects the perspectives and needs of the local population, community engagement is prioritized. The participatory approach includes both qualitative and quantitative techniques designed to capture the lived experiences and knowledge of the community. The first step in community engagement is organizing Focus Group Discussions (FGDs) with different demographic groups, such as farmers, women, and youth. FGDs serve as a platform to explore localized water management practices, community perceptions of water scarcity, and the socio-economic impacts of drought. These discussions also highlight gender-specific challenges, such as the additional burden placed on women in securing water for household needs.

4.6.1 Focus Group Discussion (FGD)

The aim of the FGD primarily focuses on understanding how local communities experience and manage water availability, quality, and access. Participant's insights into the challenges they face with water management in daily life, especially in the context of agriculture, which is the dominant livelihood in the Barind Tract is extracted through FGD. The FGD also allows us to assess the awareness of climate change impacts on water resources and explore alternative strategies for better water governance, such as rainwater harvesting, efficient irrigation methods, and community-based management.

4.6.1.1 Participant Demographic Structure of FGD

The participants in the FGD should be carefully selected to represent a cross-section of the community to gather diverse opinions on water management. This will ensure that all stakeholders, including those who are directly impacted by water scarcity and those responsible for policy and governance, are included.

Farmers and agricultural workers in the Barind Tract are the primary water users, as the region's agriculture relies heavily on irrigation systems. These participants, aged between 25 to 65 years, will bring first-hand knowledge about the challenges they face in obtaining water for crops. They can provide insights into the seasonal variations in water availability, the types of irrigation systems they use, and the impacts of water scarcity on their livelihoods. It's also essential to include both male and female farmers and workers, as women often play a critical role in managing water within the household and performing agriculture-related tasks, particularly in irrigation and post-harvest activities. Women, especially in rural settings, also take on the responsibility for water collection for domestic use.

Community leaders and local government representatives, aged between 30 to 60 years, play a key role in overseeing water distribution and the implementation of water-related policies. Their insights into the governance and institutional frameworks for managing water in the region will be crucial. These participants can offer information on local policies, regulations, and the extent of government intervention in water management. Furthermore, they can shed light on community-driven efforts to improve water conservation and distribution, as well as the level of support or resources available for implementing water management practices. Their presence ensures that the discussions are framed within the context of local governance and policymaking.

Women in rural communities are often responsible for collecting water for household use, making them key players in water management at the domestic level. Including women aged 25 to 55 years in the FGD is critical for understanding the impact of water scarcity on domestic life, including the time spent fetching water, the quality of water available for cooking, cleaning, and drinking, and the strategies they employ to cope with water shortages. Women also play a crucial role in agricultural practices, often contributing to crop management and food security. Gathering their perspectives will ensure that the discussion addresses gender-specific challenges and that solutions consider the broader social dynamics of water use.

Including youth participants, aged 18 to 30 years, will allow the FGD to capture a forward-looking perspective on water management. Young people are often more receptive to new ideas, technologies, and innovations that can contribute to solving water-related challenges. They may have ideas about new technologies, such as digital water management systems, or ways to adapt to changing climatic conditions. Additionally, youth will be able to discuss the future impacts of water scarcity on their lives and the livelihoods of the next generation. Their involvement ensures that the conversation addresses long-term solutions and considers the perspectives of future water resource users.

Local business owners, particularly those involved in industries that rely on water, such as small-scale manufacturing or brick kilns, can provide important insights into how water scarcity affects local businesses. This group of participants, typically aged between 30 to 55 years, will help identify how water availability impacts the local economy and livelihood beyond farming. They can also discuss the cost of water-related technologies or services and offer suggestions for how businesses and agriculture can collaborate in using water resources more efficiently.

Water management professionals, including planners, hydrologists, and representatives from NGOs or international organizations working on water issues, will bring technical expertise to the discussion. These participants, aged 35 to 60 years, can offer solutions based on their knowledge of water-saving technologies, such as drip irrigation, rainwater harvesting systems, and groundwater recharge techniques. They can also provide a broader view of the regional and national policy landscape, including water management projects and funding initiatives. Their expertise will be essential for proposing viable technical interventions and innovations to address water scarcity in the Barind Tract.

Elderly residents, aged 60 and above, possess invaluable historical knowledge about water availability and management practices in the region. They have witnessed changes in water availability over time, including shifts in rainfall patterns, changes in groundwater levels, and the evolution of local water management systems. Including older participants will ensure that traditional water management practices, which may have been effective in the past, are taken into account. Their long-term perspective can also inform discussions about how water management has changed in the context of environmental and socio-economic shifts.

4.6.1.2 Key Discussion Themes of FGD

The FGD should focus on several key themes to ensure that diverse perspectives are gathered:

Water Availability and Access: Participants will discuss the availability of water from different sources (e.g., groundwater, surface water, rainwater) and challenges related to access. This includes seasonal fluctuations and the impact of water scarcity on both domestic and agricultural needs.

Water Quality and Contamination: This theme will address concerns related to the quality of available water sources, particularly concerning contamination, and health risks.

Current Water Management Practices: The group will discuss existing water management strategies, such as irrigation practices, water conservation methods, and community-level initiatives. This will help identify gaps in current practices and areas for improvement.

Impact of Climate Change: Participants will explore how changing weather patterns, including reduced rainfall and higher temperatures, are affecting water availability and what adaptive strategies can be implemented.

Alternative Water Management Solutions: The discussion will focus on potential solutions such as rainwater harvesting, efficient irrigation technologies (e.g., drip irrigation), water-efficient domestic practices, and community-led water management systems.

Social and Economic Impacts: The group will also explore the broader social and economic impacts of water scarcity, including its effects on livelihoods, gender roles, and community dynamics.

Policy and Governance: Finally, the FGD will discuss the role of local government, NGOs, and community organizations in water management. Participants will offer suggestions for better governance and policy reforms to support sustainable water practices.

In addition to FGDs, Key Informant Interviews (KIIs) are conducted with local leaders, elders, and long-term residents of the region. These interviews provide historical insights into the patterns of water availability and the evolution of water-related challenges over time. Local knowledge about traditional water management techniques, crop patterns, and climate change impacts is invaluable in designing sustainable interventions. Furthermore, stakeholder consultations are held with a broader range of actors, including local government officials, agricultural extension officers, and representatives from NGOs working in the area. These consultations focus on identifying barriers to effective water management, potential funding sources, and opportunities for collaboration. Stakeholders also provide feedback on the study's objectives, ensuring that the research aligns with local priorities.

4.6.2 Key Informant Interviews

Key informant interviews (KIIs) are a qualitative research method that includes several in-depth interviews with individuals who have expert knowledge or insights about a specific subject. This method is especially beneficial for the gathering of detailed information that can be used to inform policy development, program evaluation, and decision-making.

4.6.3 Venn Diagram & Seasonal Diagram

Seasonal diagrams are graphical representations that illustrate the seasonal patterns of data or events over a specific period, typically a year. These diagrams help visualize how certain phenomena vary with the seasons, making them useful in various fields such as economics, agriculture, and environmental studies.

To understand the connection among all the seasonal changes of residents' need usage and water resources this study visualizes the seasonal diagram in line diagram using Python. The code below will be used to visualize the water shortage, wetland usage, water availability, and happiness among the people for existing resource management. Ven Diagram is one of the commonly used Participatory methods to analyze the institutional relationships between different institutions

```
matplotlib.pyplot

months = ['JAN', 'FEB', 'MAR', 'APR', 'MAY', 'JUN', 'JUL', 'AUG', 'SEP', 'OCT', 'NOV', 'DEC']

wetland_usage = [2, 3, 4, 5, 5, 4, 3, 4, 5, 5, 4, 3]

water_shortage = [4, 3, 2, 2, 3, 3, 2, 3, 2, 1, 3, 2]

water_availability = [3, 3, 2, 1, 1, 3, 4, 1, 1, 1, 3, 3]

happiness = [5, 3, 3, 4, 4, 2, 1, 2, 2, 1, 3, 5]

fig, ax = plt.subplots(2, 2, figsize=(12, 8))

ax[0, 0].plot(months, wetland_usage, marker='o', color='blue', label='Wetland Usage')

ax[0, 0].set_title('Wetland Usage')

ax[0, 0].grid(alpha=0.5)

ax[0, 1].plot(months, water_shortage, marker='o', color='red', label='Water Shortage')

ax[0, 1].set_title('Water Shortage')

ax[0, 1].grid(alpha=0.5)

ax[1, 0].plot(months, water_availability, marker='o', color='green', label='Water Availability')

ax[1, 0].set_title('Water Availability')

ax[1, 0].grid(alpha=0.5)

ax[1, 1].plot(months, happiness, marker='o', color='purple', label='Happiness')

ax[1, 1].set_title('Community Happiness')

ax[1, 1].grid(alpha=0.5)

plt.tight_layout()

plt.show()
```

4.6.4 Spider Web Diagram

Spiderweb diagrams are effective tools for visualizing and comparing multivariate data. Their unique structure allows users to quickly grasp complex relationships between variables, making them valuable in various analytical contexts.

