Salinity Scoping Study in Bangladesh

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Abbreviation / Acronym

ADM	Adaptive Delta Management
BADC	Bangladesh Agricultural Development Corporation
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BDP2100	Bangladesh Delta Plan 2100
BRAC	Bangladesh Rural Advancement Committee
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CBO	Community Based Organizations
CEGIS	Center for Environmental and Geographic Information Services
CZPo	Coastal Zone Policy
DAE	Department of Agricultural Extension
DLS	Department of Livestock Services
DOE	Department of Environment
DPHE	Department of Public Health Engineering
DPSIR	Drivers, Pressure, State, Impact and Response
EC	Electrical Conductivity
EKN	Embassy of the Kingdom of the Netherlands
EnvSoL	Environmental Management Solutions
FGD	Focus Group Discussion
GBM	Ganges–Brahmaputra–Meghna
GED	General Economics Division
GIS	Geographic Information System
GoB	Government of Bangladesh
IGRAC	International Groundwater Resources Assessment Centre
IPCC	Intergovernmental Panel on Climate Change
IWM	Institute of Water Modelling
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
KII	Key Informant Interview
LGED	Local Government Engineering Department
LGI	Local Government Institutes
LMICs	Low- and Middle-Income Countries
NAAB	Netherlands Alumni Association Bangladesh
NAP	National Adaptation Plan

NAPo	National Agriculture Policy
NARS	National Agricultural Research System
NEPo	National Environment Policy
NFP	Netherlands Food Partnership
NWP	Netherlands Water Partnership
NWPo	National Water Policy
RCP	Representative Concentration Pathway
RVO	Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland)
SDG	Sustainable Development Goals
SDGP	Sustainable Development Goals Partnership Facility
SLR	Sea Level Rise
SRDI	Soil Resources Development Institute
SWOT	Strengths, Weaknesses, Opportunities and Threats
SW&FS	Saline Water & Food Systems
TDS	Total Dissolved Solids
WMO	Water Management Organizations
WUR	Wageningen University & Research

1 Setting the Context

1.1 Background of the Study

Bangladesh faces significant challenges due to natural hazards such as salinity intrusion, particularly in its coastal regions. Among the major environmental challenges affecting Bangladesh, salinity intrusion has emerged as a significant threat to water resources, agricultural productivity, ecosystem health, and rural livelihoods (Dasgupta et al., 2015; Hossain & Li, 2024). The coastal zone of Bangladesh including districts such as Khulna, Bagerhat, Satkhira, Barguna, Bhola, Patuakhali, Noakhali, Cox's Bazar etc. is one of the most complex delta regions in the world where annual floods, cyclones, tidal surges, reduced river navigability and sea level rise have created various types of environmental risks (GoB, 2018; Feist et al., 2023). Studies indicate that a significant proportion of the coastal region is affected by varying degrees of salinity, which constrains crop production, freshwater supply, and food security (SRDI, 2010; Shawkhatuzamman et al., 2023).

In Bangladesh, this process is driven by a combination of natural processes and human activities. Key drivers include sea-level rise, tidal flooding, cyclones and storm surges, reduced upstream freshwater flow, sedimentation of rivers, and land-use changes such as shrimp aquaculture expansion. These interacting factors allow saline water to penetrate further inland, particularly during the dry season when freshwater discharge from upstream rivers declines (Feist et al., 2022; Sherin et al., 2024).

The impacts of salinity intrusion are multidimensional, affecting agriculture, ecosystems, public health, and socio-economic conditions. Increased salinity in soil reduces crop yields, limits cropping intensity, and contributes to land degradation in coastal areas. Agricultural productivity in many coastal districts has declined due to soil salinization and limited access to freshwater for irrigation (Kabir et al., 2024). In addition, salinity intrusion threatens fisheries, livestock production, and biodiversity while contributing to drinking-water scarcity and health risks among coastal populations (Nahian et al., 2018; Sarkar et al., 2023). Recent studies indicate that climate change, sea-level rise, and human activities - particularly shrimp aquaculture - are accelerating soil and water salinization, leading to declining agricultural productivity, loss of vegetation, environmental degradation, and growing risks to food security and public health (Rahman S. S., 2017).

In response to these challenges, national and international initiatives have increasingly focused on improving water management, strengthening climate adaptation strategies, and promoting salinity-resilient agricultural systems. Integrated approaches that combine infrastructure management, community-based adaptation, and climate-resilient technologies are considered essential to address the complex drivers of salinity intrusion and enhance the resilience of coastal food systems (GED, 2018; Hossain & Li, 2024).

1.2 The Saline Water & Food Systems Partnership

The Saline Water & Food Systems (SW&FS) Partnership is a strategic initiative designed to address the increasing threat of salinity to global food security. Drawing from the provided sources, its relevance can be detailed as follows:

Core Mission and Stakeholder Engagement

The partnership was initiated by the Netherlands Food Partnership (NFP) and the Netherlands Water Partnership (NWP). Its primary goal is to bring together Dutch and local stakeholders from both the water and agri-food sectors to tackle salinity-related challenges in Low- and Middle-Income Countries

(LMICs). It serves as a platform to coordinate efforts between government agencies, private sectors, knowledge institutes, and NGOs.

The Strategic "Country Approach"

The partnership has recently adopted a strategic “country approach” that focuses on four priority countries: Bangladesh, Egypt, Vietnam, and Senegal. As part of this strategy, the partnership has conducted strategic data collection and scoping studies to provide the evidence-based foundation required to develop multi-annual action plans aimed at addressing specific regional salinity issues.

Bridging the Water-Agriculture Divide

A critical relevance of the partnership in Bangladesh is its effort to integrate water management and agricultural practices, which are often treated as separate sectors. The partnership seeks to bridge the divide between to the water and food sectors, to ensure that e.g. field-level adaptations are supported by regional water infrastructure and vice versa. It emphasizes a "water and food nexus" approach, recognizing that solutions cannot be implemented in isolation.

1.3 Objectives of the Scoping Study

The objectives of this assignment are to:

- Provide an overview of salinity challenges in Bangladesh with regional differentiation.
- Identify and map key actors including government, NGOs, donors, research institutions, private sector etc.
- Review and summarize major salinity-focused programs and initiatives.
- Highlight linkages with Dutch-supported efforts and international collaborations.
- Provide evidence-based inputs for a for a multi-annual action plan under the SW&FS Country Approach.

1.4 Rationale of Selecting Bangladesh for the Study

Bangladesh is one of the most vulnerable countries in the world due to the impacts of multiple hazards such as flood, cyclones, storm surges, sea level rise, riverbank and coastal erosion, salinization etc. Bangladesh provides an important case for studying salinity intrusion due to its highly vulnerable coastal environment, complex deltaic hydrology, and the socio-economic importance of coastal agriculture. The country’s exposure to climate change impacts and its ongoing efforts in coastal management and water governance make it a suitable context for assessing salinity challenges and potential adaptation strategies. Bangladesh is a densely populated country located in the deltaic plains of the Ganges, Brahmaputra, and Meghna rivers in South Asia. According to the Population and Housing Census 2022 conducted by the Bangladesh Bureau of Statistics, the total population of the country is 165.16 million. The census also reveals that Bangladesh still has a predominantly rural population. Approximately 68.4% of the population lives in rural areas, while about 31.6% resides in urban areas.

This study covers the salinized areas of Bangladesh (See Figure 1.1) specially the coastal zone and other parts of the country where salinity (either water or soil) ingress is occurring and would continue in the future. Currently, the country is affected by varying degrees of salinity. However, this study mainly focuses on the coastal zone which is one of the most saline prone areas of the country due to its proximity to the sea.

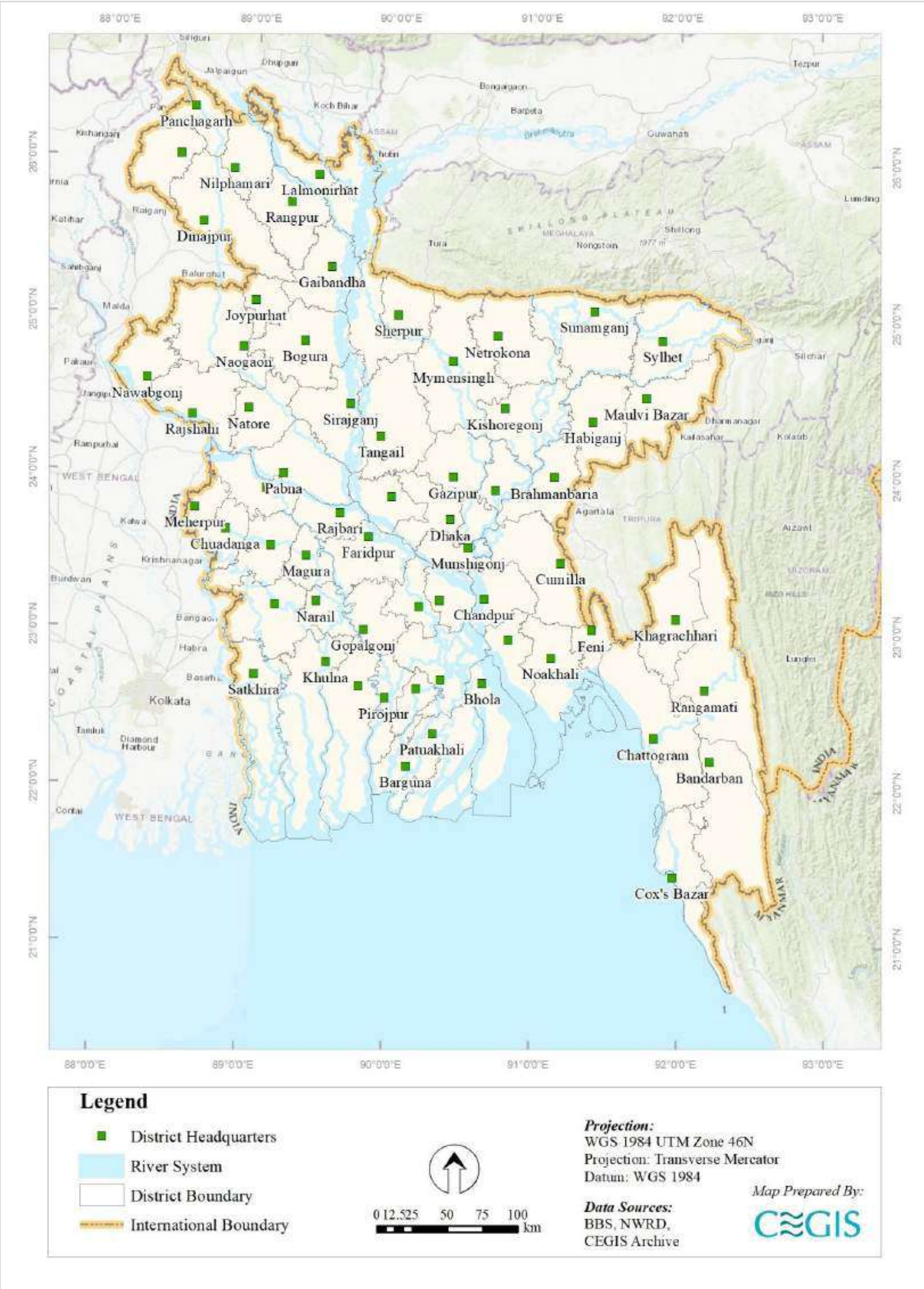

Figure 1.1: Map of Bangladesh

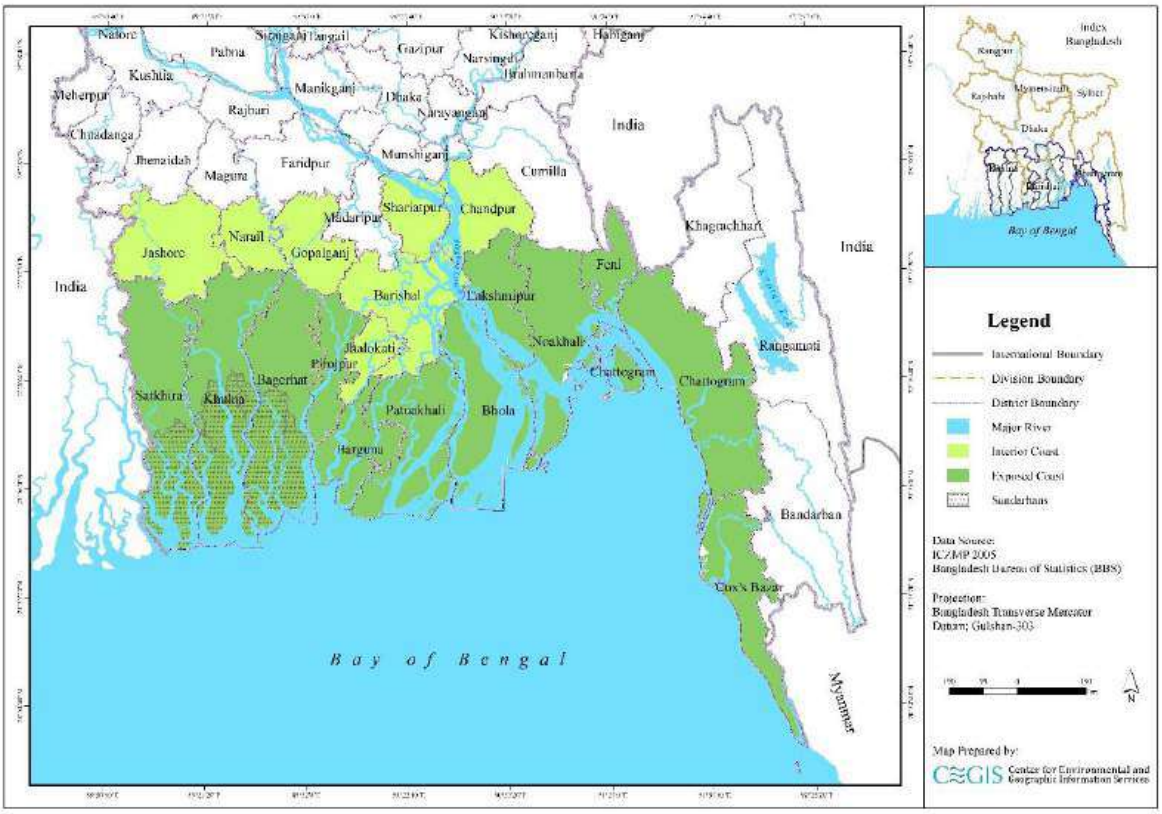

Figure 1.2: The Coastal Region of Bangladesh

The coastal zone comprises 19 districts, defined based on their physical exposure to the Bay of Bengal, tidal influence, salinity intrusion, cyclones, and storm surges. The Coastal Zone Policy (CZP), 2005 classifies these districts into Exposed (Exterior) Coastal Districts and Interior Coastal Districts to guide differential planning, regional investment and risk management strategies. The exposed coastal districts, directly faces the sea and meets high thresholds for tidal movement and cyclone risk, and the interior coast, lies behind the exposed districts but still faces significant salinity and tidal fluctuations.

The coastal region is one of the most complex delta regions, covering about 20% of Bangladesh's total land area. This region is defined by its position along the "funnel-shaped" Bay of Bengal and its unique deltaic characteristics. The topography is remarkably near-flat, with much of the land situated at an altitude of only 1 to 5 meters above mean sea level. This low-lying nature makes the area highly susceptible to tidal influence, with saltwater moving deep inland through an intricate network of rivers and canals. Environmental risks in this zone are multi-dimensional, including annual floods, cyclones, storm surges, and sea-level rise.

The reasons for selecting Bangladesh for this study is laid out below:

- **High vulnerability to salinity intrusion**: A significant portion of Bangladesh's coastal zone lies only 1–5 meters above mean sea level, making it highly susceptible to sea-level rise, tidal flooding, and saline water intrusion (Dasgupta et al., 2015; SRDI, 2010).
- **Large coastal population dependent on agriculture**: Millions of people in coastal Bangladesh rely on agriculture, fisheries, and natural resources for their livelihoods, and increasing soil and water salinity threatens crop productivity and food security (Kabir et al., 2024; Rabbani et al., 2013).

- **Complex deltaic hydrology:** Bangladesh is located within the Ganges–Brahmaputra–Meghna delta, where river discharge, sedimentation, and tidal dynamics strongly influence salinity patterns in coastal areas (Feist, Hoque, & Ahmed, 2022).
- **Climate change exposure:** The country frequently experiences cyclones, storm surges, and changing rainfall patterns, which intensify salinity intrusion and increase environmental risks in coastal regions (Awal, 2014; IPCC, 2022).
- **Impacts on water resources and public health**: Salinity intrusion affects freshwater availability for drinking and irrigation and has implications for public health and sanitation in coastal communities (Nahian, Ahmed, Lázár†, Hutton†, & Salehin, 2018).
- **Existing policy frameworks and adaptation initiatives**: Bangladesh has developed several national strategies addressing coastal management and climate adaptation, including the Bangladesh Delta Plan 2100 and the National Adaptation Plan (NAP 2023–2050), providing opportunities to analyze policy implementation and effectiveness (GED, 2018).
- **Opportunities for innovation and international collaboration:** Bangladesh hosts multiple pilot projects and research initiatives focused on salinity management, creating opportunities to scale up solutions and strengthen international cooperation in water and coastal management (Hossain & Li, 2024)

1.5 Limitations of the Study

While comprehensive, the study faced certain constraints:

- **Technical Gaps:** The study relied on existing analytical tools, models, and spatial datasets. While information on future projections for different Climate Change scenario is presented, limitations remain in capturing long-term uncertainties, and cross-sectoral interactions in a fully integrated manner. These technical gaps are particularly relevant for localized assessments and fine-scale regional level planning and decision making.
- **Data Consistency:** The study faced challenges related to the availability, accessibility, and consistency of detailed and up-to-date data. High-resolution spatial data, long-term time-series datasets, and disaggregated socio-economic information were not uniformly available across sectors or regions. In addition, variations in data formats, scales and reference years etc. constrained seamless integration and comparative analysis.