4.6.5 Semi-Structured Interview

A semi-structured interview is a qualitative research method that combines predetermined questions with the flexibility to explore topics in depth through open-ended dialogue. Serve as a versatile tool in qualitative research, enabling researchers to gather in-depth insights while maintaining a degree of structure.

4.6.6 Timeline

Timeline is an important PRA method quite commonly used to explore the temporal dimensions from a historical perspective. Timeline captures the chronology of events as recalled by local people. It is drawn as a sequential aggregate of past events.

4.6.7 Dream Map

A dream map is a visual representation of personal dreams, plans, and goals. It can cover various time frames, typically ranging from one year to several years.

4.7 Data Analysis and Synthesis

Qualitative data from FGDs and KIIs is analyzed using thematic coding techniques to extract recurring themes and patterns. These insights provide a deeper understanding of community perceptions and coping mechanisms. This integrated approach allows for a holistic assessment of the water resource challenges in the study area. After analyzing the data and systematic review the research will identify some key strategies beneficial for water resource management and to mitigate present time's impact.

4.8 Finalization of the Report

After successfully executing all the necessary steps, the final report is prepared.

4.9 Reporting and Recommendations

The final phase of the methodology focuses on compiling and presenting the findings in a manner that is actionable and accessible to stakeholders. A detailed report is prepared, documenting the current water resource scenario, challenges, and potential solutions. The report includes visual aids such as maps, charts, and graphs to ensure clarity and enhance understanding.

Recommendations are developed based on the study's findings, categorized into short-term, medium-term, and long-term strategies. Short-term recommendations include awareness campaigns on water conservation and hygiene, while medium-term strategies focus on community-led rainwater harvesting projects. Long-term recommendations involve policy-level changes, such as incentives for water-efficient irrigation practices and the establishment of a regional water management authority. To ensure that these recommendations are practical and locally relevant, a series of validation workshops is conducted with stakeholders and community members. Feedback from these workshops is incorporated into the final report, ensuring that the proposed solutions are aligned with the needs and priorities of the affected communities. The final report is then presented to local authorities, NGOs, and other stakeholders to foster collaboration and facilitate the implementation of the study's recommendation.

Chapter 5. Result & Discussion

5.1 Analyzing the Current Status of Godagari and Tanore Upazila

To acquire an extensive understanding of community-based water resource management, the first phase is to investigate the existing conditions of wetland management and the associated resources. Before Conducting the participatory approach, the change of wetlands over 10 years needs to be identified using supervised image classification. Supervised image classification is needed to analyze satellite imagery to identify changes in land cover over the decade.

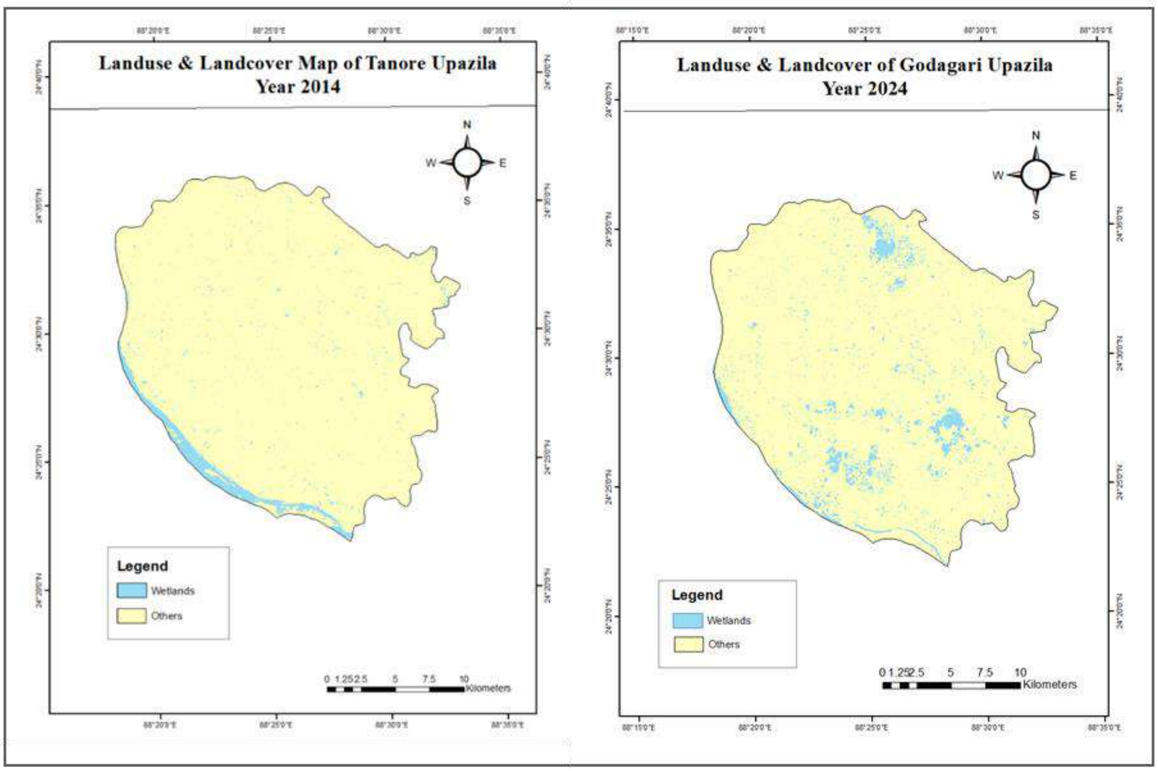


Figure 3: Waterbody Change of Godagari Upazila in 2014-2024

Source: Prepared by Authors, 2024

The above figure shows a significant change in land use and land cover in Godagari Upazila over a decade. The most prominent change showed in the main water body which decreased and many small canals were found throughout the area. This is due to both manmade and climatic changes. Increased temperature, and usage of the dam. This study figure shows the change within the Godagari upazila whereas in Tanore the scenario remains the same within wetland transformation. Here we can see that the main water body in Godagari upazila in 2014 was the bank of Padma River which over the decade decreased due to filling up char areas for housing, and fishing purposes. Over the decade many small Dug canals have been seen in the upazila in need of agriculture and household works. This Newly manmade canals are threat to the ecology as well as wetland management.

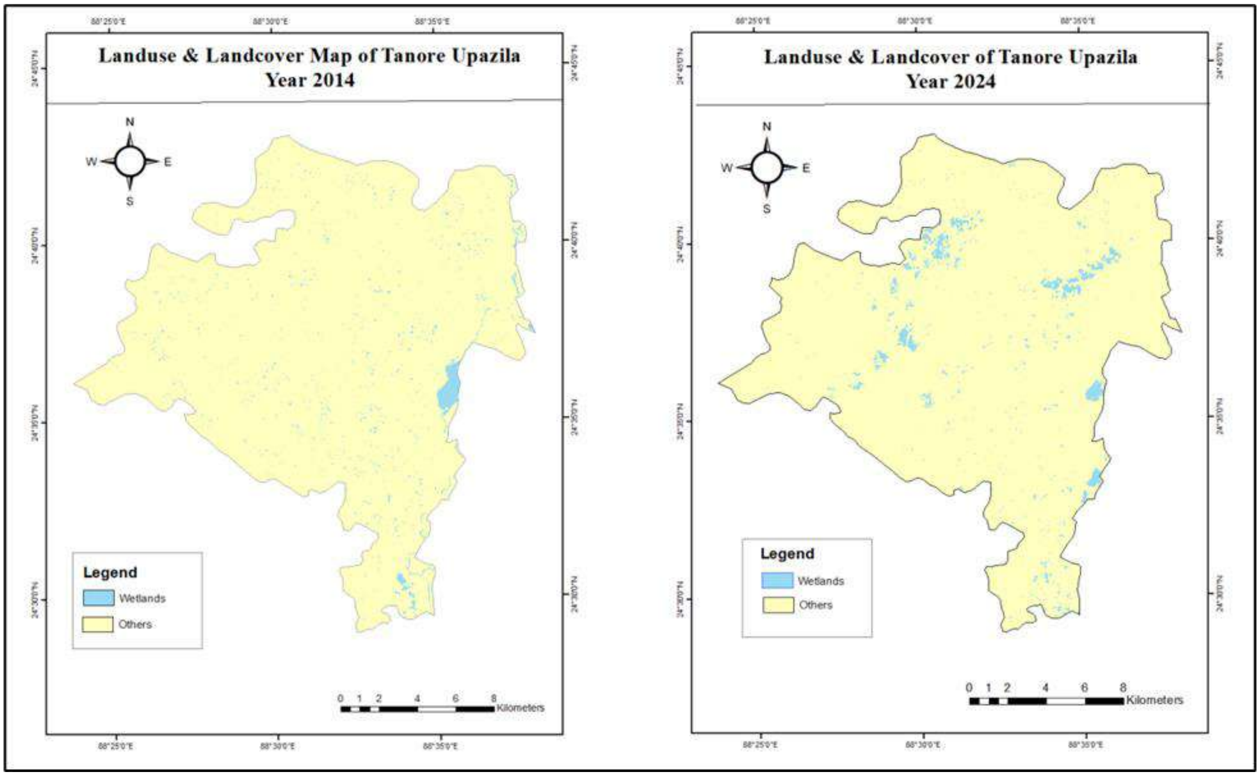


Figure 4: Waterbody Change of Tanore Upazila in 2014-2024

Source: Prepared by Authors, 2024

In 2014, The whole area had a huge wetland and many smaller natural wetlands in between. The total area's water management system depended upon the large wetland. The larger wetland named the Beel Kumari Beel has an area of 19,19,533.55 sq meters. Whereas, after a decade, the larger watershed tends to show a decline in its area. And many more small wetlands are risen. To understand the community perspective survey is being conducted to understand the local preference. The larger wetland named the Beel Kumari Beel has reduced its area to 6,69,049.1 sq meters.

There is a significant change in wetland expansion around the study area due to manmade canals and wetland conservation policies. These manmade canals are harmful as constructing canals often involves removing natural vegetation and altering landscapes, which can destroy habitats for various species. Diverting water for canals can deplete groundwater reserves in nearby areas which causes a drop in the water table. The flow of water in canals can erode their banks, leading to sedimentation downstream. Excess sediment can clog canals and affect their efficiency disturbing aquatic ecosystems.

To thoroughly identify the reason behind the change in land cover over the decade participatory appraisals are being used. To analyze the current status, this study claims a participatory approach involving the stakeholders of study area. In the current study, focus group discussion, Key Informant Information (KII), Semi structured Interview (SSI), Veen diagram, Seasonal Diagram, spider web Diagram, and TimeLine is being used to analyze the current status of both of the upazilas.

5.1.1 Focus Group Discussion and KII

Understanding the change in land use and land cover, a focus group discussion is being conducted among 8 participants, where participants provided valuable insights on the current situation of wetlands and water bodies, highlighting the changes that have occurred over time and their implications on rural livelihoods. Participants highlighted that water from wetlands and other natural water bodies continues to play an important role in supporting the community's requirements, particularly for farming activities and domestic tasks like washing, cleaning, and cooking. But they also witnessed a significant shift in how people use water in the last few years. More and more tube wells are being developed in rural areas. This makes obtaining groundwater easier and more reliable, reducing the community's dependency on water taken straight from natural bodies of water. Even though things have changed, some people continue to rely on sources of water for particular uses, like irrigation during the dry season or when tubewell water isn't enough.

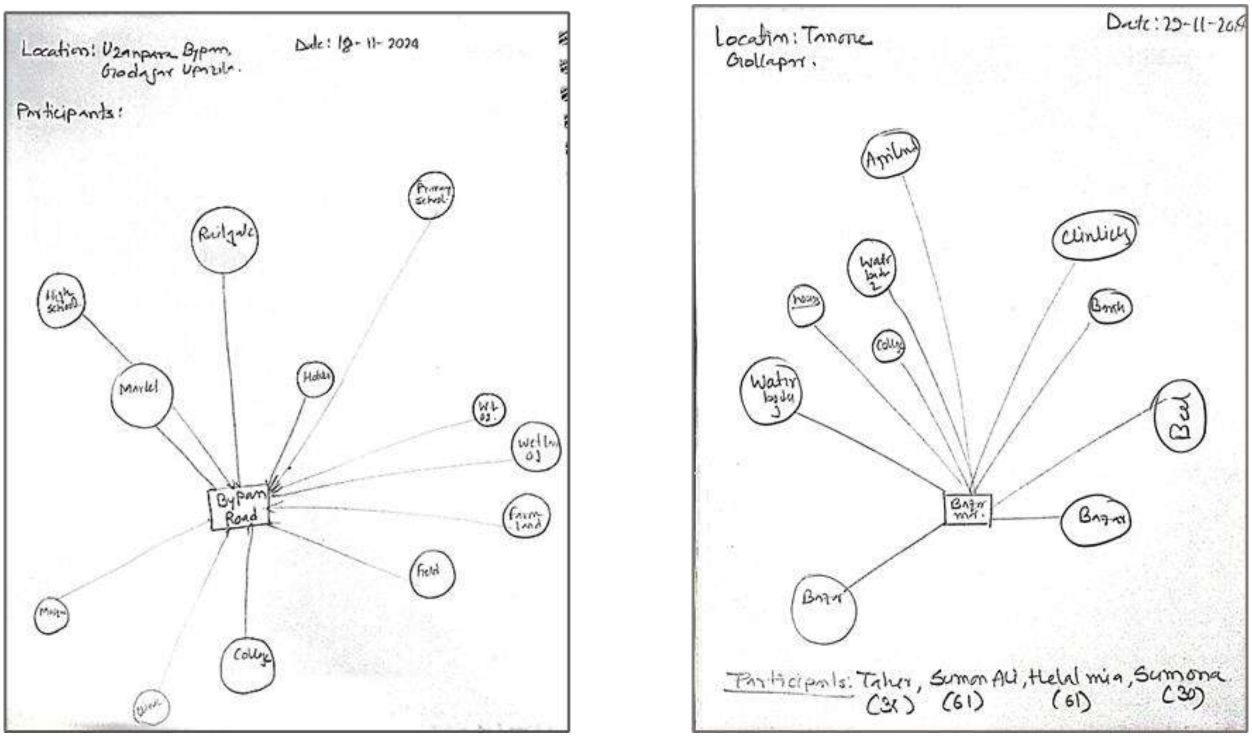
During the Key Informant Interview (KII) conducted at the BMDA (Barind Multipurpose Development Authority) office, officials provided insights into the current state of water resources and environmental challenges in Godagari and Tanore Upazilas of Rajshahi District, along with potential solutions. Both upazilas are facing severe water resource challenges, with Godagari witnessing a dramatic reduction in waterbodies as ponds and wetlands are filled for housing and agricultural expansion. This has disrupted natural groundwater recharge, leaving groundwater levels critically low. In Tanore, prolonged droughts and over-extraction of groundwater for irrigation have exacerbated the scarcity, further stressing agricultural productivity. In Godagari, improper drainage systems lead to seasonal waterlogging during the rainy season, while in Tanore, extreme drought conditions dominate due to insufficient water retention infrastructure.

5.1.2 Semi-Structured Interview

Semi-structured interview refers to a non-structural Interview system where the surveyor and participants do not significantly follow the structure of the questionnaire. This SII would be beneficial to deeply understand the problems of the stakeholder and participant outer the researcher’s mindset. This method is a conversation between the participants where open access to any questions and answers is taken into account. To overlay any hidden facts regarding wetland conservation, semi semi-structured interview was taken at Godagari Upazila after the focus group discussion. According to the participants, the low level of wetland is due to mismanagement of common pool resources in the area, as people have no restrictions or rules to access the resources. Another significant factor for lower usage of wetlands is due to governmental motors and tubewell in some villages for this the common resources are used for other purposes like fish harvesting etc. Another reason people not getting enough wetland services is due to the tendering process which creates a vacancy for public use of wetlands. Through the interview, one significant output was to acknowledge filling up water bodies to build homesteads and climate change output. Due to significant changes in the climate, the low-tier water level is seen as the usage of the dam around the Padma River.

5.1.3 Venn Diagram & Seasonal Diagram

In the Venn Diagram, the bigger size means the greater influence in the area. In our study area at Godagari, the center point is kept at Uzanpara, Godagari Bypass, and Gollapara bazar mor at Tanore where the other influential institution is nearby.



***Participants**: Samsun Nahar (42), Mofiz Uddin (34), Bashir Ahmed (49), Helal Mia (61), Julekha(32), Shanta (33)*

***Facilitators**: Mehjabin Jahangir Rafjin (23), Tanveer Hossain Rhine (23)*

Figure 5: Venn Diagram to Represent the Institutional Arrangement.

Source: Prepared by Authors, 2024

From the above Venn diagram, here we can see that around the wetlands there is no necessary agricultural or water development board to evaluate the usage of wetlands. The whole community does not have any water reserves water management strategies, or drainage along the side of the waterbodies. In rural areas, the dependency on these wetlands for household work is lesser than for agriculture work. The area has small clinics, school around which have a higher influence in Godagari in Tanore Bazar and Bans have a high influence., Rapid Urbanization in rural areas created the need of motor which is creating groundwater deficiency and improper management of common pool resources and wetlands. Hence, the dependency on wetlands is very low now due to dried-up canals and the tending of water bodies by local authorities.

Table 2: Seasonal Diagram

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Wetland Usage	2	3	4	5	5	4	3	4	5	5	4	3
Water shortage	4	3	2	2	3	3	2	3	2	1	3	2
Water Availability	3	3	2	1	1	3	4	1	1	1	3	3
Happiness	5	3	3	4	4	2	1	2	2	1	3	5

Source: Prepared by Authors, 2024

Participants: Samsun Nahar (42), Mofiz Uddin (34), Bashir Ahmed (49), Lutfar Rahman (41), Rafiqul Islam (23),Helal Mia (61), Julekha(32), Shanta (33)

Facilitators: Mehjabin Jahangir Rafjin (23), Tanveer Hossain Rhine (23)

A seasonal Diagram provides the seasonal variation of usage of wetlands among the stakeholders. It is used to analyze the seasonal variation among the usage throughout the year. The Below table shows a seasonal diagram table of four different wetland components which are water usage, water shortage, water availability, and happiness with the wetland or we can say that satisfied with the resources available in both our study areas.