2 Approach and Methodology

2.1 Study Design and Approach

A structured, participatory, and evidence-based approach is used to conduct the Salinity Scoping Study in Bangladesh. The assignment applied a mixed-methods approach, combining both desk research and fieldwork. The study is designed to bridge the gap between field-level agricultural adaptation and large-scale water management. It utilizes a holistic framework that looks at temporal scales (from immediate short-term impacts to long-term future projections) to identify response measures across different spatial scales (from individual fields to regional) level. This approach ensures that the findings are both scientifically robust and practically applicable for developing multi-annual action plans under the SW&FS Partnership. The study has been designed considering 3 main components (as shown in Figure 2.1) and accordingly, the report chapters are laid out:

a) Preparatory Research and Evidence Mapping
b) In-depth Field Investigation and Data Analysis
c) Data Triangulation, Synthesis and Validation

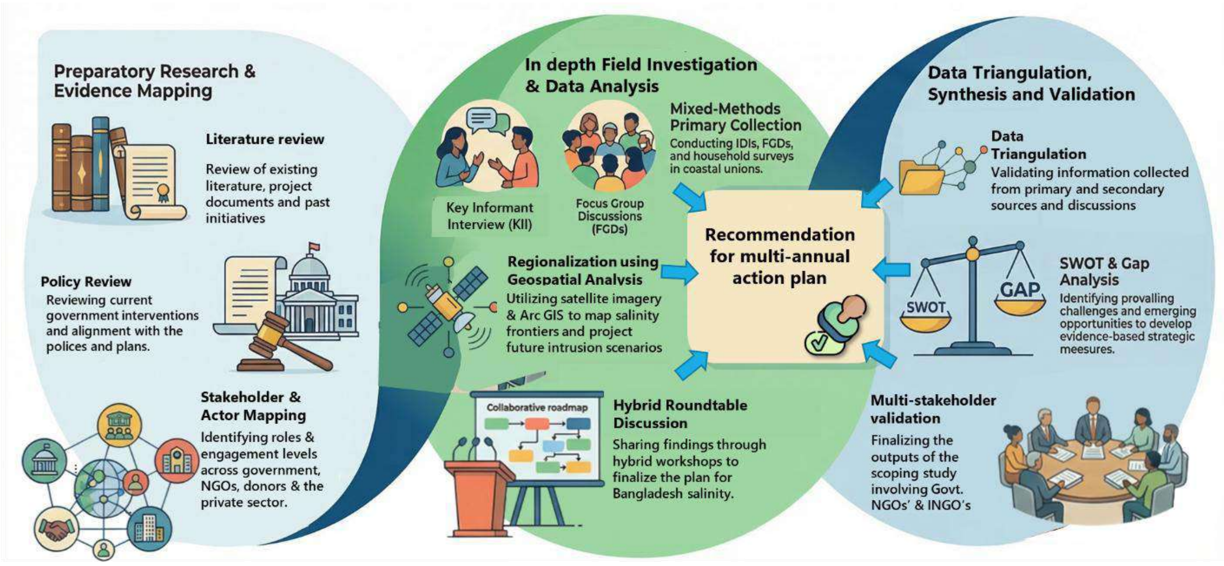

Figure 2.1: Methodological Framework

2.2 Preparatory Research and Evidence Mapping

Initially, some desk research work was done to gain an understanding of the salinity problems, issues that provided the basis of this study. The desk work included review of literature and policies on salinity.

Literature Review

As part of this study, past and ongoing salinity-focused programmes and interventions was evaluated. Particular attention was be given to identifying linkages with Dutch-supported initiatives and other international efforts aimed at addressing salinity challenges, ensuring that the study builds on existing knowledge. Key sources included:

- Project Reports: Evidence and lessons learned from major initiatives such as COASTS, SAFAL-IWRM, and Blue Gold.
- Scientific Literature: Published journals and technical analyses focusing on isohalines, soil salinity mapping, and sea-level rise (SLR) scenarios.

Policy Review

Existing policies, plans, and strategies, that are relevant to this study were collected and examined. Policy guidelines from some key policies e.g the Coastal Zone Policy, National Water Policy, Agriculture Policy, Bangladesh Climate Change Strategy and Action Plan and national level Plans such as the Bangladesh Delta Plan 2100 (BDP2100), the National Adaptation Plan (NAP 2023–2050). Apart from these polices and plans the Bangladesh Water Act 2013 was also reviewed.

2.3 In-depth Field Investigation and Data Analysis

Salinity related issues and its potential management options were obtained through primary data collection process. Information gathered from secondary sources was analyzed to provide an overview of the geographical distribution and impacts of salinity.

Geospatial Analysis

For the field work georeferenced maps were prepared and used, with the data of secondary sources Additionally, GIS-based data and maps, collected from secondary sources were analyzed to illustrate the regional distribution of salinization across the districts located in the southern part of the country.

In-depth Field Investigation

Intensive field-based engagement with diverse stakeholders included Key Informant Interviews (KII) with relevant agencies and community consultation with local people. Local perceptions helped in documenting salinity impacts and the resulting threats to food security and public health. For conducting the in-depth interviews i.e KIIs and community surveys, 3 locations were identified as indicated in the following table and map:

Table 2.1: Survey Locations

Location	Sub Location	Upazila	District
	Upazila Krishi Office	Rupsa	Khulna
	Upazila Livestock office and Veterinari Hospital	Rupsa	Khulna
	Local Farmers and Stakeholders	Rupsa	Khulna
	Chalna Bazar Government Girl's High School	Dacope	Khulna
	Department of Public Health Engineering (DPHE)	Dacope	Khulna
	Local Farmers and Stakeholders	Dacope	Khulna
	Upazila Krishi Office	Paikgachha	Khulna
	Union Chairman	Paikgachha	Khulna
	Local Farmers and Stakeholders	Paikgachha	Khulna

Institutional-Level Inquiry using Key Informant Interview (KII)

Interviews were conducted with experts and practitioners from government agencies (e.g., BWDB, DAE, SRDI), research institutions, and the private sector (e.g., Lal Teer Seeds). These interviews provided specialized insights into policy gaps, technical limitations, and institutional challenges that are often not available in statistical datasets.

Figure 2.2: KII with Upazila Agriculture Officer, Khulna

Figure 2.3: KII with Headmaster, Chalna Bazar Govt. Girls High School, Dacope, Khulna

Community-Level Inquiry through Consultations

This involved Focus Group Discussions (FGD) with local farmers, fishers, and marginalized groups, particularly women. The survey captured local perceptions on salinity trends over the last decade, specific crop losses (e.g., paddy and Rabi vegetables), and the effectiveness of existing coping strategies like rainwater harvesting and salt-tolerant seed varieties.

Figure 2.4: Community Survey at Tilldanga, Dacope, Khulna

Figure 2.5: FGD at Dacope, Khulna

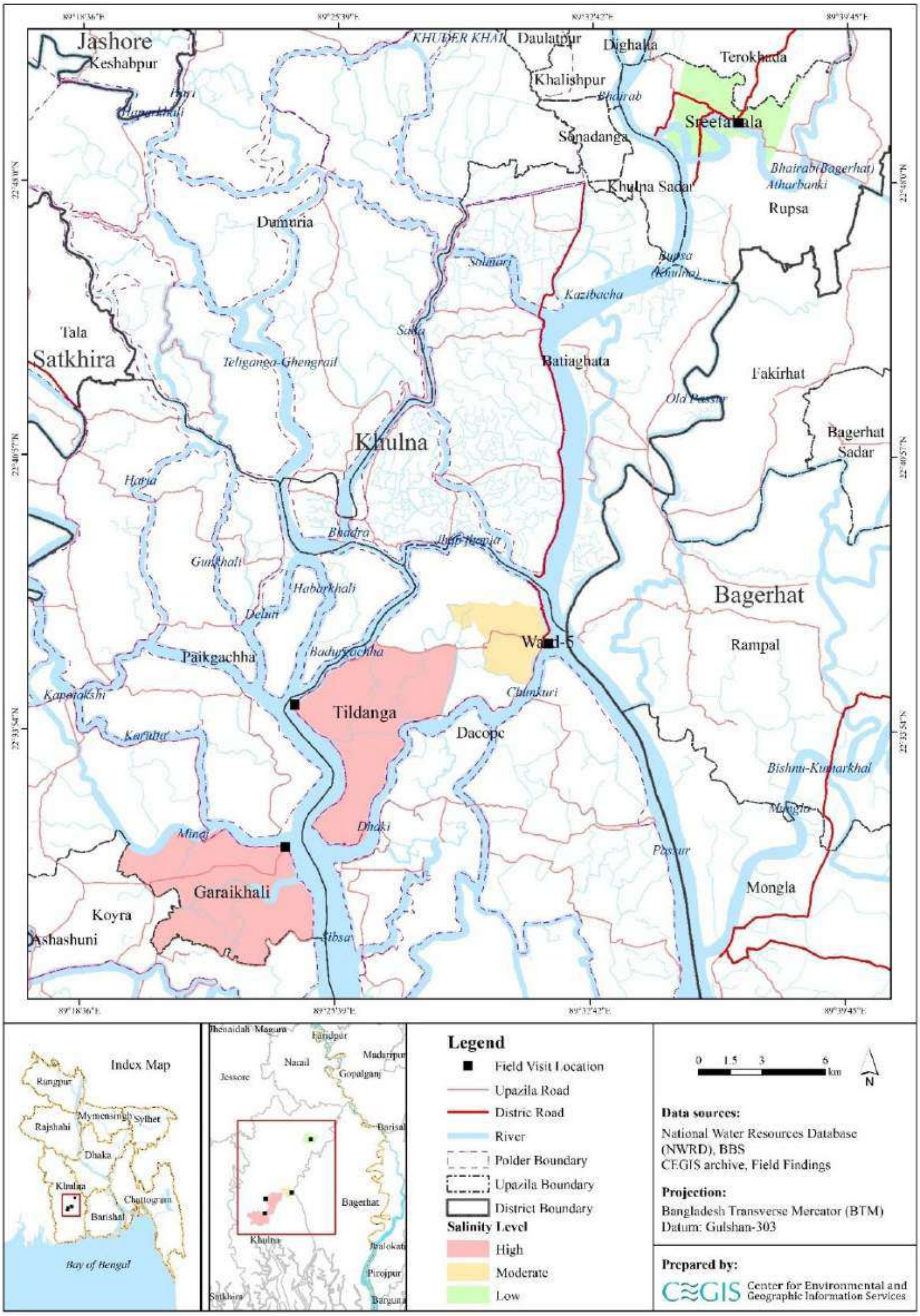

Figure 2.6: Locations of field investigation

2.4 Data Triangulation, Synthesis and Validation

All interview findings were thoroughly documented and analyzed to highlight the prevailing challenges, existing gaps, and emerging opportunities for tackling salinity-related issues. Together, these findings will form the evidence base and provide critical inputs for shaping a comprehensive multi-annual action plan for Bangladesh.

Data Triangulation

The collected data were screened and analyzed to ensure accuracy and policy relevance. In parallel, key insights from the review of relevant policies, plans, and programmes were extracted and synthesized.

SWOT and Gap Analysis

Primary interview findings were documented and cross-referenced with secondary model-computed data to identify SWOT (Strengths, Weaknesses, Opportunities, and Threats) factors affecting salinity management. Accordingly, gaps related to salinity management, policy implementation and knowledge gaps were identified through a systematic process.

Validation and Finalization

The preliminary findings of the study were shared in a hybrid round table session through multi-stakeholder involvement including the NFP, NWP, the Embassy of the Netherlands. This session provided a platform to exchange perspectives, and facilitate dialogue on the identified challenges, gaps, and opportunities. Finally, a validation workshop was organized and the relevant key stakeholders, development partners, academicians, etc. from mainly Bangladesh and the Netherlands were invited. It also helped validate the findings and also build a consensus on priority actions and strengthen collaboration among stakeholders for addressing salinity-related issues in Bangladesh and other countries.

3 Preparatory Desk Research and Evidence Mapping

3.1 Exploring Salinity in Bangladesh

3.1.1 Drivers and Pressure of Salinization

Salinity intrusion refers to the movement of saline water into freshwater systems such as rivers, canals, aquifers, and agricultural soils. Salinity intrusion is widely recognized as one of the major environmental challenges affecting coastal Bangladesh. It poses as a significant to agriculture, freshwater availability, ecosystems, and the livelihoods of coastal communities (SRDI, 2010; (Dasgupta, Hossain, Huq, & Wheeler, 2015). Increasing salinity levels in soil and water resources reduce agricultural productivity, limit the availability of safe drinking water, and disrupt ecological balance in many coastal areas. The process of salinity intrusion is closely linked to broader environmental and hydrological processes occurring across the delta. Changes in river systems, coastal geomorphology, and climate variability influence the movement and distribution of saline water within the coastal landscape. These processes collectively contribute to increasing salinity levels in surface water, groundwater, and soils across different parts of the coastal region (Feist, Hoque, & Ahmed, 2022; Hossain & Li, 2024).

The links between driving forces that cause and enhance salinization and create pressure on the water and soil system are indicated in the DPSIR (Drivers, Pressure, State, Impact, Response) Framework (Figure 3.1). The framework also shows the resulting impacts on different sectors and provides some examples of response measures. The drivers, pressure and impacts obtained from literature review are presented in following paragraphs in detail. The subsequent policy responses and initiatives which can be adopted to manage salinity are provided in Chapter 4.

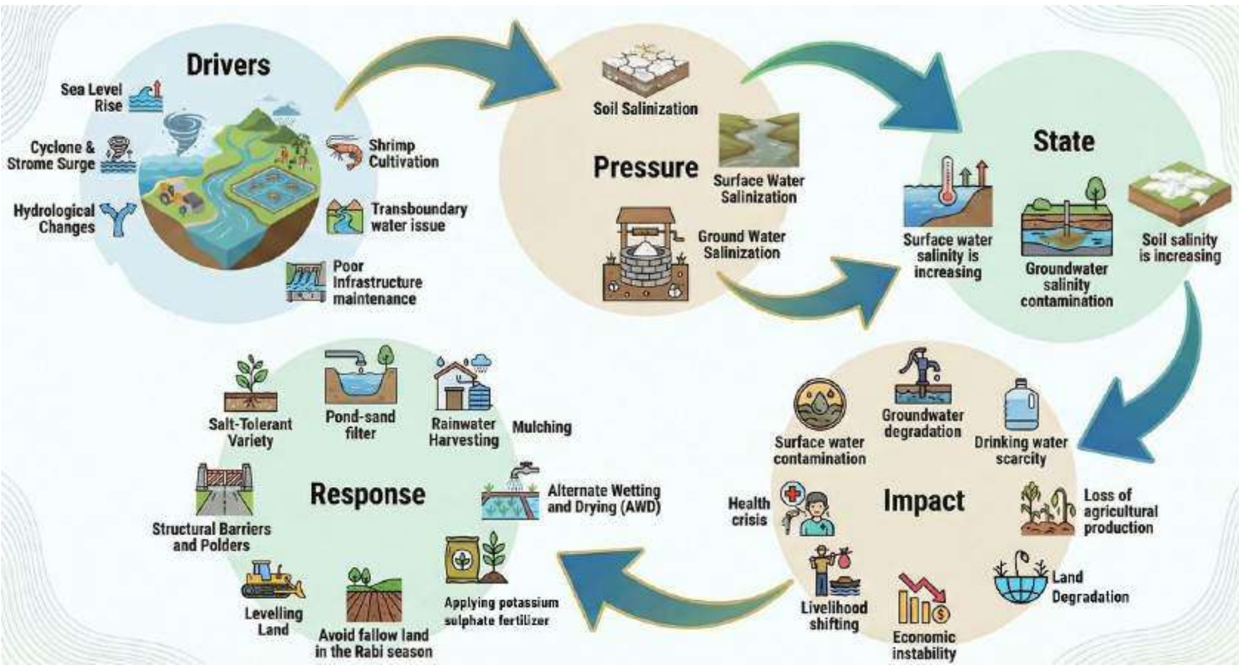

Figure 3.1: DPSIR Framework

Source: Modified from Shammi, M., et al. 2020

Key Drivers of Salinity

The sources categorize the drivers of salinity into natural, anthropogenic (human-induced), and institutional factors:

Climatic Drivers:

- **Sea Level Rise (SLR):** Sea level rise is one of the primary drivers of salinity intrusion in coastal Bangladesh. As sea levels rise, saline water from the Bay of Bengal penetrates further inland through tidal rivers, canals, and estuaries. Bangladesh's low-lying deltaic landscape and funnel-shaped coastline further intensify tidal influence, allowing saline water to move deeper into inland water systems (Nur, Aktar, Setu, & Rahim, 2024; Dasgupta, Hossain, & Huq, 2015). This process significantly increases the exposure of coastal agricultural land and freshwater sources to saline conditions.
- **Cyclones and Storm Surges:** Cyclones and storm surges are major climatic drivers that accelerate salinity intrusion in coastal Bangladesh. Extreme weather events such as Cyclones Sidr, Aila, and Amphan have repeatedly breached embankments and polders, allowing large volumes of saline water to inundate agricultural fields, ponds, and settlements. In many cases, saline water remains trapped in low-lying areas for long periods, leading to persistent soil salinization and long-term damage to agricultural productivity (Awal, 2014; Rabbani, 2013).
- **Hydrological Changes:** Hydrological changes in river systems also contribute to salinity intrusion. Sedimentation in river channels reduces river depth and navigability, which limits the capacity of rivers to carry freshwater toward coastal areas. As riverbeds rise due to sediment accumulation, freshwater flow during the dry season decreases, allowing tidal saline water to move further upstream into inland rivers and canals (Rahman & Navera, 2018;Feist et al., 2022). This process gradually increases salinity levels in surface water bodies and adjacent agricultural lands.
- **Temperature and Evaporation:** Increasing temperatures associated with climate change can intensify salinity in coastal soils and water bodies. Higher temperatures accelerate evaporation from soil and surface water, particularly during the dry season when freshwater availability is already limited. As water evaporates, salts remain in the soil and shallow water systems, leading to higher salt concentrations in the root zone and increased stress on crops and vegetation (Hassani et al., 2020; Hossain & Li, 2024).