The seasonal map indicates that during summer and late autumn, Godagari Upazila experiences water scarcity and decreased water availability due to irregular seasonality and recent heat waves. According to the participants in recent years 2022-2024, the production of tomatoes is harmed significantly due to low water availability in the area. The farmlands don't use water from the wetlands as the wetlands are usual Common Pool Resource (CPR) throughout the decade which tends to create a low water level of wetlands in recent times. The wetland usage increases from mid-September to October as the number of heatwaves is higher at that time. The seasonal variety arises as the heat in barind tract areas is higher than in any other region which makes the rivers and canals dry up, increasing the usage of water due to excessive heat in the area which decreases the happiness during those times. Another significant drop is seen in the June-July region when the rainfall is higher. These areas don't have sustainable resource management which is why the excessive water from rainfall cannot be managed and stored back in dried wetlands A graphical representation of all four components where we can see that in the dry season, there is water scarcity whereas in the wet season due to low resource management happiness level drops as in farmlands excessive flood also create a loss of crops and capital in rural area.

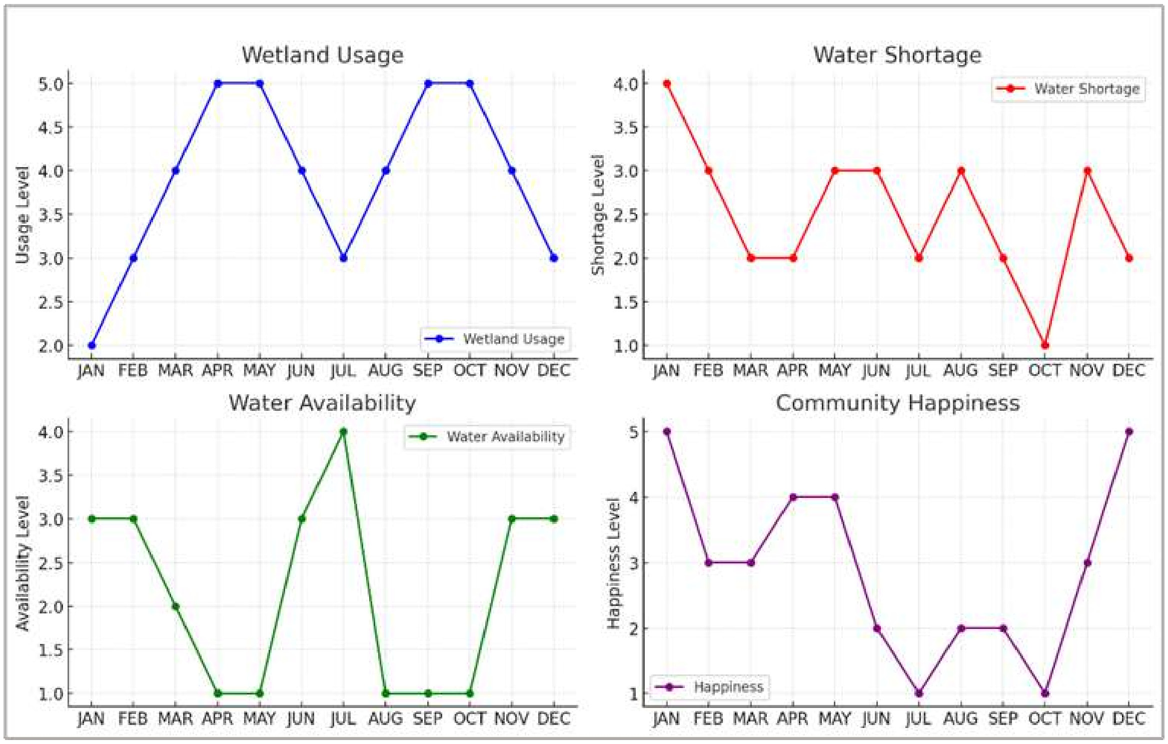


Figure 6: Graphical Presentation of Seasonal Differences for Godagari and Tanore Upazila

Source: Prepared by Authors, 2024

5.1.4 Spider Web Diagram

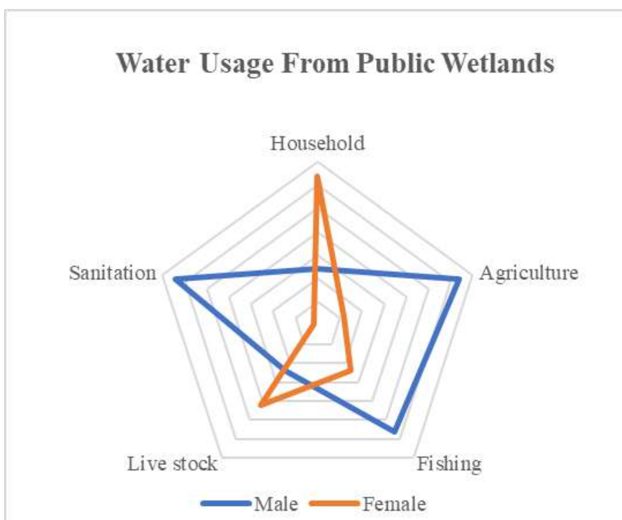


Figure 7: Water Usage from Public Wetlands

Source: Prepared by Authors, 2024

The above spider diagram is useful for understanding gender-specific trends in water use. Wetland preferences among males and females differ by their usage. This will help to identify which group relies more on wetlands for specific purposes and also will help to develop targeted interventions or support programs based on the needs of each group. From the figure, we can see that the highest wetland usage is for fishing and household work but in recent times public wetlands are no longer a common pool resource for household usage. Maximum water resources are being used for fish cultivation and the wetlands are being authorized by government-oriented programs. People who live in these areas often rely on motors or tube wells that are built into their homes for drinking water for daily use and farming. Some families also build dips to store water for farming. But problems still exist, even with these systems. Water supply is frequently disrupted by problems with motors and tubewells or changes in the seasons that make it hard to get to water. This makes things harder for both farming and everyday life, making people even more dependent on wetlands and making it harder to keep them in good shape. This changing situation shows how important it is to use combined methods for handling water resources that take into account the different needs that wetlands have that are always changing.

5.1.5 Time Line

Table 3: Time line of Climate Extreme in Study Area

Study Area: Godagari & Tanore *Date: 18-11-2024*

1987	Flood
1988	Flood
2006	Drought
2007	Flood
2016	Flood
2018	Drought
2020	Flood
2022	Heatwave

Participants: Samsun Nahar (42), Mofiz Uddin (34), Bashir Ahmed (49), Lutfar Rahman (41), Rafiqul Islam (23)

Facilitators: Tanveer Hossain Rhine (23), Mehjabin Jahangir Rafjin (23)

Source: Prepared by Authors, 2024

The table lists the major natural disasters that have affected both Tanore and Godagari Upazila over time, along with the consequences they have had on the area. It highlighted the region's susceptibility to monsoonal flooding by causing extensive damage to infrastructure and agriculture beginning with the 1987 Flood. These difficulties were reaffirmed by a comparable flood in 1988. A change in water scarcity issues was signaled by the 2006 drought, which drastically decreased agricultural yields. Heavy monsoon rains in 2007 caused waterlogging, which interfered with local life and agriculture. The 2016 flood brought even more attention to the inadequate drainage infrastructure, which resulted in extreme water congestion. 2018 saw yet another protracted drought that worsened groundwater depletion and affected access to water for both agriculture and homes. Due to insufficient infrastructure, the 2020 Flood made urban and rural waterlogging worse, while the 2022 Heatwave made drought conditions worse, negatively impacting agriculture and water supplies. This timeline shows how Godagari is becoming more and more susceptible to droughts and floods, which calls for immediate action to manage water resources and disasters sustainably. There is a notable change due to the flood of Tanore Upazila in 2020 people benefitted as they cultivated cops during that season whereas in Godagari the scenario is different.

5.2 Sustainable Water Management Strategies

After the participatory involvement of stakeholders to clarify the current status of wetlands in the study area, a sustainable water management process must be taken into account.

5.2.1 Focus Group Discussion and KII

Focus Group Discussion with the participants highlights the importance of rainwater harvesting and using a central water sewerage system to recycle water for ground recharge. People in both upazilas prefer water tanks and central water management systems for proper water resource systems. BMDA officials suggested a range of solutions to address these issues. For both upazilas, restoring and conserving remaining water bodies through dredging, re-excavation, and community-based initiatives is a priority. Afforestation and soil conservation measures were recommended to enhance natural groundwater recharge. To address water scarcity, affordable rainwater harvesting systems for households and community spaces were proposed, along with modern irrigation techniques, such as drip and sprinkler systems, to reduce groundwater dependency. For Godagari, BMDA emphasized the urgent need for modern drainage systems and the use of sustainable urban drainage solutions to tackle monsoonal water congestion. In Tanore, check dams and groundwater recharge wells were recommended to retain water during droughts. Additionally, centralized water supply systems, such as overhead reservoirs, were identified as a necessity to provide equitable water access, especially for impoverished communities. The officials stressed that integrated water management, combined with government and community collaboration, is essential for creating a sustainable and resilient water future in both upazilas.