Anthropogenic (Human) Drivers:

- **Shrimp Farming:** The horizontal expansion of **saline aquaculture (shrimp ghers)** is a major human-induced driver. Saltwater is intentionally brought inland into enclosures, which then seeps into surrounding agricultural lands, destroying soil structure and permanently increasing local salinity.
- **Transboundary Water Issues:** Human interventions such as dams and barrages (e.g., the Farakka Barrage) in neighboring upstream countries have significantly reduced the dry-season flow of fresh water in major river systems like the Ganges, diminishing the "backwater effect" that would otherwise push saline water back toward the sea.
- **Groundwater Extraction:** Over-extraction of groundwater for irrigation and domestic use lowers the water table, facilitating the upward or lateral movement of saline groundwater.
- **Local level Interventions:** Sometimes local people adopt practices (e.g shrimp farming, embankment breaching etc.) which although having short term positive impact might have negative impacts on the long run.

Institutional and Political Drivers:

- **Fragile/fragmented Water Governance:** Inadequate municipal water governance and a lack of coordination among agencies such as the Bangladesh Water Development Board (BWDB) and the Department of Agricultural Extension (DAE) hinder effective salinity management. The overlap in institutional mandates between line agencies implementing water management at the field level leads to operational complexities at the local, regional, and headquarters level. This institutional overlap leads to organizational entropy and a lack of trust between the agencies. Integrated and holistic salinity management initiatives necessitate adherence to ADM and IWRM principles at the micro-level for seamless and coherent implementation. Too many organizations trying to solve a single issue.
- **Poor Infrastructure Maintenance:** Coastal polders and sluice gates are often poorly maintained or damaged by shrimp farmers to let in saltwater, allowing it to flow inland unhindered.

Major Pressures

According to the DPSIR framework, pressures represent the direct stresses on environmental systems as a result of driving forces. In coastal Bangladesh, one of the main pressures is the salinization of soil, surface water, and groundwater systems. Soil salinization occurs when saline water intrudes into agricultural land through tidal flooding, poor drainage, or seepage from nearby saline water bodies. The accumulation of salts in soils reduces soil fertility, limits crop growth, and decreases agricultural productivity (Shammi, et al., 2016). Similarly, surface water salinization occurs when saline tidal water moves inland through rivers, canals, and ponds, particularly during the dry season when upstream freshwater flow is reduced. This process gradually increases salinity levels in freshwater bodies that are traditionally used for irrigation and domestic purposes. In addition, groundwater salinization occurs when saline water infiltrates aquifers or when excessive groundwater extraction allows saline water to move upward or laterally into freshwater layers, reducing the quality of groundwater used for drinking and irrigation. These pressures lead to observable changes in the state of the environmental system.

3.1.2 State of Salinity

Salinity intrusion is the movement of the saline front toward the land. Sea Level Rise makes this process happen faster. The tidal prism, or the amount of water that flows into the estuaries during a tidal cycle, gets bigger as the sea level rises. This pushes saltwater deeper into the river networks. This is not simply a problem on the coast of Bangladesh; the saline front has moved over 100 kilometers inland through the major river systems' interconnecting estuaries and water inlets. Salinity is an escalating environmental crisis in the coastal zone, which constitutes approximately 20% of the country's area and 32% of its total landmass (Baten, Seal, & Lisa, 2015).

In many coastal areas of Bangladesh, the environmental state is characterized by increasing salinity levels in soils, rivers, canals, and groundwater aquifers. Surface water bodies experience higher salinity concentrations, particularly during the dry season when freshwater inflow is minimal. Groundwater sources are also increasingly affected by salinity contamination, reducing access to safe drinking water in coastal communities. At the same time, agricultural soils show rising salt concentrations, which contribute to declining crop yields and reduced cropping intensity in saline-affected areas (Shammi, et al., 2016). An overview of salinization spread across surface and ground water and also soil is presented in the following paragraphs.

Surface Water Salinity

Surface water salinity is primarily driven by tidal interactions and reduced upstream freshwater discharge, allowing saltwater to move towards inland during the dry season (Dasgupta, Hossain, Huq, & Wheeler, 2015). This intrusion is exacerbated by the reduction of freshwater flow from upstream, largely due to human interventions like the Farakka Barrage. In exposed areas, river water salinity can exceed 30 dS/m, rendering it unfit for consumption or irrigation use (Lam, Winch, Nizame, Broaddus-Shea, & Harun, 2021).

To better understand these dynamics, a comprehensive study was conducted using an advanced salinity modeling framework developed within the Delft3D Flexible Mesh system. This multi-dimensional hydrodynamic simulation tool analyzed the complex and variable flow and transport processes influenced by tidal movements and meteorological conditions within the unique and highly dynamic river networks of the Ganges-Brahmaputra-Meghna Delta. The model simulations provide important insights into how climate-induced changes, particularly sea level rise, may alter salinity distribution and influence the interaction between coastal populations and their critical resources, including agricultural land and potable water supplies. The table below delineates the exact Representative Concentration Pathway (RCP) scenarios utilized in the modeling procedure, establishing a clear baseline for the subsequent analysis, and illustrating diverse levels of Sea Level Rise (SLR) based on the most recent international climate evaluations.

Table 3.1: SLR under different RCP Scenarios

RCP Scenario	Scenario Level	Sea Level Rise (Meters)
RCP 4.5	Medium (Ensemble Mean)	0.5
RCP 4.5	Extreme (Ensemble Maximum)	0.7
RCP 8.5	Medium (Ensemble Mean)	0.62
RCP 8.5	Extreme (Ensemble Maximum)	0.95

<u>Salinity intrusion in a tidal dominated delta</u>

In practical terms, **salinity intrusion** is the inland reach (and intensification) of brackish to saline water in rivers, distributaries, and canals - water that communities may depend on for irrigation, domestic supply, and ecosystem functions. Here the outputs, intrusion is communicated through **isohalines** and pragmatic thresholds, especially the **1 ppt and 5 ppt** bands used to describe where "slightly brackish" conditions begin and where constraints typically become far more limiting (for freshwater uses and many crops).

Two interacting controls are emphasized by the modelling approach:

- **Downstream push:** rising mean sea level strengthens tidal influence and supports landward movement of saline water along the river network.
- **Upstream pullback (reduced freshwater resistance):** reduced dry-season discharge weakens the counterflow that normally keeps the salinity front closer to the estuary.

<u>Seasonal Changes and Transboundary Issues</u>

The amount of salt in the water in Bangladesh changes in a strict seasonal way. The huge amount of fresh water that flows out of the GBM system during the monsoon pushes the salty front back toward the sea. But during the dry season, which is usually from December to May, the flow of freshwater drops a lot. This is often made worse by withdrawals upstream, as those at the Farakka Barrage, which lower the rivers' flushing capacity. Because of this, the salinity of rivers in southern districts has already gone up over time, and the future model projections suggest that the dry-season buffering capacity of the river system may weaken even more.

It is to be noted that sea-level rise and reduced freshwater flow do not act separately; they reinforce each other. Sea-level rise strengthens tidal penetration from downstream, while reduced discharge weakens resistance from upstream. The result is not only stronger salinity in the estuaries, but also a deeper and more prolonged seasonal reach of saline water into inland river systems. In a country where river connectivity is so dense, this means that a dry-season salinity problem in one part of the delta can become a wider regional water-management problem. The projected appearance of non-coastal districts in the affected list under future scenarios is therefore consistent with the broader hydrological logic of a delta under rising sea level and declining dry-season flushing.

<u>Regional differentiation of areas affected by surface water salinity</u>

The district-wise assessment (Table 4.1, 4.2 and 4.3) provides a clear picture of how this inland expansion unfolds under different salinity thresholds and SLR scenarios. For the 1 ppt threshold, which marks the onset of slight brackishness and is important for irrigation and freshwater services, the number of affected districts increases from 18 districts under 0.50 m SLR to 20 districts under 0.62 m SLR, and then rises sharply to 28 districts under 0.95 m SLR. This is not a marginal increase. It shows that once sea-level rise reaches the higher-end scenario, the salinity front expands well beyond the traditionally affected coastal belt and begins to involve a much wider regional geography.

For the 5 ppt threshold, which represents a more restrictive salinity condition for many freshwaters uses and crops, the same pattern is visible, though the extent is more concentrated. The total number of affected districts rises from 13 districts under 0.50 m SLR to 17 districts under 0.62 m SLR, and then to 23 districts under 0.95 m SLR. In practical terms, this means that not only does saline water move inland, but the severity of that salinity also intensifies across a larger area under higher SLR conditions.

The spatial pattern is equally important. Under all scenarios, the exterior coastal districts remain the first line of exposure. Districts such as Bagerhat, Barguna, Bhola, Khulna, Patuakhali, and Satkhira remain affected across both salinity thresholds and across all SLR cases, showing a persistent and structural vulnerability. However, the modelling also reveals a progressive inland shift toward interior coastal districts such as Barisal, Gopalganj, Jessore, Jhalokathi, Narail, and Pirojpur. This suggests that the salinity problem is not static; it advances through the estuarine-riverine network and gradually transforms districts that are not usually considered frontline coastal salinity zones.

Another striking outcome of the model is the appearance of non-coastal districts in the affected list. Under the 1 ppt, 0.50 m SLR scenario, already four non-coastal districts - Chuadanga, Jhenaidah, Madaripur, and Magura - are projected to be affected. This number remains four at 0.62 m SLR, but under 0.95 m SLR it rises to nine non-coastal districts, with Bandarban, Comilla, Faridpur, Khagrachhari, and Rangamati joining the affected list. A similar inland transition is visible under the 5 ppt threshold. At 0.50 m SLR, Bandarban, Chuadanga, and Khagrachhari appear in the affected list; by 0.62 m SLR, Jhenaidah and Magura are added; and by 0.95 m SLR, Comilla and Faridpur also emerge. This is one of the strongest findings of the analysis, because it demonstrates that future sea-level rise may push salinity influence into districts that are currently treated as outside the main salinity-risk zone.

The following table summarizes the projected landward expansion of saline zones across different SLR scenarios:

Table 3.2: Anticipated SLR Impacts and Major Impacted Districts

SLR Scenario	Impact on Coastal Zone	Major Impacted Districts
0.50 m	Salinity remains concentrated in exposed coastal and selected interior districts, with early signals in a few non-coastal areas	Pirojpur, Patuakhali, Bhola, Chuadanga
0.62 m	The affected zone expands across more exterior coastal districts and becomes more established in interior coastal districts	Bagerhat, Barguna, Khulna, Noakhali, Feni
0.95 m	A much broader inland spread occurs, including new interior coastal and non-coastal districts	Barisal, Gopalganj, Shariatpur, Comilla, Faridpur, Bandarban, Rangamati

Currently, districts like Gopalganj and Shariatpur do not face major salinity stress in the 1–5 ppt range in the same way as the exposed coast. Under the 0.95 m SLR scenario, however, the modelling result done by CEGIS suggests that these districts begin to enter the salinity-affected zone. That change is important because it means the geography of salinity risk is no longer confined to the outer coastal edge; it starts to reshape inland districts that depend on rivers, canals, and connected floodplain systems for water and livelihoods.

The landward ingress distances strengthen this interpretation. For the 1 ppt front, the model suggests an additional inland movement of about 21 km from 0.50 m to 0.62 m SLR, 48 km from 0.62 m to 0.95 m SLR, and as much as 69 km from 0.50 m to 0.95 m SLR. For the 5 ppt front, the additional ingress is estimated at 16 km, 45 km, and 53 km for the same transitions, respectively. These distances show that salinity intrusion is not simply becoming stronger near the coast; it is also migrating inland in a measurable and potentially disruptive way.

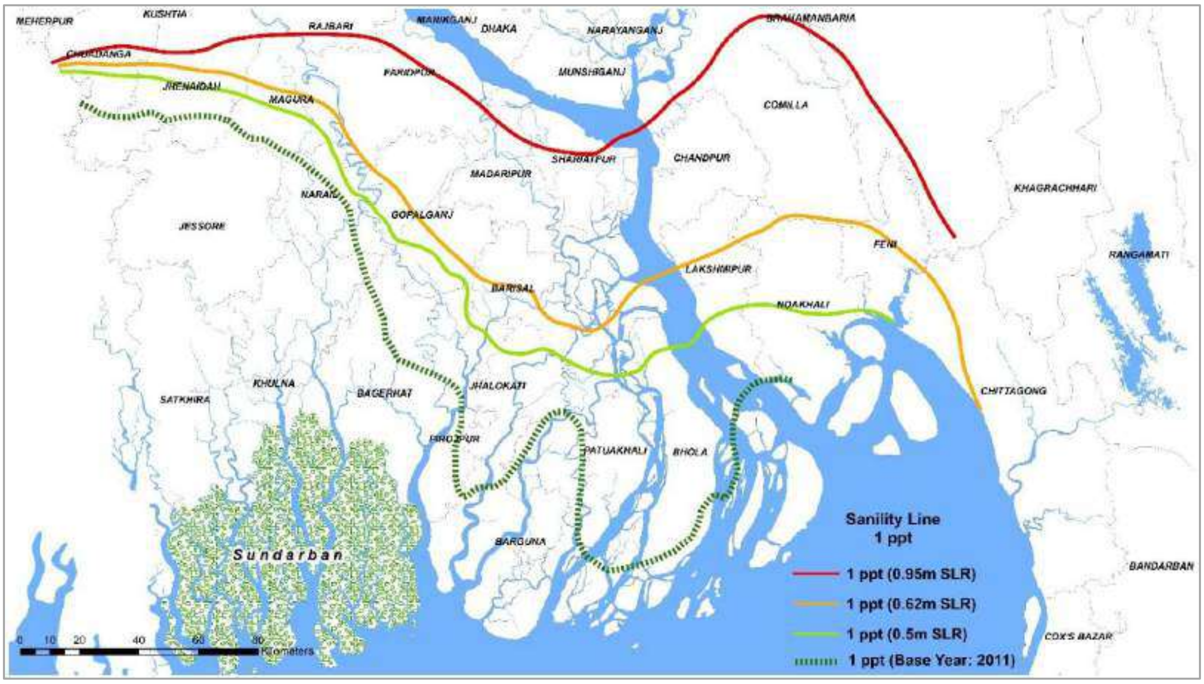

Figure 3.2: Map showing Ingress of Salinity (1 ppt- Isohaline) for Different SLR Scenario

(Source: DOE, 2024)

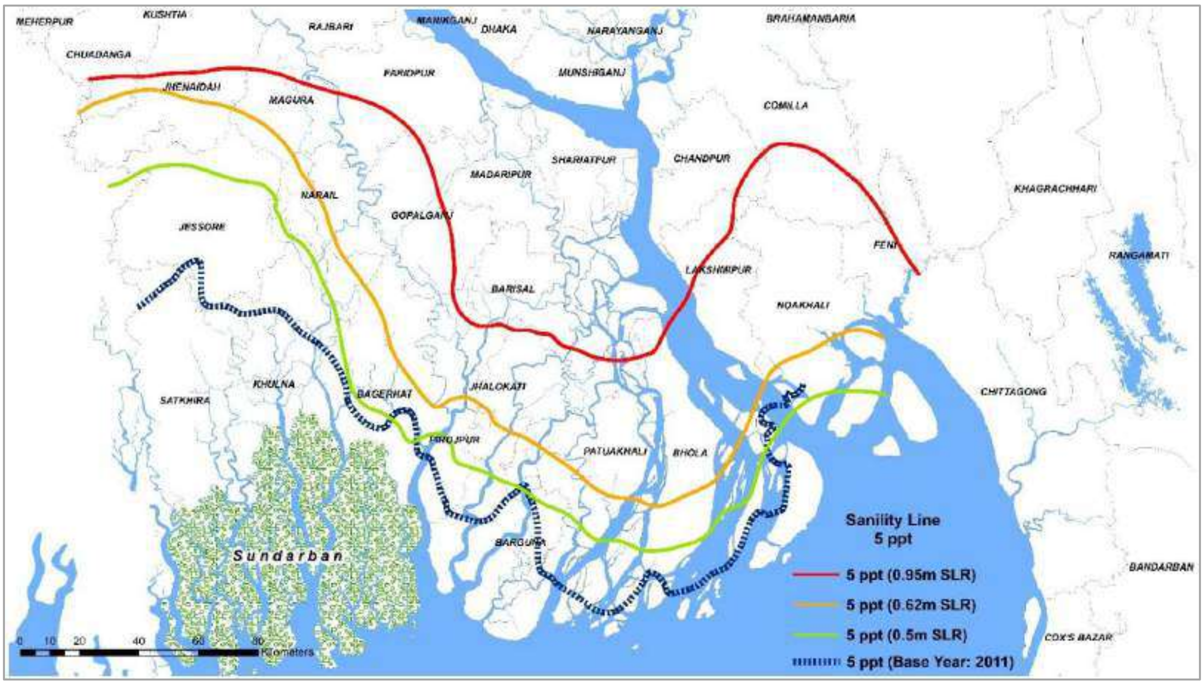

Figure 3.3: Map showing Ingress of Salinity (5 ppt- Isohaline) for Different SLR Scenario

(Source: DOE, 2024)

Table 3.3: Affected Districts under different salinity and SLR scenarios[1]

District	Status	1 ppt 0.5 m	1 ppt 0.62 m	1 ppt 0.95 m	5 ppt 0.5 m	5 ppt 0.62 m	5 ppt 0.95 m
Bagerhat	Coastal	✓	✓	✓	✓	✓	✓
Barguna	Coastal	✓	✓	✓	✓	✓	✓
Bhola	Coastal	✓	✓	✓	✓	✓	✓
Chandpur	Coastal	-	-	✓	-	-	✓
Chittagong	Coastal	-	✓	✓	-	-	✓
Cox's Bazar	Coastal	-	-	✓	✓	✓	✓
Feni	Coastal	-	✓	✓	-	-	✓
Khulna	Coastal	✓	✓	✓	✓	✓	✓
Lakshmipur	Coastal	✓	✓	✓	-	-	✓
Noakhali	Coastal	✓	✓	✓	-	✓	✓
Patuakhali	Coastal	✓	✓	✓	✓	✓	✓
Satkhira	Coastal	✓	✓	✓	✓	✓	✓
Barisal	Coastal	✓	✓	✓	-	-	✓
Gopalganj	Coastal	✓	✓	✓	-	-	✓
Jessore	Coastal	✓	✓	✓	✓	✓	✓
Jhalokathi	Coastal	✓	✓	✓	✓	✓	✓
Narail	Coastal	✓	✓	✓	-	✓	✓
Pirojpur	Coastal	✓	✓	✓	✓	✓	✓
Shariatpur	Coastal	-	-	✓	-	-	-
Rangamati	Non-coastal	-	-	✓	-	-	-
Chuadanga	Non-coastal	✓	✓	✓	✓	✓	✓
Jhenaidah	Non-coastal	✓	✓	✓	-	✓	✓
Magura	Non-coastal	✓	✓	✓	-	✓	✓
Comilla	Non-coastal	-	-	✓	-	-	✓
Faridpur	Non-coastal	-	-	✓	-	-	✓
Madaripur	Non-coastal	✓	✓	✓	-	-	-

[1] Note: Coastal-district tagging follows the standard Bangladesh coastal-zone policy definition. “Exterior/Exposed” and “Interior” are shown here as practical district-level groupings for presentation, although the formal exposed/interior distinction is defined mainly at upazila level. The BDP hotspot shown is the dominant district-level hotspot used for reporting, since hotspot coverage may overlap

Table 4.3: Additional landward ingress under different SLR transitions

Salinity threshold	SLR comparison	Additional landward ingress
1 ppt	0.50 m to 0.62 m	21 km
1 ppt	0.50 m to 0.95 m	69 km
1 ppt	0.62 m to 0.95 m	48 km
5 ppt	0.50 m to 0.62 m	16 km
5 ppt	0.50 m to 0.95 m	53 km
5 ppt	0.62 m to 0.95 m	45 km

Although salinity intrusion is often discussed as a coastal problem, the modelling results show that the challenge is more spatially diverse and more dynamic than a simple "coast versus non-coast" distinction. In Bangladesh, salinization risk is most pronounced in the Coastal Zone hotspot, where tidal influence, estuarine connectivity, low dry-season freshwater flow, and sea-level rise combine to create the most direct exposure. Within this hotspot, the exposed coastal districts such as Bagerhat, Barguna, Bhola, Khulna, Patuakhali, and Satkhira remain consistently vulnerable across all scenarios, reflecting their direct hydraulic connection with the Bay and the lower estuarine system. At the same time, the modelling also shows that the impact does not stop at the immediate coastline. Several interior coastal districts such as Barisal, Gopalganj, Jessore, Jhalokathi, Narail, and Pirojpur are also projected to experience salinity intrusion, indicating that saline water can propagate inland through the intricate network of tidal rivers, distributaries, and canals.

A particularly important message from the scenario analysis is that future salinity risk extends beyond the conventional coastal hotspot. Under higher SLR conditions, salinity signatures begin to appear in districts associated with other BDP 2100 hotspot settings, including the River Systems and Estuaries, Barind and Drought-Prone Areas, and even the Chattogram Hill Tracts. This is a critical planning insight. It means salinity should not be treated only as a coastal embankment or estuarine management issue; rather, it is a broader delta-wide water management issue that may reshape freshwater availability, irrigation suitability, and ecological conditions across multiple regions of Bangladesh.

It is important to clarify that the regional differentiation discussed in this section refers specifically to modelled surface-water salinity intrusion under SLR scenarios. In this analysis, salinity movement is primarily controlled by tidal penetration from downstream and reduced freshwater discharge from upstream during the dry season. Based on the modelling results, even under the higher-end 0.95 m SLR scenario, the 1 ppt salinity front does not appear to advance toward the northern region under normal conditions. This suggests that large-scale northward expansion of surface-water salinity, driven by sea-level rise alone, is not strongly indicated by the present simulation.

However, this does not mean that salinity is absent from northern or other inland regions of Bangladesh. In those areas, salinity may occur through different pathways, including groundwater mineralization, soil salinity, irrigation-induced accumulation, local hydrogeological conditions, or the effects of extreme events. Therefore, salinity in Bangladesh should be understood as a multi-dimensional issue: coastal river salinity intrusion is one important form, but groundwater and soil salinity in non-coastal regions may follow different processes and require separate assessment and interpretation.

Groundwater Salinity

Groundwater is the primary drinking source for 97% of the rural population, yet it is increasingly contaminated by salt (Nahian, Ahmed, Lázár†, Hutton†, & Salehin, 2018). Mapping indicates that only 16% of coastal groundwater is considered safe, while 33% is classified as "very harmful"(BADC, CEGIS, 2019). In certain southwestern regions, salinity has been detected in aquifers as deep as 1,800 feet. This salinization is driven by over-extraction for irrigation and domestic use, which causes lateral saltwater intrusion and the "up-coning" of deeper saline wedges (Lam, Winch, Nizame, Broaddus-Shea, & Harun, 2021).

Regional differentiation of areas affected by ground water salinity

Groundwater contamination is as severe as the surface water salinization; with salinity detected in aquifers as deep as 1,800 feet in southwest region, as found from our survey data. This crisis, most intense in southwestern districts is projected to expand inland as sea-level rise continues to push saline fronts deeper into the delta.

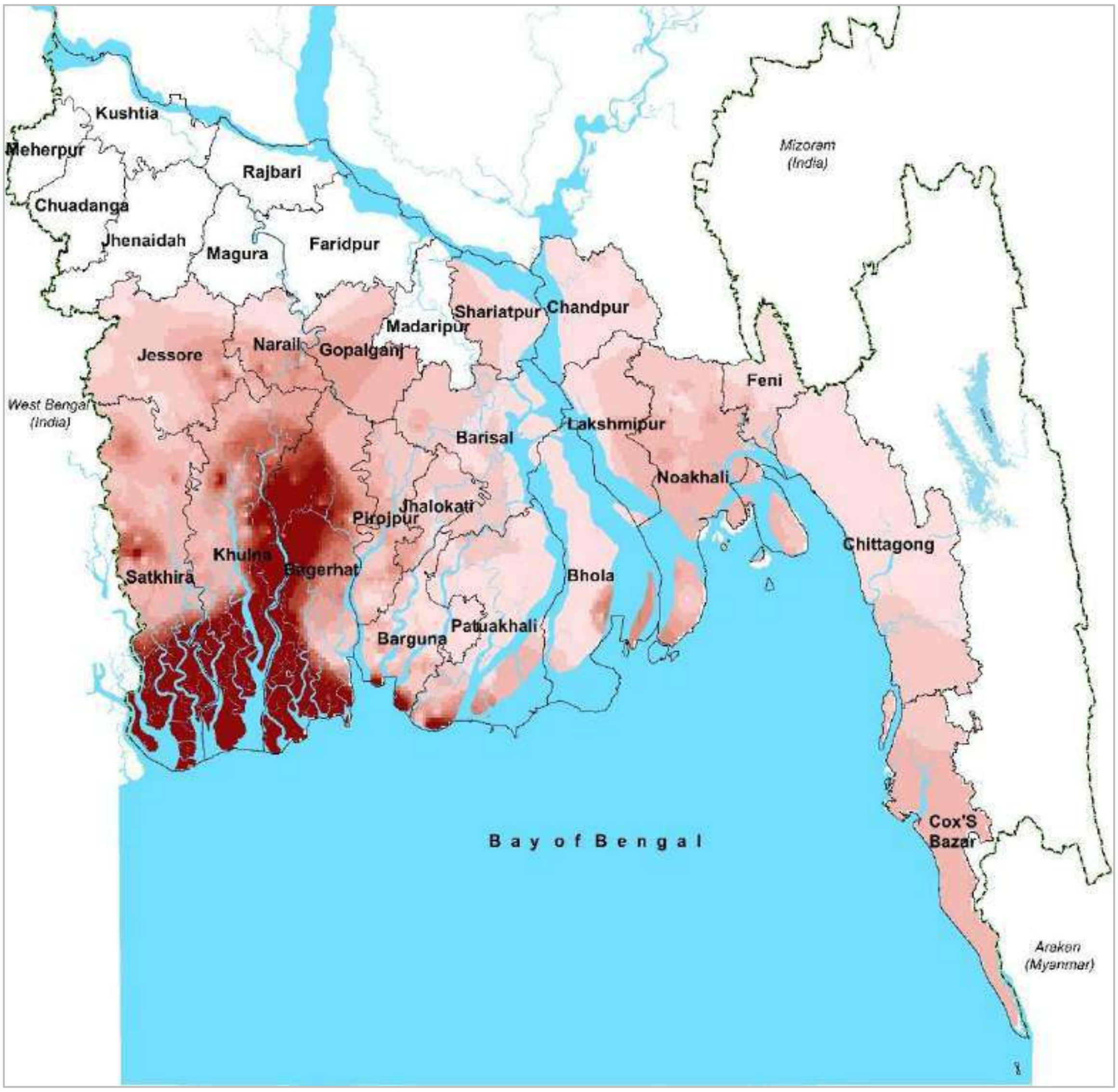

Figure 3.4: Groundwater Salinity Map of the Coastal Zone of Bangladesh

Source: (BADC, 2019 and CEGIS)

In north-west Bangladesh, salinity is not widely recognized as a significant coastal-style surface-water intrusion issue. The evidence suggests that the problem of groundwater salinity is more localized and is mostly caused by hydrogeological conditions, irrigation dependence, and activities that are specific to the site (Afroza et al., 2009; Mazumder et al., 2014). A hydrochemical study in the Lower Tista Floodplain found a clear difference between fresh groundwater in the north and saline groundwater in the south. The salinity level tended to rise with depth. The same study found that water from 20 to 30 meters deep was generally good for drinking and irrigation, but water from 30 to 50 meters deep was usually bad and not good for irrigation (Afroza et al., 2009). In the Lower Atrai Floodplain, researchers found a two-part aquifer system. The upper aquifer has different levels of salinity, while the lower aquifer is usually saltier. They also found that saline groundwater had already been found in about 61 km^2 of the area and that irrigation development had depended on more than 8,000 deep tubewells and 96,000 shallow tubewells (Mazumder et al., 2014).

Recent evidence from the broader High Barind region indicates the presence of salinity, albeit typically at relatively low and localized concentrations in contrast to the coastal belt. In one official test of 50 groundwater samples, the salinity ranged from 0.13 to 0.95 ppt, the electrical conductivity ranged from 186 to 1,190 μS/cm, and the total dissolved solids ranged from 82 to 580 mg/L. Forty-six of the fifty samples were deemed suitable for consumption, while the remaining four were considered acceptable. This supports a balanced view: salinity in the northwest is real, but it is not the main water problem in the region like it is along the coast (IWM, 2024).

At the same time, the stress on groundwater in the north-west is much more severe and well-known. A recent study of the Barind region found that more than 97% of groundwater is used for farming. This is because a thick clay layer, which is about 20 to 80 meters deep in many places, stops water from moving down. The same study found that 13 of Rajshahi's 71 unions, 10 of Chapai Nawabganj's 45 unions, and 24 of Naogaon's 99 unions had very high levels of water stress. This indicates that the primary regional issue continues to be the scarcity and depletion of groundwater, while salinity serves as a significant yet geographically confined groundwater-quality concern (Islam et al., 2026).

Another important issues that were observed during a recent study is that certain interventions e.g shrimp farming have made the salinity condition worse. A report from Rajshahi, Natore, and Naogaon that was linked to the BWDB found higher groundwater EC values in some fish-farming areas. For example, Durgapur had values between 800 and 1,400 μS/cm, and Puthia had values between 953 and 1,218 μS/cm. Atrai and Singra had lower values, but they were still significant. A fish farmer from Durgapur Upazila said in that report, "We dump about 50 kg of salt into our three-acre pond twice every winter." This does not indicate a region-wide salinity crisis; however, it suggests that in certain areas of north-west Bangladesh, salinity may be developing as a localized, partially anthropogenic groundwater issue in a region already facing significant stress from drought and excessive groundwater extraction (Roy, 2024)

Soil Salinity

This intensity of soil salinity is highly seasonal, peaking during the dry season (March–May) when freshwater flow from upstream is minimal and evaporation rates are at their highest. The phenomenon exhibits a distinct regional differentiation, with the highest levels found in the southwestern districts like Khulna, Satkhira, and Bagerhat, while the eastern coast remains relatively less affected.

Historically, the salt-affected area has expanded significantly, rising from 0.833 million hectares in 1973 to 1.056 million hectares by 2009. The total coastal and offshore area of the country is about 2.85 million hectares. Out of this, 1.056 million hectares of land is affected by varying degrees of soil salinity. That is, 7.2% of the total land of Bangladesh is affected by salinity. The 'Severe' and 'Very Severe' land category covers 6,14,645 hectares, which is 4.2% of the country's land (SRDI, 2010). The very severely (S4 and S5 classes) affected land nearly doubled between 2000 and 2020 (SRDI, 2000).

Table 3.4: Changes in soil salinity area (ha) by category, 2000–2020

Salinity Category	Area in 2000 (Ha)	Area in 2020 (Ha)	Change in Area (Ha)	Change in Area (%)
Slightly Saline	157,010	312,529	+155,519	+99.05%
Moderately Saline	439,180	740,489	+301,309	+68.61%
Highly Saline	309,190	329,219	+20,029	+6.48%
Extremely Saline	115,370	763,344	+647,974	+561.65%
Total Area	**1,020,750**	**2,145,581**	**+1,124,831**	**+110.20%**

<u>Regional differentiation of areas affected by soil salinity</u>

Based on the salinity maps produced by SRDI, soil salinization in Bangladesh mainly covers the 19 coastal districts with varying degrees of severity. According to the SRDI, the most critically affected districts in the Southwest coastal region are Satkhira, Khulna, Bagerhat, Pirojpur and Barguna. While, in the South-central coastal region the districts with a mix of moderate and severe salinity are Barisal, Bhola, Patuakhali and Jhalokati. SRDI data also shows landward expansion of salinity, which is important: Jashore, Narail, Gopalganj, Madaripur, Faridpur (partly) and Magura. These districts are not usually saline, but due to tidal intrusion, reduced upstream freshwater flow, and drainage issues, salinity is expanding towards new areas as shown below and indicated in Figure 3.5 and Figure 3.6.