5.2.2 Dream Map

Poverty and excessive groundwater extraction are the main causes of the major problems that the people of both Godagari & Tanore Upazila face concerning infrastructure and water resources. Traditional tubewells are no longer functional due to groundwater depletion, and most people cannot afford modern water extraction methods like submersible pumps. Limited relaxation is offered by seasonal rains since water congestion during the rainy season disrupts daily life and agriculture due to a lack of rainwater harvesting systems and adequate drainage infrastructure. The community hopes to create a centralized water infrastructure, like an above-water reservoir, to solve these problems and guarantee fair access to water. A sustainable drainage system is also crucial to reducing waterlogging during the rainy season and enhancing living conditions in general. Residents of Godagari and Tanore can have their vital water and infrastructure demands met by putting into practice solutions like rainwater collection, community-managed reservoirs, and contemporary drainage networks, as well as by actively involving the community. The two dream maps represent the needs of residents living in both upazila which include Central Tank, Sewerage System, rainwater basin, Water reservoirs, Water Drainage, Drip or Sprinklers, and Individual Tanks for houses. This map emphasizes the need of people, helping the policymakers to manage watersheds including a community-led water system management system.

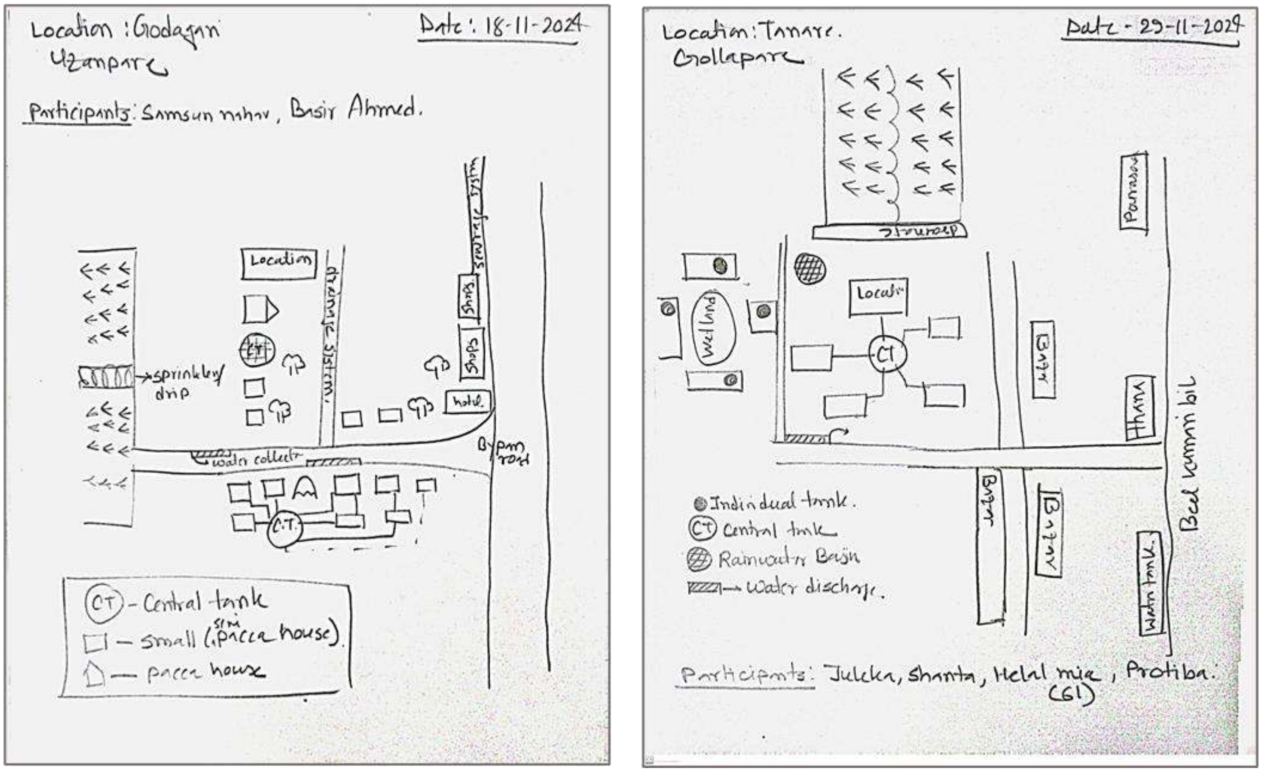


Figure 8: Dream Map to Show Alternative Water Infrastructure

Source: Prepared by Authors, 2024

Participants: Samsun Nahar (42), Mofiz Uddin (34), Bashir Ahmed (49), Lutfar Rahman (41), Rafiqul Islam (23)

Facilitators: Tanveer Hossain Rhine (23), Mehjabin Jahangir Rafjin (23)

5.3 Systematic Review

This systematic review analyzes case studies from around the world to investigate community-based water management (CBWM) practices. In rural and semi-urban settings, it emphasizes approaches, sustainable practices, difficulties, and innovations related to water resource management. The efficacy of traditional and modern methods, policy frameworks that improve long-term sustainability, and participatory governance are among the key findings. This systematic review analyzes case studies from around the world to investigate community-based water management (CBWM) practices. In rural and semi-urban settings, it emphasizes approaches, sustainable practices, difficulties, and innovations related to water resource management. The efficacy of traditional and modern methods, policy frameworks that improve long-term sustainability, and participatory governance are among the key findings. The review analyzes research from Asia, Latin America, and Africa, providing in-depth analyses of popular approaches and innovative sustainable solutions.

Participatory research design, data collection methods, analytical frameworks, stakeholder involvement, and policy review are the categories into which the methodologies used in the various studies can be divided. Local communities were involved in participatory research designs through focus groups, community gatherings, and cooperative water-use planning. For instance, research in South Africa and Nigeria evaluated water scarcity and adaptation through community discussions, while research in Uganda investigated the functioning of water systems through qualitative fieldwork. Causal Loop Diagrams (CLD) were used in Cameroon to analyze water management models through participatory learning sessions.

Techniques for gathering data included a variety of approaches, including technical evaluations, interviews, and surveys. Structured questionnaires were used in Ethiopia and Kenya to gauge system maintenance procedures and community knowledge. To assess traditional water systems, such as the Ahar-Pyne irrigation network, historical documents, and socioeconomic data were examined in India. Similar to this, community consultations and surveys were essential to comprehending the changing nature of water management in Brazil and Cameroon.

Thematic analysis, comparative analysis, and economic evaluation models were common analytical frameworks. In South Africa, community reports about water scarcity and climate resilience were subjected to thematic analysis. Namibia used economic models to assess the cost-effectiveness of rainwater harvesting, while Tanzania conducted comparative studies between traditional and government-managed systems. The implementation of the water supply system in Brazil was guided by operational and financial sustainability models.

Involving stakeholders turned out to be essential to the success of CBWM. The design, maintenance, and financial management of the system were heavily influenced by local government representatives, water committees, and community leaders. For instance, local leaders in Brazil managed operational and fee-collection duties to guarantee sustainability, while water user committees in Cameroon actively participated in water-use planning. Government support frameworks were examined in policy and institutional reviews. The abolition of India's Zamindari system highlighted the historical decline of the Ahar-Pyne system, while studies conducted in Namibia and South Africa emphasized government-community collaboration.

Several sustainable solutions that were present in all of the case studies were found in the review. Integrated water management strategies that combined conventional and contemporary techniques worked well. While India's Johad system revitalized rivers and restored groundwater tables, Tanzania's traditional knowledge resulted in superior water quality. A key component of sustainability has been identified as community ownership. Local water management organizations in Nigeria used ownership-based models to maintain their systems, whereas households in Brazil paid fees for upkeep and repairs.

The effectiveness of water management was influenced by gender and socioeconomic factors. While women played important roles but were not adequately represented in decision-making in Cameroon, community training enhanced the delivery of water services in Kenya and Ethiopia. Access to water was also enhanced by technological advancements and alternative water sources. Nigeria's roof and ground catchments improved water availability, while Namibia's rainwater harvesting systems facilitated microcredit financing.

Two common themes were institutional support and policy integration. Research focused on incorporating community-led projects into official governance frameworks. Whereas integrating traditional and modern irrigation techniques was advised for sustainability in India, cooperative policy frameworks improved system performance in South Africa and Kenya.