- Khulna → Jashore–Narail–Gopalganj belt
- Barisal → Madaripur inland direction

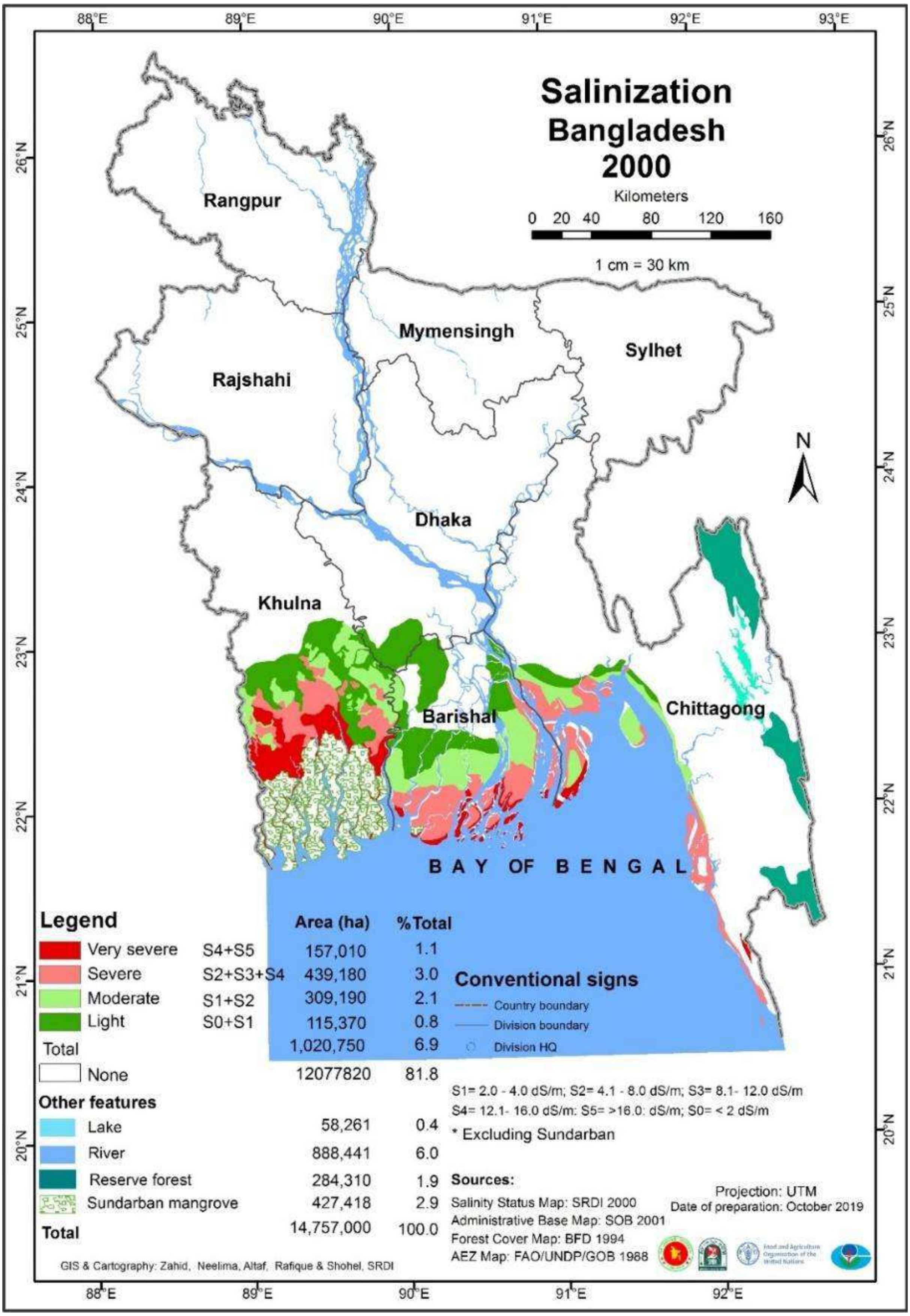

Figure 3.5: Soil Salinity of Bangladesh in 2000

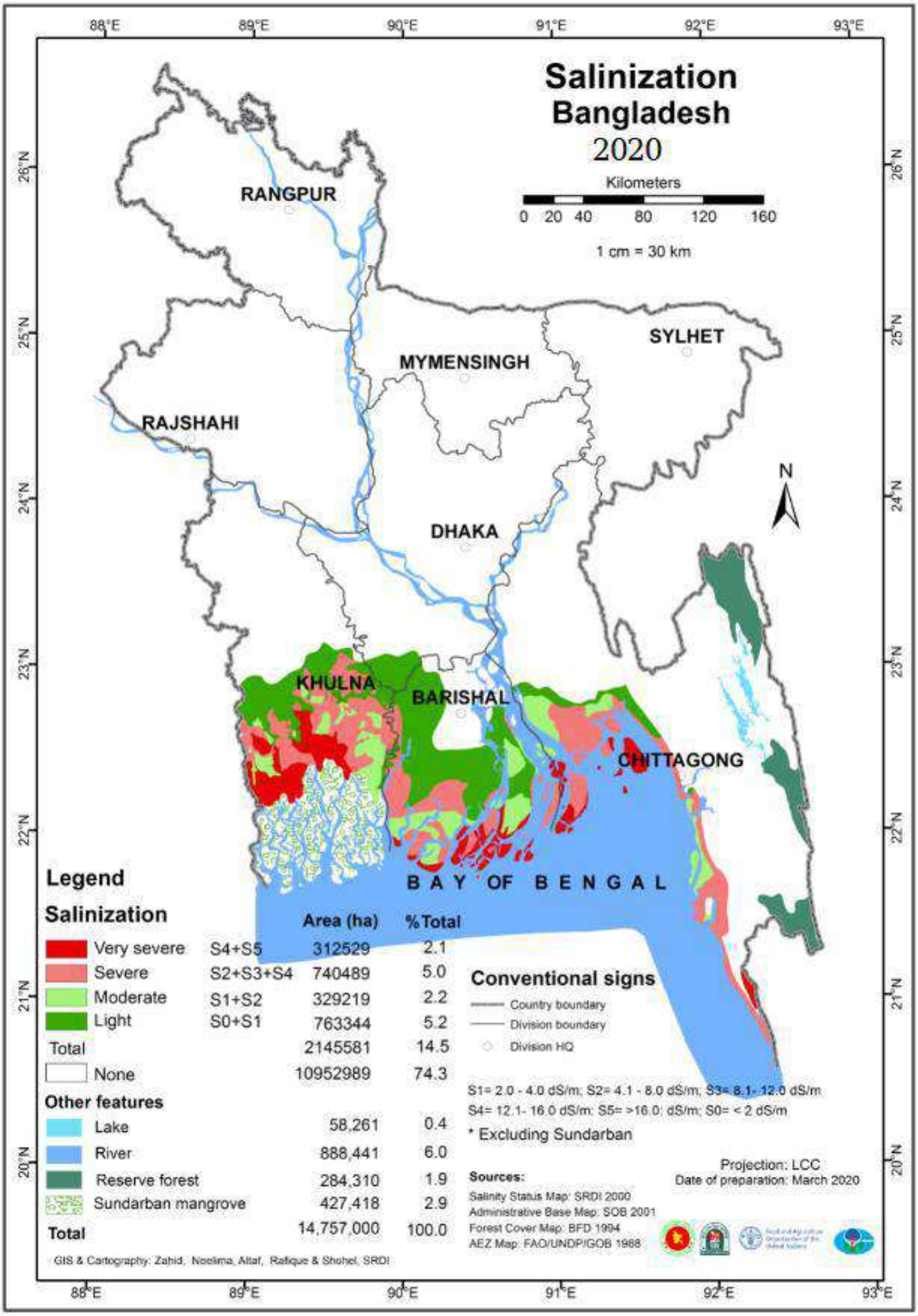

Figure 3.6: Soil Salinity of Bangladesh in 2020

3.1.3 Observed Impact of soil, surface and groundwater salinity

The increasing salinity of soil, surface water, and groundwater in coastal Bangladesh, driven by climate-induced sea-level rise and human interventions, creates a systemic crisis across agriculture, health, and economic sectors. The following subsections present the overarching impacts of salinity on different sectors based on secondary analysis. considering the significance of surface water salinity in salinity intrusion, impact of surface water salinity based on quantitative analysis is also presented in the following subsections.

Impact on Agriculture

Salinity intrusion is widely recognized as one of the major environmental constraints affecting agriculture in the coastal region of Bangladesh. The coastal zone covers approximately one-third of the country's cultivable land, and a significant portion of this area is affected by varying degrees of soil and water salinity, which limits agricultural productivity and cropping intensity (SRDI, 2010; Shawkhatuzamman et al., 2023).

Salinity affects crop production through several biophysical processes. High salt concentrations in soil reduce plant water uptake, cause ion toxicity, and disrupt nutrient balance, which ultimately inhibits plant growth and reduces yields (Hossain & Li, 2024; Miah et al., 2020). These effects are particularly severe in low-lying coastal areas where saline water intrusion occurs frequently through tidal flooding and saline groundwater.

Empirical studies in the coastal districts of Bangladesh indicate that salinity intrusion significantly reduces crop productivity. Yield losses in major crops such as rice, wheat, pulses, and vegetables are estimated to range from 20% to 40% depending on salinity levels and crop tolerance (Miah et al., 2020; Dasgupta et al., 2015). As a result, many farmers face declining agricultural productivity and increased production risks.

Seasonal variation plays a major role in determining the agricultural impacts of salinity. During the dry season, reduced upstream freshwater flow and increased tidal influence allow saline water to penetrate further inland, increasing soil and surface water salinity in agricultural fields. This seasonal salinity particularly affects dry-season crops such as boro rice and vegetables, which rely heavily on irrigation water.

Salinity intrusion also influences land use patterns and agricultural practices in coastal Bangladesh. Increasing soil salinity has contributed to the expansion of brackish water shrimp aquaculture, which often replaces traditional crop cultivation in saline-prone areas (Feist, Hoque, & Ahmed, 2022). While shrimp farming can generate income for some farmers, it often accelerates soil salinization and reduces the long-term viability of crop agriculture in surrounding areas.

In addition to biophysical impacts, salinity intrusion affects farmers' livelihood strategies and agricultural decision-making. Studies show that farmers increasingly adapt to salinity stress by adopting salt-tolerant crop varieties, modifying cropping patterns, or leaving land fallow during highly saline periods (Kabir, Hossain, & Hossain, 2024). These adaptive strategies reflect the growing pressure that salinity places on coastal agricultural systems.

Recent research also highlights that salinity impacts vary across locations depending on proximity to the sea, tidal influence, river discharge, and local water management practices. Soil salinity levels differ across districts and seasons, emphasizing the need for location-specific agricultural adaptation and water management strategies (Sarkar et al., 2023; Hossain & Li, 2024).

Impact on Public Health

Salinity intrusion in coastal Bangladesh has serious impacts on public health and hygiene, mainly because it affects the quality and availability of drinking water. In many coastal areas, both surface water and groundwater become saline during the dry season, forcing people to drink water with high salt content (Nahian et al., 2018; Hossain & Li, 2024). Drinking saline water can increase sodium intake and lead to health problems such as high blood pressure and cardiovascular diseases. Studies in coastal Bangladesh have found that people who regularly consume saline drinking water have a higher risk of hypertension compared to those who drink freshwater (Nahian, Ahmed, Lázár†, Hutton†, & Salehin, 2018).

Salinity intrusion also affects maternal and reproductive health. Research shows that pregnant women who consume saline drinking water have a higher risk of conditions such as gestational hypertension and pre-eclampsia (Bodrud-Doza et al., 2019).

In addition, salinity reduces the availability of safe drinking water, which can negatively affect hygiene and sanitation practices. When freshwater sources become saline, people often need to collect water from distant or unsafe sources. This can increase the risk of water-borne diseases and poor hygiene conditions in coastal communities (Islam, 2025).

Saline water can cause skin problems and other health issues, especially when people use saline surface water for bathing and household activities. These health risks often affect vulnerable groups such as women, children, and elderly the most (Bodrud-Doza et al., 2019).

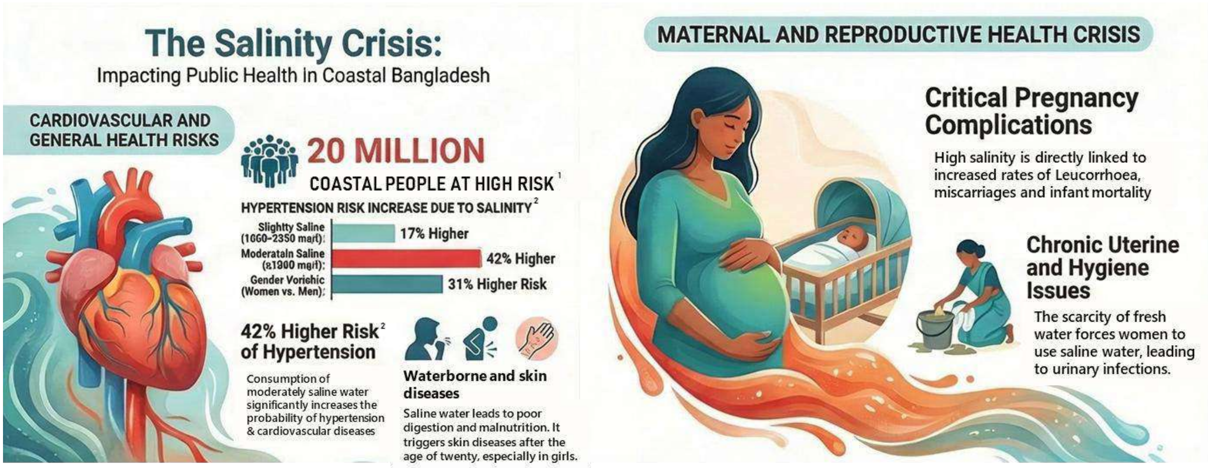

Figure 3.7: Salinity impact on health

Data Sources: (Rasheed, Siddique, Sharmin, & Hasan, 2016)[1], (Hossain, Sultana, & Mohammad Julhas Sujan, 2025)[2]

Impact on Livestock

Salinity intrusion also has significant impacts on livestock production and coastal ecosystems in Bangladesh. In saline-affected areas, freshwater scarcity and saline soil conditions reduce the availability and quality of fodder crops and grazing land for livestock. As a result, livestock productivity and health may decline due to inadequate nutrition and limited access to fresh drinking water (Hossain & Li, 2024).

High salinity levels in drinking water can negatively affect animal health and productivity. Studies show that livestock exposed to saline water may experience reduced feed intake, lower milk production, and increased physiological stress. These effects can reduce the economic benefits that rural households obtain from livestock farming (Kabir, Hossain, & Hossain, 2024)

Impact on Ecosystems

Salinity intrusion affects coastal ecosystems, including wetlands, mangroves, and freshwater habitats. Increased salinity levels can alter species composition, reduce biodiversity, and disrupt ecological balance in coastal environments. Sensitive plant and aquatic species may decline or disappear as salinity increases, while salt-tolerant species become more dominant (SRDI, 2010; Feist et al., 2022). In addition, changes in salinity can influence soil quality and ecosystem services such as nutrient cycling, water regulation, and habitat provision. These ecological changes not only affect biodiversity but also indirectly affect agriculture and fisheries that depend on healthy ecosystems (Hossain & Li, 2024)

3.1.4 Future Impacts of Water Salinization

The impacts of surface water salinity intrusion are presented in the following subsections. At the basin-wide or regional scale, surface water salinity intrusion is the predominant mode of salinity. Groundwater and soil salinity have a more localized impact, hence require further micro-level and detailed analysis. Due to the unavailability of analysis-ready GW and soil salinity datasets at national and regional scale, the future impact of groundwater and soil salinity have not been covered within this research study.

Water Resources

Salinity fundamentally degrades the quality of both surface and groundwater, which are essential for life and industry. The CEGIS developed Delft3D based Bay of Bengal model output suggests higher-end Sea Level Rise (SLR) can shift locations from **low-level (≈1 ppt)** to **more restrictive (≈5 ppt)** conditions. As the **1 ppt boundary** shifts inward, fewer surface-water abstraction points remain reliably fresh, and water-supply systems face higher treatment requirements, more seasonal downtime, or the need to shift to alternative sources.

Key water related impacts are:

Shrinking "freshwater windows" during dry periods as low-level salinity expands inland under higher SLR and reduced freshwater flushing.

Increasing inland exposure to areas currently out of the 1–5 ppt salinity isohaline regions, implying an expansion of where drinking-water salinity management may be needed.

Higher operational stakes for water-control structures (sluices, regulators, and polder drainage), because stronger tidal influence increases the likelihood of saline backflow into managed freshwater zones.

Surface Water Contamination: During the dry season (January–June), river water salinity rises as freshwater flow from upstream diminishes, often exceeding 30 dS/m in exposed areas. This makes river and canal water unfit for irrigation, household chores, or industrial condensers.

Groundwater Degradation: While 97% of the rural population relies on groundwater, only about 16% of coastal sources are considered safe for drinking. Salinity has been detected in aquifers as deep as 1,800 feet in districts like Khulna, leading to the failure of many deep tube wells (Miah, Uddin, Salam, & Islam, 2020).

Drinking Water Scarcity: Millions of people face acute potable water shortages, forcing them to rely on ponds, rainwater harvesting, or expensive reverse osmosis plants.

The expanded district analysis makes this concern much more concrete. The issue is no longer limited to the exposed coastal districts where salinity in water supply has long been recognized. Under higher SLR conditions, some interior coastal districts and non-coastal districts also begin to enter the 1 ppt and, in some cases, the 5 ppt salinity range. This means that the geography of drinking-water stress may widen considerably in the future. Areas that are currently considered outside the conventional salinity-risk belt may need to think ahead about source diversification, dry-season storage, conjunctive use of groundwater and surface water, and improved operation of sluices and regulators to prevent saline backflow.

a. Impacts on Agriculture and Food system

Salinity is the primary obstacle to year-round crop production. It causes stunted growth, grain sterility, and significant yield losses (averaging 20–40% for main crops). Approximately 7 lakh hectares of land remain fallow during the Rabi (winter) season because of high soil salinity and a lack of freshwater for irrigation.

From a farmer's perspective, salinity intrusion is experienced as a moving boundary of usable water: canals that were once fresh enough for irrigation become seasonally brackish, the timing of field preparation gets constrained, and salinity management becomes necessary farther inland. There is strong links between salinity ingress under higher SLR to reduced agricultural productivity, particularly emphasizing heavier impacts in the south-central coastal region.