Numerous important processes were emphasized in various studies. In Nigeria, the establishment of community groups aided in the decentralization of water management, and water resource inventories used data on surface water, groundwater, and rainfall to determine the amount of

Research	Author	Methods	Results	New findings
The Role of Communities in Improved Rural Water Supply Systems in Nigeria: Management Model and Its Implications for Vision 2020 (Nwankwoala, 2011)	H.O. Nwankwoala	**a) Community Group Formation:** There were smaller community (SC) zones created, with 250–500 people living there. Local water sources were managed by each community. **b) Water Resources Inventory:** To identify accessible and safe supplies, local organizations performed a seasonal inventory of groundwater, surface water, and rainfall. **c) Water Demand Assessment:** Using particular formulas for each SC region, the total water demand for irrigation, livestock, and household uses was determined.	**a) Improved Sustainability:** Community participation enhanced sustainability through a sense of ownership and cost-sharing in maintenance and operation. **b) Increased Efficiency:** Water use was optimized and waste was decreased by systematic inventory and demand assessments. **c) Adaptable Model:** Because of the approach's flexibility, each town was able to employ the water sources that were most affordable and accessible. **d) Community Empowerment:** Long-term water system functionality was ensured by the collaborative framework that was established by local involvement.	**a) Alternative Source Strategies:** An emphasis on collecting rainwater and using surface and groundwater simultaneously lessens reliance on individual sources. **b) Community Training Benefits:** The durability and functionality of water systems are improved when community people receive training in the inventory, preservation, and sustainable use of water resources.
Climate Change Impacts on Water Resources in A Rural Community in Limpopo Province, South Africa: A Community-Based Adaptation to Water	Sejabaledi Agnes Rankoana	**a) Participatory Research Design:** To evaluate the effects of water scarcity and adaptation strategies, the study actively engaged community members in Maheni, Limpopo Province.	a) **Water Resources:** The community depends on a borehole and a reticulation system from the Mutale River. Due to overuse and drought, the supply of both sources fluctuates.	**a) Community-Based Adaptation:** Compliance with water limitations and rules is ensured by local participation in water management committees. **b) Cultural Impact:** Cultural traditions like cattle farming

Insecurity (Rankoana, 2020)		**b) Sampling:** comprised of six members of the water committee and one hundred members of the community, chosen via convenience sampling. **c) Data Collection:** Twelve audio-recorded focused group discussions (FGDs) were conducted, and the transcriptions were then subjected to thematic analysis. **d) Analysis:** Themes were divided into three categories: community-based adaptations, climate change impacts, and water resource status.	b) **Climate Change Impacts:** Water scarcity was made worse by prolonged drought and high temperatures, which decreased river flows and groundwater recharge. c) **Adaptation Practices:** Among the strategies include water storage, prioritizing basic requirements, sourcing from nearby towns, and regulated water use (e.g., usage restrictions, fines).	are disrupted by water scarcity. **c) Collaborative Solutions:** A distinctive cooperative adaptation paradigm is demonstrated by the peaceful sharing of water resources amongst nearby communities. **d) Climate Resilience Building:** Sustainable climate change adaptation is supported by combining formal management systems with community-specific practices.
Blueprint For Breakdown? Community-Based Management of Rural Groundwater in Uganda (Van Den Broek & Brown, 2015)	Marije van den Broek, Julia Brown	**a) Study Design:** 107 water stations in Uganda were the subject of ethnographic fieldwork, questionnaires, and interviews with an emphasis on management and functionality. **b) Data Collection: S**urveys aimed at community residents and water user committees (WUCs). Semi-structured interviews with representatives of the	**a) Non-Functionality of Handpumps:** Just 3% of the water stations evaluated had enough money for significant repairs, while 53% had none at all. **b) Failure of Collective Action:** Due to a lack of enforcement, social conflicts, and mistrust, user fees are collected irregularly or not at all. Weak WUCs are unable to maintain participation or execute penalties.	**a) Flaws in the CBM Model:** Sustainability is threatened by a misalignment between commodification (monetary donations) and group action. Participation in the community does not guarantee sustained dedication or functionality. **b) Social and Structural Barriers:** Community-driven initiatives are hampered by power dynamics, mistrust, and a lack of togetherness. Financial models are weakened

		local administration, water users, and WUC members. WASH-based financial analysis standards for costs to evaluate the sustainability of operation and maintenance (O&M). **c) Framework:** Analysis of the Community-Based Management (CBM) model that takes into account common property resource theories, commodification theories, and collective action theories.	**c) Challenges to Sustainability:** Water commodification weakened group efforts and created societal divisions. Local ownership was undermined by reliance on NGOs for ongoing intervention.	by alternative water supplies, which lessen reliance on managed systems. **c) Need for External Support:** Functionality requires ongoing outside assistance, such as post-construction support, which calls into question the CBM model's self-sufficiency assumption. **d) Alternative Approaches:** Success in specific instances (such as profit-generating ventures or fee-collecting incentives) points to possible modifications outside the CBM framework.
The Conceptual Evolution and Practice of Community-Based Natural Resource Management in Southern Africa: Past, Present and Future (Child & Barnes, 2010)	Brian Child, Grenville Barnes	**a) Case Study Location:** conducted among the Sonjo community in Samunge village, Tanzania. **b) Data Collection:** Used participatory conversations, semi-structured interviews, and bacterial water quality tests in three different rivers. **c) Comparative Analysis:** contrasted government-controlled rivers (Rima and Kabarone) with	**a) Effective TRM**: The water quality of the traditionally maintained Ngela River was noticeably superior to that of the government-controlled rivers. **b) Community Perceptions:** The villagers' perceptions of seasonal and diurnal changes in water quality were accurate. **c) Bacterial Contamination:** Ngela had the lowest coliform levels, suggesting that traditional methods provided superior protection.	**a) Role of LEK (Local Ecological Knowledge):** Water quality is greatly enhanced by conventional methods like controlled water use and the preservation of riparian forests. **b) TRM vs. Government Management:** Due to improved community compliance and the incorporation of spiritual principles, traditional governance functioned better than government programs.

		traditionally managed rivers (Ngela). **d) Indicators:** E. coli and coliform levels were used as stand-ins for contamination while evaluating the quality of the water.	**d) Behavioral Insights:** Contamination levels were associated with seasonal and diurnal patterns of water consumption, highlighting the importance of traditional regulations in lowering risk.	**c) Behavioral and Environmental Linkages:** The necessity for integrated behavioral and environmental water management solutions is highlighted by seasonal and diurnal patterns of water contamination.
Traditional Water Resource Management and Water Quality in Rural Tanzania (Strauch & Almedom, 2011)	Ayron M. Strauch, Astier M. Almedom	**a) Study Area:** Compared traditional and state-run water systems with a focus on the Samunge community in Tanzania. **b) Data Collection:** Conducted interactive discussions and semi-structured interviews with 216 families; key informants were leaders, clinicians, and elders. Using coliform and E. coli levels, a quantitative bacterial investigation of water sources is conducted. **c) Temporal and Spatial Analysis**: Examined how daily use patterns and the seasons affect the quality of the water. **d) Sampled three rivers:** Kabarone and Rima were	**a) Water Quality:** Because of traditional management techniques, the water quality of the Ngela River was constantly improving. **b) Behavioral Patterns:** The cleanest water was collected in the early morning, according to villagers who noted daily variations in water quality. **c) Contamination Sources:** Because of grazing and policy noncompliance, the levels of bacteria in government-managed waterways were greater. **d) Seasonal Variation:** All rivers had higher levels of bacterial contamination due to wet season runoff, while the Ngela had lower levels.	**a) Effectiveness of Traditional Resource Management (TRM):** By preserving riparian areas and guaranteeing sustainable water usage, TRM fared better than government systems. Compliance and resource sustainability were enhanced by the integration of social and spiritual norms. **b) Local Ecological Knowledge (LEK):** Contamination was reduced via LEK-based techniques like activity scheduling and riparian tree care. **c) Policy Implications:** Emphasized how crucial it is to incorporate traditional knowledge into official water management plans to achieve better results.

		under government control, while Ngela was traditionally run.		
Assessment of Rural Water Supply Management in Selected Rural Areas of Oyo State, Nigeria (Gbadegesin & Olorunfemi, 2007)	Niyi Gbadegesin Felix Olorunfemi	**a) Study Area:** Oyo State has three LGAs (Local Government Areas) that are rural or semi-urban: Ibarapa, Afijio, and Lagelu. **b) Data Collection:** Structured and semi-structured questionnaires (600 distributed, 487 examined) as part of a mixed-methods strategy. Interviews with stakeholders in-depth and focus group discussions (FGDs). Examination of pertinent program and policy materials. **c) Data Analysis:** Applied both quantitative and qualitative statistical methods, using content analysis for qualitative inputs and SPSS software for numerical data.	**a)** Depending on whether government or non-governmental organization interventions are in place, communities' approaches to water management differ greatly. **b)** There is still limited availability of drinkable water, particularly in rural areas, where people must rely on contaminated sources such as streams and rainfall. **c)** Although communities indicated a desire to implement successful programs, stakeholders were not well-informed about government policies regarding water management. **d)** While some indigenous knowledge systems, like rainwater collecting and pot chlorination, are still in use, they need to be integrated with contemporary scientific methods.	**a)** Long-standing programs in Igbo-Oloyin show that community involvement and local control greatly increase the success of water delivery projects. **b)** Integrating Indigenous knowledge with scientific techniques and encouraging community involvement is essential to the viability of rural water management systems. **c)** Poor infrastructure maintenance, insufficient institutional support, and low stakeholder knowledge capacity are major obstacles. **d)** The public's perception of water provision needs to change from one of a government-only duty to one of a community-wide endeavor.
Shifting The Paradigm in	Henry Bikwibili Tantoh, Mulala	**a) Study Area:** Six rural communities in the	**a)** Despite its importance, Community-Based Water	**a) Integration Need:** CBWRM sustainability is improved by