A study (DOE, 2023) suggests that agricultural salinity risk is likely to spread from the exposed coastal districts into the interior coastal belt and then, under higher SLR scenarios, into some non-coastal districts as well. This is especially important for districts such as Gopalganj, Barisal, Narail, Madaripur, Faridpur, Jhenaidah, Magura, and Chuadanga, where irrigation planning has historically not been framed primarily around coastal salinity exposure. If these districts begin to experience seasonal or permanent intrusion of 1 ppt or even 5 ppt water into connected river systems, the implications may include changes in cropping calendar, higher irrigation uncertainty, greater dependence on rainfed windows, and pressure to shift toward more salt-tolerant crop choices or water-management practices.

While the below crop-loss tables are based on inundation-driven crop damage (Aman rice) rather than a direct salinity–yield function, they are still highly relevant because the same districts and landscapes experiencing stronger tidal influence are also those where saline intrusion tends to worsen. In practice, farmers do not experience inundation and salinity as separate hazards. They face them together, often in the same season, in the same field system, and through the same water network. That is why the salinity results matter even where the crop-loss percentages are not directly derived from salinity concentration.

The progressive increase in projected Aman production loss - from 5.80% under 0.50 m SLR to 9.10% under 0.95 m SLR - therefore reflects more than just physical inundation. It also points to a broader deterioration in production conditions across the coastal and near-coastal agricultural landscape, where stronger tidal influence, drainage congestion, and saline water intrusion are likely to reinforce one another.

Table 3.5: Production Loss of Aman Crop in Different SLR Scenarios

Scenario (SLR-only)	Aman production loss (%)
RCP 4.5 Medium (0.50 m)	5.80%
RCP 8.5 Medium (0.62 m)	7.20%
RCP 4.5 Extreme (0.70 m)	7.90%
RCP 8.5 Extreme (0.95 m)	9.10%

b. Public Health and Hygiene:

Consumption Risks: Drinking saline water is directly linked to hypertension, cardiovascular diseases, and skin infections. Approximately 20 million people are at risk of hypertension and cardiovascular diseases due to high sodium intake from drinking water.

Women's Health related Risks: Women face hardships and unique reproductive health crises, including high rates of uterine infections, (pre)eclampsia, and miscarriages. Many women must travel up to 12 kilometers daily to fetch freshwater. Scarcity of freshwater forces women in the coastal areas to use saline water for menstrual hygiene, leading to chronic uterine infections, painful menstruation, and increased risks of miscarriage and infertility. In desperate cases, some women take birth control pills to stop their periods entirely to avoid the ordeals of maintaining hygiene in salty water.

c. Impacts on Livelihoods

The socio-economic structure of coastal communities is under constant pressure from environmental shocks.

Economic Instability and loss: Traditional farming has become risky and often unprofitable, leading to increased indebtedness among farmers. Salinity also shortens the lifespan of assets like houses, boats, and fishing nets due to corrosion.

- **Social Conflict:** There is persistent conflict between shrimp farmers (who need saltwater) and traditional crop farmers (who need freshwater), often leading to social instability in coastal unions.

Livelihood Shifting and Migration: To survive, many males migrate seasonally or permanently to cities like Dhaka to work as day laborers or rickshaw pullers. In villages, some farmers have shifted to crab fattening or salt-tolerant vegetable gardening to adapt.

Livestock and Ecosystems: Increasing salinity results in a shortage of grazing pastures and fodder crops, leading to malnutrition and disease susceptibility in dairy cattle. In ecosystems like the Sundarbans, mangrove species like the Sundari are being replaced by more salt-tolerant varieties, which reduces overall biodiversity and productivity.

3.2 Review of Policies, Plans and Strategies

3.2.1 National Water Policy (NWPo), 1999

The Government of Bangladesh developed the National Water Policy (NWP) in 1999 as a strategic framework to guide the sustainable development, management, and use of the country's water resources. The goal of the policy is to control the challenging problems of pollution, water scarcity, environmental deterioration and sectoral demand. It focuses on river basin management, water allocation, public-private sector partnership, and addressing salinity, erosion, and environmental degradation. The NWPo also promotes stakeholder involvement, legal frameworks, and research to improve water governance. The objectives are:

- Recognize salinity intrusion as a major challenge in coastal and deltaic areas
- Promote Integrated Water Resources Management (IWRM) and river basin planning to reduce salinity risks
- Emphasize flood control and drainage management, which directly influence salinity conditions in polders
- Support protection of wetlands and surface water bodies that help regulate salinity
- Provide support for water quality management to prevent degradation linked with salinity
- Encourage stakeholder participation in water management, including coastal areas
- Lack specific operational guidance for in-polder salinity monitoring and control.

3.2.2 Coastal Zone Policy (CZPo), 2005

The Coastal Zone Policy, 2005 establishes a framework for the comprehensive administration of Bangladesh's coastal area. It combines socio-economic vulnerabilities, environmental hazards, and developmental prospects to ensure sustainable growth, reduce poverty, and climate resilience. The CZPo highlights the importance of environmental conservation, disaster management, gender equity, and participatory approaches. The objectives are:

- Integrate policies and strategies from different ministries for coordinated coastal water resource management.
- Utilize both structural and non-structural approaches to reduce climate and environmental vulnerabilities
- Support sustainable fisheries, eco-tourism, and marine industries while fostering innovation in coastal economies.
- Maintain adequate upland flow to mitigate effects of salinity intrusion
- Focuses more on livelihood adaptation than on hydrological salinity control inside polders
- Promote the sustainable use of land, water, fisheries, and forests.

3.2.3 National Agriculture Policy (NAPo), 2018

The NAPo is directly relevant to salinity management as it recognizes soil and water salinity as key constraints to agricultural productivity in coastal and southwest Bangladesh. The policy provides strategic guidance for promoting salinity-tolerant crops, climate-resilient farming practices, and improved water management, making it a core reference for salinity scoping in agriculture-dependent areas. The objectives are:

- Identify waterlogging and salinity as major constraints to agricultural productivity, particularly in coastal and low-lying areas
- Promote development and dissemination of salinity-tolerant and waterlogging-tolerant crop varieties to sustain production under adverse soil and water conditions
- Emphasize coastal agriculture as a special focus area, acknowledging salinity intrusion, tidal flooding, and cyclones as dominant stresses affecting farming system.
- Support soil and water salinity management through improved water control infrastructure, irrigation conservation, and adaptive cropping patterns in coastal regions
- Encourage adaptive farming systems (crop–fish–livestock integration) to reduce livelihood risks under saline and waterlogged conditions
- Highlight the need for area-specific and climate-resilient agricultural technologies, including for saline and disaster-prone environments
- Promote research and extension on stress-tolerant crops and technologies suitable for saline soils and brackish water conditions
- Recognize that centralized planning dominates implementation, with limited operational guidance for localized, polder-level salinity management and farmer-led adaptation

3.2.4 National Environment Policy (NEPo), 2018

Bangladesh is committed to conserve its national resources guided by policy, law, strategies, international treaties, and conventions. Bangladesh is moving fats to fulfill the vision 2021 and vision 2041 for becoming a developed country. Sustainable development however cannot be achieved without considering the environment. Conservation, protection and wise use of resources are all key in maintaining growth which is threated by continuous development in unplanned manner. While the effects of disaster and impacts on climate change are visible. Hence, taking all of these into consideration and to foster development in the country through environmentally sound use of natural resources within the framework of sustainable development, the environmental policy of 1992 was revised and the National Environmental Policy, 2018 was prepared by the Ministry of Environment, Forest and Climate Change.

The vision of environmental policy is to ensure sustainable development through environmental protection, control of pollution, preservation of biodiversity and protecting the country from the adverse impacts of climate change. The specific objectives are:

- Natural equilibrium provision and overall development of the country through environmental protection and sustainable management
- The spread of adaptation programs to reduce the adverse effects of climate change on the country
- Encourage collection and adoption of low carbon emission technology in the country
- Identification and control of all types of environmental pollution and degradation activities
- Ensure environmentally sound development in all fields
- Ensure sustainable long-term and environmental use of all natural resources
- Exploring and expanding the areas of mutual cooperation in the regional and international arena for the development of the global environment
- Application of environment education, capacity building, public awareness and public opinion to protect the environment
- Public-Private partnership initiatives to improve the environment

- Maintain and streamline environmental policies and strategies among other policies and strategies in the interest of sustainable development.
- Building community capable of dealing with all kinds of environmental and atmospheric issues, including climate change
- Ensure performance of Environmental Impact Assessment and Strategic Environmental assessment for all required cases
- Discourage artificial intrusion of foreign and invasive species of animals and plants and if necessary, make decisions through adequate research
- Be as actively involved as possible with all international and national environmental initiatives and to take necessary actions at local and national level
- Take measures to reduce poverty through environmental protection
- Strengthen observation on proper adherence to environmental laws and regulations

3.2.5 Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2008

The BCCSAP recognizes salinity intrusion as a primary threat to the country's coastal interior, food security, and public health. It frames salinity management through a multi-pillar approach designed to build long-term resilience.

- Development of salinity-tolerant cultivars (rice and other crops) through the National Agricultural Research System (NARS).
- Aims to screen indigenous varieties that already withstand salt and disseminate new climate-resilient cropping systems to farmers.

Acknowledges that rising sea levels move salinity inland, making safe drinking water a "big challenge" and calls for monitoring water quality and investing in deep-set groundwater technologies and rainwater harvesting in saline-affected zones.

- The "greenbelt" coastal afforestation programme involves planting salt-tolerant mangrove species along 9,000 km of shoreline to reduce the impact of storm surges - which carry saline water deep into agricultural land

3.2.6 National Adaptation Plan of Bangladesh (NAP 2023-2050)

The NAP identifies salinity intrusion as a major climate change impact affecting water resources, agriculture, and livelihoods. It informs salinity scoping by outlining priority adaptation measures, vulnerable regions, and sectoral responses related to freshwater security and salinity-resilient systems.

- Recognize salinity intrusion as a critical climate risk driven by sea-level rise, tidal inundation, and reduced freshwater flows in coastal regions.
- Promote development of salt-tolerant crops and climate-resilient agricultural systems to sustain productivity under saline conditions.
- Prioritize adaptive water resources management, including improved drainage, freshwater retention, and reservoir development.
- Monitor and map soil, surface water, and groundwater salinity to inform evidence-based planning and decision-making.
- Support structural measures such as heightened dikes, freshwater retention ponds, and river dredging to limit saline ingress.

- Introduce community-based, low-cost desalination and freshwater supply solutions for drinking water security.
- Strengthen climate products, services, and research to support salinity adaptation and risk forecasting.
- Encourage locally led and coordinated implementation across water, agriculture, environment, and local government institutions.

3.2.7 Bangladesh Delta Plan (BDP), 2100

The BDP2100 provides a long-term vision for managing deltaic risks, including salinity intrusion under climate change and sea-level rise. For salinity scoping, it offers guidance on adaptive polder management, freshwater retention, drainage improvement, nature-based solutions, and long-term monitoring demand.

- Identify salinity intrusion as a major long-term threat to coastal water security, agriculture, and livelihoods
- Recognize sea-level rise, reduced upstream freshwater flows, and climate change as key drivers of increasing salinity
- Promote integrated water resources management (IWRM) across basin, regional, and polder scales
- Emphasize controlled tidal and drainage management to balance freshwater retention and saline water exclusion.
- Support adaptive polder management, including improved operation of sluice gates and drainage systems
- Encourage salinity-resilient agriculture, aquaculture, and livelihood diversification in coastal zones
- Highlights the need for soil, surface water, and groundwater salinity monitoring as part of adaptive planning
- Promote nature-based solutions (wetland restoration, afforestation) to reduce salinity impacts
- Calls for institutional coordination among water, agriculture, environment, and local government agencies
- Acknowledge effective salinity management for decentralized and locally responsive implementation mechanisms
- Identify gaps in implementing long-term strategies for operational plans and monitoring systems.

3.2.8 National Water Act, 2013

The National Water Act (2013) establishes the legal and regulatory framework for the development, management, protection, and conservation of water resources in Bangladesh. It defines water rights, regulates water use and abstraction, and outlines the responsibilities of government institutions for water governance, environmental protection, and sustainable water resource management.

- Provide legal authority to regulate activities that worsen salinity intrusion
- Protect wetlands, aquifers, and surface water bodies from degradation
- Restrict alterations to natural water flows, including within polders
- Require prior approval for water abstraction and infrastructure development in saline-prone areas

- Identify and regulate water-stressed and environmentally sensitive zones, including coastal regions
- Support basin-wide planning to maintain freshwater inflows that counter saline intrusion
- Prohibit pollution and contamination of water bodies that can compound salinity impacts
- Mandate conservation of environmental flows to protect ecosystems affected by salinity

3.3 Mapping Adaptive Capacity Across the Stakeholder Network

3.3.1 Identifying Key Actors

The stakeholders are envisioned to be engaged in salinity management in Bangladesh in 3 tiers, denoting the hierarchy of salinity management at macro or national scale, meso or regional scale and micro or local scale. Following the project development and implementation life cycle, these stakeholders can be categorized in four key parts of project management – planning, design, implementation, and operation & maintenance. The stakeholder landscape is illustrated in figure and briefly explained in the following subsections.

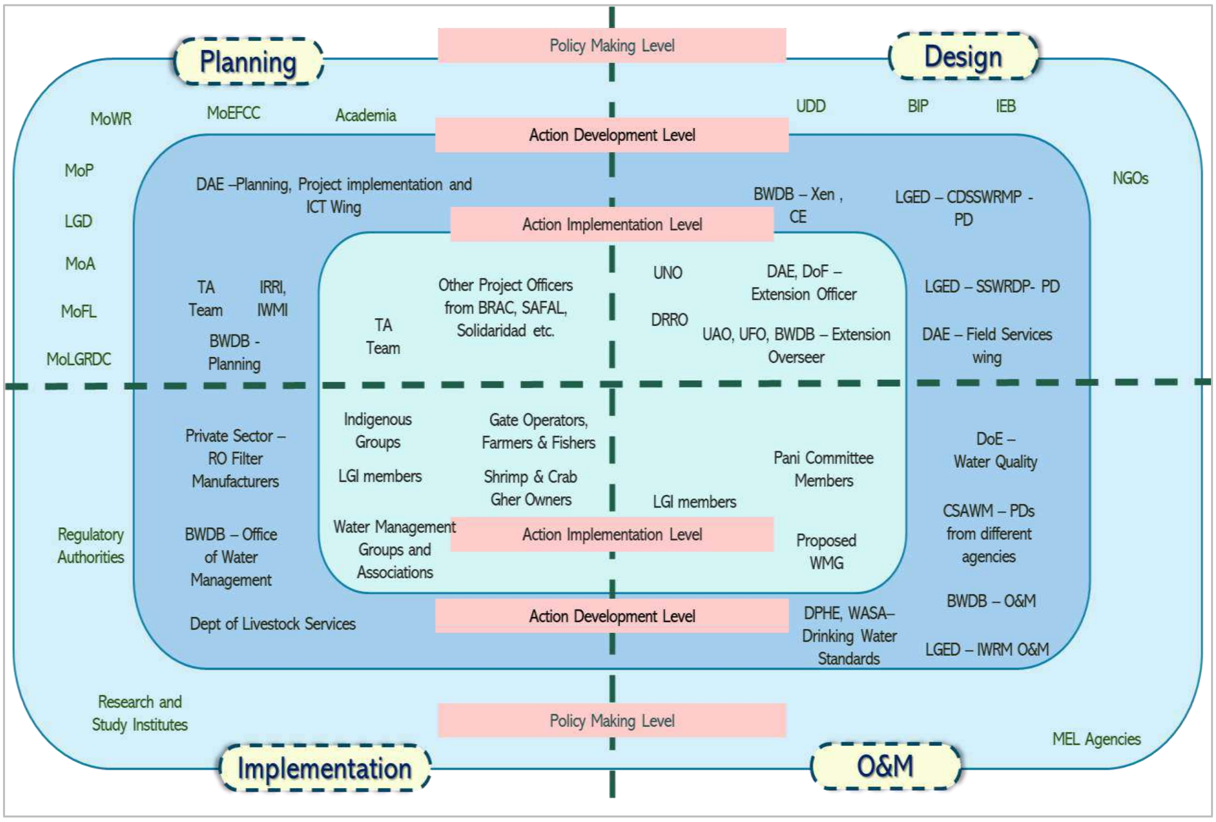

Figure 3.8: Stakeholder Map for Salinity Management in Bangladesh

Institutional Framework: The Three Tiers of Governance

The institutional landscape of salinity adaptation in Bangladesh is characterized by a vertical hierarchy that dictates the flow of resources and decision-making power (Khan, Nag, Babu, Krupnik, & J., 2024)

- **Policy Making Level (Macro-Level):** Strategic direction is managed by central ministries, including the **Ministry of Water Resources (MoWR)** and **Ministry of Agriculture (MoA)**. Their primary mandate is the creation of long-term visions, such as the *Bangladesh Delta Plan 2100*, which establishes the regulatory and budgetary environment for salinity management (GED, 2018).
- **Action Development Level (Meso-Level):** This tier serves as the technical engine of the state. Agencies like the **Bangladesh Water Development Board (BWDB)** and the **Local Government Engineering Department (LGED)** translate policy into technical blueprints. This level is responsible for the technical vetting of infrastructure and the coordination of multi-sectoral projects (Shawkhatuzamman, et al., 2023)
- **Action Implementation Level (Micro-Level):** The "frontline" of adaptation consists of **Water Management Groups (WMGs)**, **Union Parishads**, and individual land-users (farmers and fishers). Their role is the practical execution of adaptation measures, from the operation of sluice gates to the adoption of salt-tolerant crop varieties (Abdullah, et al., 2025)

Functional Stages of Salinity Adaptation

The lifecycle of an adaptation intervention follows four distinct stages, each requiring unique stakeholder interactions:

- **Planning & Design:** Dominated by the **Policy** and **Development** levels. Input from research bodies like **IRRI** and **IWMI** is critical here to ensure "Design" parameters (e.g., embankment height or seed salinity thresholds) match climate projections (Dasgupta, Hossain, Huq, & Wheeler, 2015)
- **Implementation:** A collaborative phase where **Project Directors (PDs)** coordinate with local **NGOs** (e.g., BRAC, Solidaridad) and contractors to deliver physical and social assets.
- **Operations & Maintenance (O&M):** Often the most vulnerable stage, O&M is the primary responsibility of the **Implementation Level**. The sustainability of coastal polders relies on the daily vigilance of **Gate Operators** and **Pani Committees** to regulate saline flows (Netherlands Enterprise Agency (RVO), 2024)

3.3.2 Institutional Arrangements: Allocation of Responsibilities

The success of salinity adaptation depends on the clear demarcation and coordination of responsibilities across these actors to avoid duplication and ensure polder-level efficiency.

- **Infrastructure & Operation (BWDB & LGED)**: Under formal MoUs, the BWDB focuses on the design and maintenance of major embankments, while the LGED handles small-scale subprojects within those hydrological units. The **BWDB's Office of Water Management** oversees the strategic operation of water control structures, whereas the LGED ensures that rural infrastructure (like paved embankments) does not hinder drainage or flood control functions.
- **Agricultural Adaptation (DAE & MoA)**: The **DAE's Field Services and Planning wings** are responsible for identifying and disseminating saline-tolerant seeds and sustainable soil management practices. They coordinate with research institutes like **BRRI (Rice Research)** and **SRDI (Soil Resource)** to ensure that field-level interventions are evidence-based.
- **Participatory Management (WMGs & WMOs)**: Responsibility for "action implementation" lies heavily with **Water Management Organizations (WMOs)**. These community-led bodies are mandated to operate the gates and canals, ensuring that polders are drained during the monsoon and protected from saline high tides during the dry season.

- **Social and Livelihood Resilience (NGOs & LGD)**: While the **Department of Public Health Engineering (DPHE)** under the Local Government Division (LGD) is responsible for providing safe drinking water (e.g., through Pond Sand Filters or rainwater harvesting), NGOs like **Cordaid** and **Solidaridad** facilitate market linkages for alternative livelihoods, such as crab or shrimp farming in highly saline areas.
- **Monitoring and Regulation**: The **Department of Environment (DoE)** and **Regulatory Authorities** monitor water quality and soil salinity levels to inform future policy adjustments at the "Policy Making Level."

4 Adaptation and Management Options for Salinity

4.1 Current Practices for Salinity Management

Current salinity management in the coastal delta is characterized by a "dual-track" adaptation model, where large-scale government engineering projects are augmented by community-led localized interventions (Shawkhatuzamman, et al., 2023)

Governmental Interventions: The state focuses on structural protection and large-scale water resource augmentation. Key actions include:

- **Structural Barriers and Polders:** The construction and rehabilitation of sustainable polders (e.g., Polder 31) to prevent tidal saline intrusion (Netherlands Enterprise Agency (RVO), 2024).
- **Water Resource Augmentation:** Large-scale excavation of canals and ponds to store freshwater, alongside river dredging to enhance flow and mitigate sedimentation (GED, 2018).
- **Infrastructure and Supply:** In urban areas (Pourashavas), the government prioritizes centralized water supply arrangements and the installation of large-capacity Reverse Osmosis (RO) plants and Shallow Tube Wells (STW) in safe, low-salinity aquifers (Hossain & Li, 2024).

Community and Household Interventions: Local communities focus on immediate survival and agricultural productivity through "climate-smart" practices such as:

- **Potable Water Supply:** Households rely on Rainwater Harvesting (RWH) during the monsoon, supported by community Pond Sand Filters (PSF) and household-level storage tank (Saha, Rahman, & Islam, 2024).
- **Agricultural Adaptation:** Farmers have shifted toward saline-tolerant varieties and short-term crops (rabi season) to utilize residual moisture before soil salinity peaks ((Abdullah, et al., 2025)
- **Water Regulation:** Local Water Management Groups (WMGs) play a critical role in "sluice gate management," timing the intake of river water to coincide with low-salinity periods during ebb tides (CGIAR, 2025).
- **Vegetables with rice and fish in moderately saline area:** In this technique, vegetables grow on bunds, allowing them to creep towards land. Fish are grown in the dug ditch and rice is grown in the rest part.
- **Tower gardening in saline and intermittently shallowly flooded areas in coastal region:** This technology is mainly found in Shyamnagar. The size of the tower is about 3 feet in height, mostly round in shape with 3 feet diameter. Soil cased in bamboo net re-enforced by bamboo mat or polythene. Mostly the women are involved in this farming method. Creeping vegetables are mainly grown in this area.
- **Integrated homestead farming in slightly saline area:** It is practiced in Pankhali village of Pankhali Union in Dacope Upazila under Khulna District.
- **Usage of cut-off river water to increase cropping intensity in saline area:** This technology is adopted in Pankhali village of Pankhali Union in Dacope Upazila in Khulna District.
- ***Tree Plantation to protect Embankment/Dykes:*** This technology is adopted in Fultala Union in Batiaghata Upazila.

Figure 4.1: Integrated (Rice-fish and Vegetable) Farming in Saline Area

Figure 4.2: Tower Gardening

Figure 4.3: Integrated Homestead Farming

Figure 4.4: Usage of cut-off river water to increase cropping intensity in saline area

Figure 4.5: Climate Resilience Vegetable Farming

Figure 4.6: Tree Plantation to Protect Embankment/Dykes

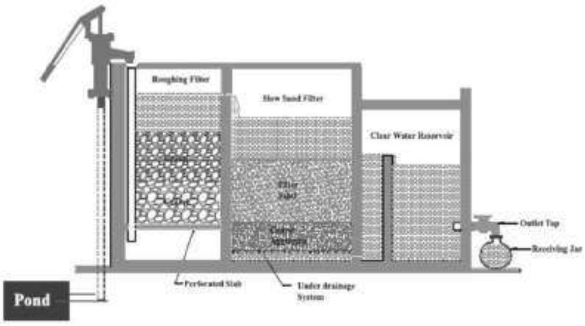

Figure 4.7: Pond Sand Filter*

Figure 4.8: Rain Water Harvesting

*Source: (DOE, 2023), *(DPHE, 2008)*

4.2 Salinity-Focused Dutch Funded Initiatives

Through desk research, this study identified some major programs which have addressed salinity management. The EKN has been one of the most important development partners of Bangladesh in addressing challenges related to salinity intrusion, climate-resilient agriculture, and long-term food security in the coastal delta. Increasing soil and water salinity caused by SLR, tidal flooding, reduced upstream freshwater flow, and climate variability has significantly affected agricultural productivity and rural livelihoods in the coastal regions of Bangladesh. As a result, Dutch cooperation focuses on integrated water management, salinity-resilient agriculture, sustainable land use, and strengthening agricultural value chains in the delta.

Literature review and field visits, revealed some key findings from Salinity-Focused Dutch funded Initiatives e.g Blue Gold, COASTS, SaFaL, SAIWRPMP and other studies- addressing the complex challenge of salinity in coastal Bangladesh, which are synthesized below. A WUR's research on spatio-temporal scales (Terwisscha, C., Snethlage, & Islam, 2024), highlights how coordinated infrastructure, community-led water management, and adaptive agricultural practices are essential for long-term resilience.

4.2.1 Programmes and Projects

Blue Gold Project

Water Management Groups (WMGs) were formed under Blue Gold project for water management. This project has particular relevance to improved water availability, that canals inside the polders which were utilized to store rainwater which was used during dry season when salinity in water bodies are usually higher. Through Blue Gold, project communities were involved in water management, which reduced the impact of salinity, this project also provided a platform for conflict resolution and to engage with the water management organizations such as BWDB. DAE, remained working mainly through their Community Based Organizations/Farmar's Field School (FFS). According to the report, the interaction between the WMGs and FFS is not happening much, this could have been improved to have more inclusive polder water management and integrated with agriculture planning. The project addressed salinity intrusion and waterlogging as core constraints in coastal polders.

Specifically, the objectives were to:

- Improve water management and agricultural productivity in coastal polders of Bangladesh through participatory planning and infrastructure improvement.
- Strengthen institutional capacity and community engagement for sustainable polder operation and maintenance.
- Enhance resilience to water-related stress, including salinity and waterlogging, by improving hydrological control and livelihood options.

The key activities of the project were:

- Establish and strengthen Water Management Organizations (WMOs) and Water Management Groups (WMGs) for participatory water management
- Rehabilitate and improve sluice gates, drainage canals, and embankments to regulate saline and freshwater flows
- Improve Operation and Maintenance (O&M) of water control infrastructure to reduce salinity intrusion and waterlogging

- Promote controlled drainage and freshwater retention to manage seasonal salinity variability within polders
- Support canal re-excavation and cleaning to improve internal water circulation and flushing of saline water
- Facilitate coordination between water and agriculture agencies (e.g., BWDB, DAE) for salinity-sensitive decision-making
- Provide training and capacity building for farmers and water management institutions on adaptive water management
- Promote salinity-tolerant crop varieties and adaptive cropping practices in coastal polders

Coastal Opportunities and Agricultural Solutions to Tackle Salinity (COASTS)

Mainly focused on saline agriculture, the COASTS project funded by Netherlands Enterprise Agency (RVO) is a public-private partnership project. Partners include the Soil Resource Development Institute (SRDI) as a public partner, the Bangladesh Agriculture University (BAU) as an academic partner, Lal Teer Seed Limited as a private company partner and Cordaid as an NGO and lead partner. The project framed salinity as a combined challenge of soil degradation, freshwater scarcity, and climate-induced coastal hazards.

The objectives were to:

- Enhance agricultural productivity and sustainability on saline-affected coastal lands
- Promote adaptive farming practices and salinity-adapted technologies for resilient crop production
- Improve seed systems, particularly access to saline-tolerant vegetable and crop varieties
- Strengthen community-level engagement in saline agriculture
- Bring approximately 5,000 hectares of coastal fallow land under productive use.

With specific reference to salinity and water management, the project:

- Focused on salinity-tolerant and climate-resilient crop varieties, including vegetables, suitable for coastal and polder environments
- Improved access, availability, and supply chains of salt-tolerant vegetable seeds to support commercial vegetable production in saline-prone area
- Promoted adaptive cropping systems, including crop diversification and crop–fish integration, to reduce salinity-related livelihood risks
- Emphasized improved in-polder water management, including freshwater retention and controlled drainage, to reduce soil salinity accumulation
- Supported soil and water salinity monitoring and mapping to guide agricultural planning and intervention targeting
- Promoted nature-based and ecosystem-based solutions, including wetland conservation and landscape-level adaptation
- Strengthened Farmer Business Associations (FBAs) by improving service delivery and providing appropriate inputs, materials, and technical support to farmers
- Encouraged community-led innovation, integrating local knowledge into salinity adaptation strategies

- Generate evidence and decision-support tools to inform policy, planning, and scaling of salinity-resilient agricultural practices
- Highlight the need for coordination between agriculture and water management institutions for effective salinity control.

Sustainable agriculture, food security, and linkages (SaFaL) for IWRM Project

The SaFaL, a project funded by Ministry of Foreign Affairs, Netherlands addressed salinity and water stress as key constraints to sustainable agriculture and food security in southwest Bangladesh. The project focuses on community-based water management for enhancing water use efficiency in agriculture to contribute towards a systemic change in the operationalization of IWRM in Southwest Bangladesh. Water management is observed through re-excavation and rejuvenation of 80 canals with community involvement, drainage will be improved and rainwater water will be stored which will be used during the dry season. The project mainly:

- Promoted community-based planning and multi-stakeholder approaches to support systemic operationalization of IWRM in saline-prone regions
- Promoted Integrated Water Resources Management (IWRM) to balance freshwater availability and salinity control across sectors
- Supported re-excavation and rejuvenation of canals and water bodies to improve drainage and reduce salinity accumulation
- Improved drainage systems to prevent saline water stagnation and soil salinity build-up
- Supported rainwater harvesting and freshwater storage for use during the dry season to dilute salinity
- Promoted salinity-resilient agricultural practices, including crop diversification and stress-tolerant varieties
- Improved coordination between water and agriculture institutions to align water management with salinity-sensitive cropping systems
- Supported adaptive local and landscape-scale water management to manage seasonal salinity variability
- Strengthened linkages between water management, agriculture, and food security outcomes in saline-prone areas.

Southwest Area Integrated Water Resources Planning and Management Project (SAIWRPMP)

The SAIWRPMP *project* identified salinity intrusion as a result of combined natural processes (tidal influence, sea-level rise, reduced freshwater flow) and human-induced factors (infrastructure modification, drainage constraints). The main objectives were to reduce salinity intrusion through rehabilitation of coastal polders and water control structures, prevent saline water ingress by improving embankments and restoring effective sluice gate operation and improve drainage systems to reduce soil salinity accumulation and waterlogging. The main objectives of the project mainly:

- Promote integrated water resources planning and management in southwest Bangladesh to address water-related challenges at regional and polder scales.
- Improve water security and resilience by balancing freshwater availability, drainage, and protection from water-related hazards.
- Rehabilitate and manage water infrastructure to reduce adverse impacts of salinity intrusion and waterlogging.

- Support sustainable use of water resources through coordinated planning, data use, and stakeholder engagement.

The key outcomes of the project are:

- Improved polder infrastructure performance, including embankments, sluice gates, and drainage systems
- Enhanced control of saline and freshwater flows, reducing salinity intrusion and seasonal water stress
- Improved drainage efficiency and freshwater retention, contributing to better soil and surface-water conditions
- Increased availability of freshwater during the dry season through storage and improved circulation
- Strengthened regional water management planning, informed by data and integrated sectoral inputs
- Improved understanding of natural and human-induced drivers of salinity intrusion
- Enhanced community safety, agricultural productivity, and well-being resulting from improved water management.

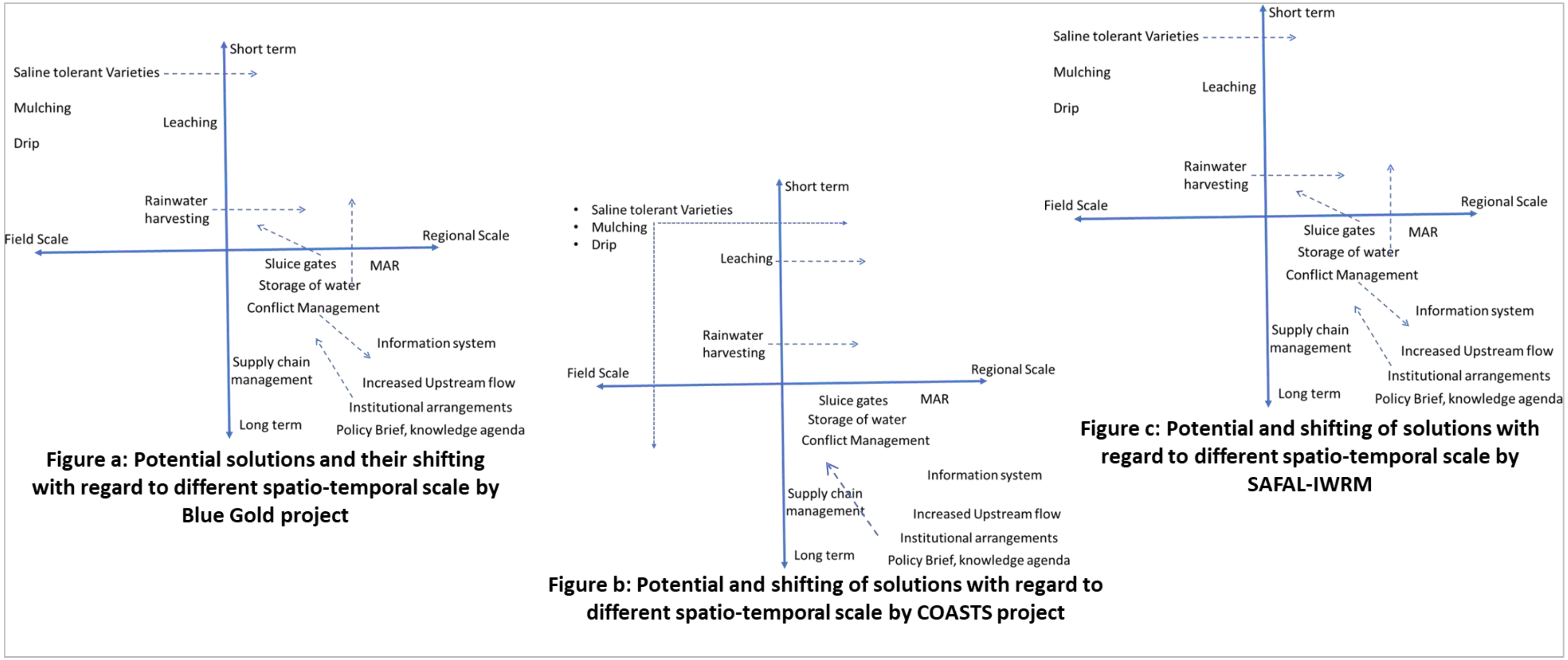

Figure a: Potential solutions and their shifting with regard to different spatio-temporal scale by Blue Gold project

Figure b: Potential and shifting of solutions with regard to different spatio-temporal scale by COASTS project

Figure c: Potential and shifting of solutions with regard to different spatio-temporal scale by SAFAL-IWRM

Figure 4.9: Potential and Shifting of Solutions in different Salinity-focused Initiatives

Source; (Terwisscha, C., Snethlage, & Islam, 2024)

4.2.2 Research studies

Water management to address salinity in agriculture in Bangladesh

The challenge of salinity cannot be solved with a single intervention; practical experience shows that a multifaceted/multiple solutions need to be applied in a coordinated manner. Therefore, as part of the Impact Accelerator of the Sustainable Development Goals (SDG) Partnership Facility (SDGP) and funded by the Netherlands Enterprise Agency (RVO), the Wageningen University and Research (WUR) examined potential intervention strategies at various levels, such as farmers (field level, including mulching, agroforestry, and cover crops) and polder/river basins. It addresses needs of key players in the water and agriculture sectors, including farmers, communities, government, knowledge institutes, NGOs, and the role of private actors (both in Bangladesh and the Netherlands), as well as potential financing options and the type of financing, taking into account the actors, the scale of interventions, and the knowledge and information that the various actors may need. This study (Terwisscha, C., Snethlage, & Islam, 2024)identified potential solutions in agriculture practices and water management addressing salinity at different spatio-temporal scale as indicated in the frameworks.