Community-Based Water Resource Management In North-West Cameroon: A Search For An Alternative Management Approach (Tantoh, Simatele, & Ebhuoma, 2020)	Danny Simatele, Eromose Ehije Ebhuoma	districts of Ndu, Njinikom, and Mbengwi in North-West Cameroon. **b) Data Collection:** In-depth interviews, content thematic analysis, focus group discussions (FGDs), and instruments for participatory learning and action. **c) Analysis:** To assess stakeholder interactions and create management plans, the Causal Loop Diagram (CLD) and the Systems Thinking Approach (STA) were used.	Resource Management (CBWRM) faces obstacles such as inadequate institutional frameworks, a lack of political will, and unequal representation of women in decision-making. **b)** Centralized government reduces traditional powers, despite their crucial importance. **c)** Water management committee performance varies; better results are associated with active participation.	a concerted effort involving community members, NGOs, municipal administrations, and traditional authorities. **b) Systemic View:** STA draws attention to the connections between resource management, community involvement, and governance. **c) Gender Dynamics:** Although they make a substantial contribution to the upkeep of water systems, women are underrepresented in decision-making. **d) Policy Implications:** For sustainable management of water resources, a shift from centralized to community-driven frameworks is essential.
Towards A Pro-Community-Based Water Resource Management System in Northwest Cameroon: Practical Evidence and Lessons of Best Practices (Tantoh, Simatele, Ebhuoma, Donkor, & McKay, 2021)	Henry Bikwibili Tantoh, Danny Mulala Simatele, Eromose Ebhuoma , Kwabena Donkor, Tracey J. M. McKay	**a)** Using random selection, fieldwork was carried out in six villages in Northwest Cameroon. **b)** Information was gathered through focus groups with officials and people of the community, interviews, and surveys (156 homes). **c)** The analysis made use of participation metrics and	**a)** Better water management results are correlated with stronger community participation. **b)** Mandatory participation and effective conventional leadership improve project performance. **c)** Low technical capacity, inadequate financing, and centralized control are major obstacles.	**a)** The maintenance of rural water systems depends heavily on traditional leadership. **b)** Water projects have greater success rates when community involvement is required. **c)** Long-term sustainability requires a community-driven, decentralized strategy.

		thematic content analysis.		
Factors Influencing Sustainability of Rural Water Supplies in Kenya (Tifow, 2013)	Ally Abdi Tifow	**a) Study Area:** Investigated 259 UNICEF-supported rural water projects in three districts (Kisumu, Siaya, and Busia) in Kenya's Lake Victoria South and North regions. **b) Sampling:** 10% stratified random sampling, focusing on community members and Water and Sanitation (WASH) Committee members. **c) Data Collection:** Used structured questionnaires targeting two WASH members and one household representative from each water facility. **d) Analysis:** Data was analyzed using descriptive statistics and SPSS software.	**a) Community Participation:** Projects with strong community involvement showed improved sustainability, with better maintenance and ownership. **b) Technology Choice:** Simpler, locally manageable technologies contributed to longer-lasting water systems. **c) Committee Skills:** Training and skills of WASH committees positively correlated with water facility functionality and sustainability. **d) Post-Implementation Support:** Regular technical and financial support ensured better system performance and user satisfaction.	**a) Capacity Building:** Ongoing training for WASH committees is crucial for sustained water service delivery. **b) Collaborative Governance:** Projects integrating community input in decision-making saw greater long-term success. **c) Policy Recommendations:** Highlighted the need for structured post-implementation monitoring and support from government and NGOs.
Rural Water Supply Management and Sustainability: The Case of Adama Area, Ethiopia (Tadesse, Bosona, & Gebresenbet, 2013)	Abebe Tadesse, Techane Bosona, Girma Gebresenbet	**a) Study Design:** Mixed-methods approach (quantitative and qualitative) to evaluate rural water supply systems in Adama District, Ethiopia. **b) Data Collection:**	**a) Water Accessibility:** Water schemes were within 2 km of households, but only 15% of beneficiaries received adequate daily water (20 liters/person). **b) Community Participation:** Strong in	**a) Role of Women:** Women actively participated in water management but faced limited representation in decision-making roles. **b) Environmental Challenges:** Schemes were vulnerable to contamination from human waste, livestock, and

		Surveys with 148 households across four water schemes (boreholes, gravity-flow pipes, ponds, hand pumps). Focus group discussions and key informant interviews. **c) Assessment Areas:** Community participation, sanitation and hygiene practices, financial management, external support, and functionality of water schemes.	project initiation and labor contribution but limited in technology choice. **c) Sanitation Practices:** Only 3.4% used improved pit latrines; open defecation was widespread. **d) Functionality:** Water schemes faced technical and operational challenges, with some being partially functional or non-operational. **e) Financial Sustainability:** Communities practiced cost-sharing for operations but lacked standardized water tariffs.	flooding, exacerbated by poor waste management. **c) Policy Implications:** Emphasized the need for stronger external support, enhanced community training, and improved monitoring systems to ensure sustainability.
Sustainable Technological Policy Options for Rural Water Supply Management in Selected Rural Areas of Oyo State, Nigeria (Gbadegesin & Olorunfemi, 2011)	A.S. Gbadegesin, F.B. Olorunfemi	**a) Study Area:** Focused on three rural/semi-urban LGAs in Oyo State, Nigeria: Ibarapa, Afijio, and Lagelu. **b) Data Collection:** Conducted surveys (600 questionnaires, with 487 valid responses) and Focus Group Discussions (FGDs). Semi-structured interviews with stakeholders, including government officials and community members.	**a) Knowledge Gap:** Stakeholders had limited knowledge of socio-economic, technological, and ecological aspects of water resource management. **b) Indigenous Knowledge:** Some communities utilized indigenous methods like rain harvesting, alum use, and sand filters for water purification, though this required improvement.	**a) Community-Led Management:** Demonstrated potential for sustainable water systems if initial infrastructure is provided, with examples like the Igbo-Oloyin borehole project sustained through community contributions. **b) Integration of Indigenous Knowledge:** Highlighted the need to combine traditional practices with modern technologies for sustainable water management.

		Reviewed government policy documents. **c) Analysis:** Combined qualitative and quantitative methods, with descriptive statistics for questionnaire data and content analysis for FGDs and interviews.	**c) Challenges:** Poor institutional coordination, reliance on government-led boreholes without sustainable maintenance, and limited rural infrastructure hindered water accessibility. **d) Women's Role:** Women actively participated in water management but lacked adequate representation in decision-making.	**c) Policy Implications:** Recommended decentralized governance, improved training, and targeted financial support to enhance water access and quality in rural Nigeria.
Rainwater Harvesting as An Alternative Water Resource in Rural Sites in Central Northern Namibia (Sturm, Zimmermann, Schütz, Urban, & Hartung, 2009)	M. Sturm, M. Zimmermann, K. Schütz, W. Urban, H. Hartung	**a) Technical Assessments:** Roof and ground catchment designs were evaluated for water collection efficiency. **b) Economic Analysis:** A dynamic cost analysis using net present value (NPV) compared costs and potential water savings. **c) Social Engagement:** Local participation and training were considered to ensure sustainability.	**a) Roof Catchments:** Economically viable, achieving cost recovery in 5-7 years depending on materials. **b) Ground Catchments:** Require moderate subsidies due to higher initial investment. **c) Water Yield:** Roof systems generated 27.8 m^3/year, sufficient for household and small-scale farming. Ground catchments produced 141 m^3/year, suitable for livestock and irrigation.	**a) Affordability:** Roof catchments can be self-financed with microcredits. **b) Economic Feasibility:** Ground catchments need a 32% subsidy for competitiveness. **c) Social Potential:** Community management models and local material use enhance sustainability.
Rural Water Access and Management Approaches in Southern Africa: Lessons from Namibia	Selma Karuaihe, Alfons Mosimane, Charles Nhemachena,	**a) Secondary Data Review:** Analysis of government reports, policy documents, and academic studies from	**a) Namibia:** Community-Based Management (CBM) programs improved rural water access, raising	**a) Affordability Issues:** Water tariffs and maintenance costs remain burdensome for rural communities.

and South Africa (Karuaihe, Mosimane, Nhemachena, & Kakujaha-Matundu, 2014)	Omu Kakujaha-Matundu	Namibia and South Africa. **b) Primary Data Collection:** Interviews with officials, water point associations (WPAs), and local communities. **c) Data Analysis:** Statistical and qualitative techniques using Excel and SPSS.	coverage from 43% in 1991 to 80% by 2001. Only 21% of water points were fully handed over by 2003 due to financial and resource challenges. **b) South Africa**: Despite policy frameworks, rural water access remains uneven due to poor infrastructure maintenance and limited municipal capacity. CBM models were abandoned in 2002 but showed potential in some districts like Alfred Nzo.	**b) Institutional Gaps:** Capacity building and institutional support are critical for CBM's success. **c) Policy Insights:** Integrated community-government partnerships can enhance rural water services.
Developing Sustainable and Replicable Water Supply Systems in Rural Communities in Brazil (Enéas da Silva, Heikkila, de Souza Filho, & Costa da Silva, 2013)	Francisco Osny Enéas da Silva , Tanya Heikkila , Francisco de Assis de Souza Filho, Daniele Costa da Silva	**a) Project Planning:** Surveys assessed existing water sources, infrastructure, and community preferences in Ceará, Brazil. **b) Community Engagement:** Local leaders and residents participated in system design and operational planning through workshops and meetings. **c) Pilot Implementation:** Water supply systems were built in two rural communities, integrating technical and financial sustainability models.	**a) Improved Water Access:** Water supply coverage increased, reducing health issues like waterborne diseases. **b) Community Ownership:** Locals managed daily operations, maintenance, and payment collection. **c) Financial Sustainability:** Households paid fixed or usage-based fees, covering operational costs and saving for future repairs.	**a) Sustainability Framework:** Social capital, technical capacity, and environmental considerations are critical for replicable models. **b) Adaptive Planning:** Flexible designs tailored to local needs can enhance resilience to droughts. **c) Policy Integration:** A municipal water plan model supports expansion with public-private partnerships and donor funding.

		d) Monitoring & Evaluation: Regular surveys and system checks ensured operational performance and community satisfaction.		
Traditional Water Management Systems - An Overview of Ahar-Pyne System in South Bihar Plains of India and Need for Its Revival (Koul, Singh, Neelam, & Shukla, 2012)	Divy Ninad Koul, Swati Singh, Ganesh Neelam, Gopal Shukla	**a)** Conducted a comprehensive review of the Ahar-Pyne Indigenous irrigation system in South Bihar, India **b)** Analyzed historical records, government data, and existing literature **c)** Examined institutional, management, and socio-economic aspects of the water harvesting system	**a) Historical Irrigation Coverage** In the early 20th century, Ahar-Pyne irrigated about 35% of 2.5 million hectares in South Bihar By 1997, the system irrigated only 12% of the total irrigated area in Bihar The area declined from 0.94 million hectares in 1930 to 0.53 million hectares in 1997 **b) Unique System Characteristics** Rectangular water harvesting structures (Ahars) with three embanked sides Artificial channels (Pynes) to divert river water Enabled paddy cultivation in an otherwise unsuitable agricultural region	**a) Success Factors:** Equitable land distribution Low-cost irrigation Strong community participation Synchronized agricultural operations Sophisticated water distribution mechanisms **b) Reasons for Decline:** Abolition of the Zamindari (landlord) system Emergence of new irrigation sources like tube wells Lack of integration with modern irrigation schemes **c) Revival Recommendations:** Integrate traditional and modern irrigation systems. Leverage community participation Use government programs like NREGA for system maintenance Recognize the sustainability and cost-effectiveness of traditional methods

Water Resources Management: Traditional Technology and Communities as Part of The Solution (Hussain, Husain, & Arif, 2014)	J. Hussain, I. Husain, M. Arif	**a)** The study focuses on traditional water harvesting techniques in Rajasthan, India, particularly the johad system **b)** The research involved documenting various traditional water conservation methods like kunds, jhalaras, tanks, and johads **c)** The primary method examined was the construction of johads (small earthen check dams) in Alwar District	**a)** 8,600 johads were built across 1,086 villages covering 6,500 km² **b)** The groundwater table dramatically improved from 100-120m depth to 3-13m **c)** Cropped area increased significantly: Single cropping: from 11% to 70% Double cropping: from 3% to 50% **d)** Forest cover increased from 7% to 40%	**a)** Johads are extremely cost-effective (Rs. 0.2-3 per cubic meter of water storage) **b)** Annual per capita income rose from Rs. 126 to Rs. 3,585 **c)** Revived five seasonal rivers to perennial status **d)** Demonstrated how community-driven water management can transform local ecosystems and economies **e)** Showed that traditional, low-cost water harvesting techniques can be more effective than large-scale government infrastructure projects

Available water. In Tanzania and India, participatory mapping identified sources of contamination by combining technical evaluations with local ecological knowledge. In Namibia and Brazil, fee collection was guided by financial sustainability models and bolstered by dynamic cost analysis. Lastly, policy integration made sure that community-led water projects in Ethiopia, India, and South Africa complied with official governance frameworks.

All things considered, this systematic review emphasizes how crucial policy integration, technological innovation, and participatory governance are to sustainable water management. Long-term success depends on combining traditional and modern methods, improving institutional support, and fortifying community training. CBWM can efficiently manage water resources and guarantee sustainability in a variety of geographical areas by addressing socioeconomic dynamics and encouraging cooperation.

Chapter 6. Recommendation & Conclusion

This Research aims to manage the wetlands in barind tracts for better watershed management and provide alternative solutions for water resource management. Barind tracts are areas having high heat and low rainfall causing dried-up waterbodies. To preserve these wetlands strategies should be undertaken, and policies should be integrated. The result shows possible solutions including wetland management, community-led water resources, and central tanks. Supervised classification showed the change of waterbodies over the past decade showing low levels of water resources and increased use of manmade ponds which is disrupting the land use pattern along with the ecology.

Focus group discussions, key informant interviews, and semi-structured interviews are all types of participatory appraisals that helped illustrate how much local communities depend on water supplies for farming, household tasks, and fish farming. However, mismanagement of common pool resources, unsustainable practices, and inadequate policies have increased water scarcity and reduced the utility of wetlands as community resources. Seasonal and spider web diagrams show the cyclical challenges of water availability, highlighting the impacts of heatwaves, droughts, and flooding on agricultural productivity and community satisfaction.

To address these challenges, the study identifies the need for sustainable water management strategies for example rainwater harvesting, modern irrigation techniques, and community-led wetland conservation initiatives. Proposed solutions, including centralized water supply systems, improved drainage infrastructure, and groundwater recharge mechanisms, aim to create a more resilient and equitable water management system.

The study drags down some recommendations to overcome the impact of climate change and provide sustainable water resource management, which are-

Category	**Recommendations**	**Policy Suggestions**
Existing Wetland Management	✓ Restore degraded wetlands through reforestation, and conservation initiatives.	✓ Enforce strict regulations to prevent the filling up of wetlands.
Integrated Water Resource Management (IWRM)	✓ Promote rainwater harvesting systems for households and public spaces. ✓ Construct check dams and groundwater recharge wells to store rainwater.	✓ Develop subsidies for modern irrigation methods like drip and sprinkler systems. ✓ Integrate IWRM into regional land-use planning for sustainable water use.

Climate Adaptation Measures	✓ Introduce heat-tolerant crops and trees to mitigate rising temperatures. ✓ Provide support for seasonal water storage and flood management infrastructure.	✓ Implement flood mitigation strategies with sustainable drainage systems. ✓ Align adaptation policies with national climate goals.
Infrastructure Development	✓ Build centralized water supply systems (e.g., overhead reservoirs). ✓ Upgrade drainage systems for proper sanitation and waste management	✓ Ensure proper distribution of CPR through public-private partnerships. ✓ Develop region-specific infrastructure to address seasonal water challenges.

By integrating traditional knowledge along with modern practices, providing financial incentives, community-government collaboration, and sustainable water management in the Barind Tract can mitigate climate change vulnerabilities, restore wetland ecosystems, and enhance the livelihoods of local populations.

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Appendix A

FGD Questionnaire

Category	Questions
Existing Watershed	1. What is the current scenario of existing waterbodies? 2. How much do you rely on these water bodies? 3. What is the main source of water supply in your house? 4. Is the level of water decreased over the time? 5. Is the Watershed being Dugged Manually?
Previous climate Condition	6. What was the highest climatic condition in your upazila? 7. How the hazard affected the water body? 8. Have you faced excessive flood or drought in recent time? 9. Does recent heatwave affect the waterbody?
Watershed management	10. How do you manage the waterbody nearby? 11. Is there any government initiative? 12. Are you interested in community led watershed management? 13. What are the management ways you follow to preserve the waterbody? 14. Is there any rules and regulations incorporating the usage?
Upgradation Regarding Watershed Management	15. What do you prefer for a better watershed management process? 16. What measures should be taken for integrated watershed management program?

KII Questionnaire:

Interviewer: Tanveer Hossain Rhine **Informant:**

BMDA

1. Can you describe the key water resource management strategies currently employed by BMDA in the Barind Tract?
2. How does BMDA ensure efficient allocation of water resources for agricultural and domestic use?
3. What are the primary challenges BMDA faces in managing water resources in the Barind Tract?
4. How does BMDA address issues related to groundwater depletion and climate change?
5. To what extent does BMDA involve local communities in water resource management planning and decision-making?
6. Are there any specific community-based initiatives currently in place? If so, can you elaborate?
7. What policies or regulations guide BMDA's water resource management practices?

8. Has BMDA considered or implemented any alternative management approaches? If yes, what are they, and how effective have they been?
9. What role does technology play in BMDA's water resource management, and are there any new technologies being explored?

Appendix B

Location: Tanore **Date: 04-10-2024 & 30-11-2024**










Location: Godagari **Date: 18-11-2024 & 28-11-2024**