- Stronger collaboration is needed between BWDB and DAE within the polder area; as well as CBOs (such as WMO and FFS) working together under a unified umbrella to formulate integrated and inclusive water management and agricultural plans.
- Water and soil salinity are influenced by both local/regional practices and national policy-based interventions; but stakeholder mapping/consultation shows that communication between national and regional stakeholders is very limited - therefore, an effective platform and facilitation are needed to enhance cross-scale collaboration.
- Communication and coordination among regional stakeholders (and across levels) is weak; therefore, coordination at the same level, across levels, and at the field level needs to be strengthened.

Action Research on Sustainable Polder Management (Polder 31)

Polder 31 at Dacope stands as a benchmark for integrated management. Research indicates that by leveraging strategic sluice gate operation and canal-based water storage, farmers in this polder have achieved two-to-threefold increases in cropping intensity (Rashid & Miah, 2020). The polder successfully balanced the competing needs of traditional rice farming and profitable *Golda* (prawn) cultivation by regulating saline intake. Another ongoing initiative is the Action Research on Sustainable In-Polder Water Management and Resilient Livelihood in Polder 31. The aim of this ARP is to pioneer a paradigm shift in water governance in Polder 31, with a focus on establishing and empowering local community (e.g., WMOs) for in-polder water management and integrated development through fostering resilient livelihoods.

Living Polders: Dynamic Polder Management for Sustainable Livelihoods, applied to Bangladesh

This is a research-driven approach that rethinks traditional polder systems in the coastal delta of Bangladesh by integrating natural processes, engineering, and community-based governance to enhance long-term resilience and livelihoods. This research, funded by the Netherlands Organisation for Scientific Research (NWO) and implemented through international collaboration (including BUET and Utrecht University), introduces dynamic polder management. This concept promotes working with natural delta processes rather than controlling them rigidly.

A key principle is the “Building with Nature” approach, where controlled flooding and sedimentation are used to restore ecological balance and improve land elevation, soil fertility, and water management. The project recognizes polders as complex socio-ecological systems, where hydrology, infrastructure, institutions, and livelihoods are interconnected.

Livings Labs for Adaptive Delta Management in Bangladesh

In addition to these development programmes, several research collaborations between Bangladeshi and Dutch institutions contribute to improving coastal agriculture and food security. The NWA programme ADM-LAB is ongoing research conducted through joint collaboration between Bangladeshi universities and knowledge institutes which seeks to strengthen sustainable and knowledge-driven policymaking on ADM and support its implementation under the BDP2100. It builds upon existing knowledge generated in earlier initiatives, ensuring its consolidation while promoting further knowledge development to accelerate the application of ADM approaches in both Bangladesh and the Netherlands.

For example, this research programme will explore innovative approaches such as sediment management, tidal river management, and climate-resilient cropping systems to sustain agricultural production in saline coastal environments. The programme will provide practical insights and actionable guidance for policymakers and practitioners to enable future-resilient delta management. It also fosters an effective platform for knowledge exchange and collaboration among science, policy, and practice, enhancing integrated decision-making around ADM.Other initiatives

Some other initiatives on salinity adaptation where technology meets participatory governance are as follows:

- **AI-Driven Irrigation Advisories:** Recent pilots by CGIAR and IWMI introduced AI-based salinity modeling to provide real-time forecasts to farmers. This has empowered WMGs to close sluice gates precisely when river salinity is below 4 dS/m, effectively turning canals into freshwater reservoirs for the dry season (CGIAR, 2025) .
- **GCA-UNDP Community Rainwater Harvesting:** The Global Climate Change Alliance (GCA) project implemented by UNDP has provided gender-responsive drinking water solutions for over 30,000 households through large-scale community RWH and pond-based ultra-filtration systems (UNDP Bangladesh, 2022).

4.3 Learning from Existing Community-led Practices

In the coastal polders of Khulna, particularly Polders 30 (Batiaghata) and 31 (Dacope), climate adaptation extends far beyond simply adopting new agricultural technologies. Driven by encroaching salinity and systemic waterlogging, local adaptation here is fundamentally about resource reclamation, conflict resolution, and community-enforced governance. The physical landscape is shaped by the daily, competing behavioral interactions of local actors, requiring adaptation strategies to address both environmental shifts and deep-seated power imbalances. An illustration, outlining the community-led adaption practices is also presented in **Error! Reference source not found.**. This i llustration provides a visual breakdown of community-led water management in coastal Bangladesh, splitting resilience efforts into **physical infrastructure** and **social governance**. It depicts grassroots actions like canal re-excavation, embankment defense, and the removal of illegal saltwater pipes alongside social strategies such as "freshwater-only" zoning and legal advocacy.

- **Community-Led Canal Re-excavation and Freshwater Management –** In Polder 31 (Dacope) and in Polder 30 (Bariaghata), re-excavating internal canals is a strategic act of resource reclamation. Beyond just removing silt, local communities mobilize to dismantle "cross-dams" illegally built by influential landowners to capture water. By restoring these channels, farmers create a collective freshwater reservoir that captures monsoon rain. This is the only lifeline for growing high-value dry-season crops like watermelon, maize, or sesame, and it provides a critical "flush" to push out residual soil salinity.

- **Grassroots "Embankment Defense" and Infrastructure Maintenance -** Because the Bangladesh Water Development Board (BWDB) often lacks the immediate presence to manage daily wear, local Water Management Groups (WMGs) act as the first line of defence. This involves voluntary labor where villagers use local materials - bamboo, sandbags, and mud - to patch minor breaches before they become catastrophic during tidal surges. This practice is driven by the local understanding that even a small leak can lead to permanent soil degradation for an entire village.
- **Systematic Removal of Unauthorized Saltwater Intake Infrastructure -** A highly contentious but vital adaptation practice is the physical identification and removal of illegal PVC pipes. These pipes are often stealthily installed by shrimp gher owners to pierce the polder embankments and draw in tidal saltwater. Local informal water user groups or cooperatives now conduct "pipe audits," and physically dismantling them to prevent the "creeping salinity" that destroys paddy yields in adjacent plots.
- **Social Mobilization for "Freshwater-Only" Zoning -** In parts of Dacope and Batiaghata, communities are moving toward banning brackish-water shrimp farming entirely in favor of integrated freshwater systems, such as *Macrobrachium rosenbergii* (local name Galda shrimp) with paddy. This is a political adaptation; it involves local committees negotiating with powerful elites to establish "No Saline Water" zones. This shift is driven by the need to restore the local labor market, as crop farming requires significantly more manual labor and provides better food security than large-scale, capital-intensive *Penaeus monodon* (local name: Tiger Shrimp or Bagda) farming.
- **Decentralized Household Water Harvesting and PSF Governance -** With groundwater rendered undrinkable, the governance of drinking water has shifted to the household and neighborhood level. This includes the management of 2,000-liter (typically sized) rainwater harvesting tanks and the strict protection of "sweet water" ponds. Local informal water user groups often enforce the rules of these ponds—banning bathing or cattle washing—to ensure that Pond Sand Filters (PSFs) remain functional throughout the gruelling dry season.
- **Community-Based Enforcement and Rule of Law Advocacy -** Lacking formal police presence in remote polder corners, local farmers have developed advocacy networks to force the "rule of law." This involves submitting collective petitions to the Upazila Nirbahi Officer (UNO) and BWDB to report illegal embankment cutting. They use their deep local knowledge to argue for the correct placement of sluice gates and regulators, often challenging "top-down" engineering designs that don't account for the actual tidal flow and drainage patterns of the polder.

5 SWOT and Gap Analysis

5.1 SWOT Analysis

To better understand the current situation and identify strategic pathways for addressing salinity intrusion in coastal Bangladesh, a SWOT analysis was conducted. This analytical framework evaluates the **internal strengths and weaknesses** of existing institutions, policies, and practices, as well as the **external opportunities and threats** that influence salinity management. By systematically assessing these factors, the analysis provides insights into the key challenges and potential areas for intervention.

STRENGTHS

1. Strong research and data-based evidence on coastal salinity (CEGIS, SRDI, NAP, BDP2100);
2. Regional salinity mapping using GIS and Spatial Analysis;
3. Successful field experience of COASTS, SAFAL, Blue Gold projects;
4. Proven effectiveness of salt-tolerant crop, AWD, drip irrigation, MAR technology;
5. Strong stakeholder network (government, NGOs, research institutions, donors);

WEAKNESSES

1. Lack of long-term water-soil-salinity dynamics model;
2. Lack of coordination in information and planning in the water-agriculture-environment sectors
3. Institutional coordination between BWDB, DAE, LGED and WMG is weak;
4. Crop selection according to agro-ecological zone is weak;
5. Farmers' financial constraints and barriers to technology adoption;

OPPORTUNITIES

1. Opportunities for long-term planning through BDP 2100 and NAP 2023–2050;
2. The Netherlands and the potential for expanding international cooperation;
3. Scale-up opportunities for salt-tolerant crops and water management technologies;
4. MAR, canal re-excavation and polder-based water management;
5. Global financing for climate adaptation and food security.

THREATS

1. Lack of long-term water-soil-salinity dynamics model;
2. Lack of coordination in information and planning in the water-agriculture-environment sectors
3. Institutional coordination between BWDB, DAE, LGED and WMG is weak;
4. Crop selection according to agro-ecological zone is weak;
5. Farmers' financial constraints and barriers to technology adoption;

Figure 5.1: SWOT Analysis

5.2 Gap Analysis

5.2.1 Policy Gaps

Addressing the salinity crisis in Bangladesh is complicated by several critical policy and institutional gaps that hinder effective long-term management.

- Institutional fragmentation: Responsibilities for salinity management are spread across multiple sectors such as water resources, agriculture, fisheries, and environment, leading to weak coordination among government agencies.
- Limited implementation capacity: Local government institutions often lack sufficient financial resources, technical expertise, and infrastructure to implement large-scale salinity management interventions.
- Project-based interventions: Many salinity-related initiatives are implemented through short-term donor-funded projects, which are often limited in geographic scope and may not be sustained after project completion.
- Conflicting land-use practices: Economic activities such as brackish water shrimp aquaculture can increase soil and water salinity, sometimes conflicting with policies aimed at promoting sustainable agriculture.
- Insufficient integration of policies: Existing policies related to water management, climate adaptation, and coastal development are often implemented separately rather than through an integrated coastal management approach.
- Limited stakeholder participation: Local communities and farmers are not always adequately involved in planning and implementing salinity management measures, which can reduce the effectiveness and sustainability of interventions.

Weak monitoring and enforcement: Although policies exist, monitoring mechanisms and regulatory enforcement are often limited, reducing the effectiveness of policy implementation.

Institutional Coordination and Governance Gaps

Fragile Local Governance: Municipal water governance frameworks at the local level are often inadequate to manage the complex interplay between natural salinity and human activities like shrimp farming.

Inter-Agency Disconnect: There is a significant lack of coordination between key agencies such as the Bangladesh Water Development Board (BWDB), the Department of Agricultural Extension (DAE), and the Local Government Engineering Department (LGED). This fragmentation means that water management projects often fail to align with agricultural needs at the field level.

Centralized Planning: Policy implementation is dominated by centralized planning, which lacks specific operational guidance for localized, polder-level monitoring and farmer-led adaptation.

Ambiguity in Responsibility: Stakeholders often face confusion regarding who holds ultimate authority over vital infrastructure; for example, there is disagreement over whether the Ministry of Water or politically appointed local committees control sluice gate operations.

Technical and Data Limitations

Lack of Integrated Models: There is no comprehensive, long-term water-soil-salt relationship model. This makes it difficult for policymakers to predict high-resolution future risks and develop precise action plans.

Data Standardization: Accessibility to uniform data standards across various government and non-government sectors remains problematic, preventing seamless integration of findings into policy.

Monitoring Gaps: Farm-level monitoring systems to track real-time salinity changes are currently underdeveloped.

Construction and Maintenance Hurdles

Infrastructure Neglect: While the BWDB is responsible for polder restoration, many structures are poorly maintained or intentionally damaged by shrimp farmers to allow saltwater ingress, leading to further soil degradation.

Regulatory Enforcement: Governments face challenges in enforcing existing regulations, such as buffer zones or restrictions on unauthorized saltwater aquaculture.

Equity and Accessibility: Existing policies often fail to involve local governing bodies and NGOs that have better access to marginalized communities. Furthermore, assistance is sometimes disproportionately distributed toward those with more power rather than the most vulnerable.

5.2.2 Knowledge Gaps

The literature and field interviews highlight several critical knowledge gaps that hinder effective salinity management in Bangladesh.

Technical and Modeling Gaps

- Lack of Integrated Models: There is no comprehensive, long-term model that integrates the dynamics between water, soil, and salt. This makes it difficult to predict high-resolution future risks for specific agricultural zones.
- Projection Limitations: While regional projections exist, there is a lack of actionable plans based on high-resolution downscaling that can guide local-level adaptation.
- Technology Lag: There is a concern that the time required to pilot and scale salt-tolerant crop varieties (often 4–5 years) cannot keep pace with the rapidly escalating salinity levels.

Data and Monitoring Gaps

- Standardization Issues: Accessibility to uniform data standards across government and non-government sectors remains problematic, preventing seamless policy integration.
- Real-Time Tracking: There is a lack of farm-level monitoring systems to track real-time salinity changes, which is essential for immediate agricultural decision-making.

Socio-Economic and Health Gaps

- Under-representation of Gender: Current salinity and food systems policies lack specific gender-sensitive dimensions, despite women being disproportionately affected by health and fetching-water hardships.
- Health Correlations: There is limited quantitative data regarding the correlations between salinity and health beyond hypertension, such as broader nutritional impacts and specific reproductive crises.
- Governance Ambiguity: There is a lack of study on local governance structures, often leading to confusion over who holds authority over vital infrastructure like sluice gates.

Agricultural Systems Gaps

- Zonal Misalignment: Crop selection is often not properly aligned with specific agro-ecological zones, leading to suboptimal yields.
- Farm-Scale Outcomes: The link between observed regional salinity levels and specific food outcomes at the individual farm scale remains weak.

5.2.3 Coordination Gaps

Apart from the policy and knowledge-oriented gaps there are also lack of coordination among the implementing agencies. Some of the key gaps related to coordination are:

- Institutional Disconnect: A critical gap exists between the Bangladesh Water Development Board (BWDB), which manages infrastructure, and the Department of Agricultural Extension (DAE), which manages crops.
- Centralized Planning: Decision-making remains top-down, lacking specific operational guidance for localized, polder-level monitoring and farmer-led adaptation.

Socio-Economic Neglect: There is an inadequate integration of gender, local governance studies, and social conflict management (such as shrimp vs. crop farming) within long-term water policy.

5.2.4 Implementation Gaps

Despite significant investment, several areas continue to face implementation barriers due to technical, social and maintenance issues.

- **Operational & Maintenance (O&M) Failure:** A significant portion (approx. 24–36%) of community RWH and PSF systems are non-functional due to inadequate maintenance and a lack of clear O&M funding at the village level (Ghosh & Ahmed, 2022).
- **Lack of Community Ownership:** Over-reliance on NGO/Government setup without long-term community ownership often leads to infrastructure decay (Saha et al., 2024).
- **Unintended Consequences of Infrastructure Development:** While polders prevent saline flooding, they often lead to "internal waterlogging" and salt accumulation within the polder due to poor drainage design (Feist, Hoque, & Ahmed, 2022). Furthermore, dredging efforts are sometimes negated by rapid re-sedimentation when excavated soil is left on riverbanks (Prothom Alo, 2026).

5.2.5 Synergies and Overlaps

The management of salinity in Bangladesh relies on a complex network of government agencies, NGOs, research institutions, and international donors.

Synergies

The Water-Food Nexus: Synergies are emerging through integrated approaches that treat water management and agricultural practices as a single system.

- **Public-Private Partnerships**: Projects like COASTS utilize consortia of NGOs, private seed companies, and government research bodies to bridge the gap between scientific innovation and field-level adoption.

- **International Collaboration**: The Salinity – Water & Food Systems (SW&FS) Partnership facilitates lateral learning, allowing Dutch and local stakeholders to co-create sustainable business models and multi-annual action plans.

Overlaps

- **Geographical Crowding**: Multiple NGOs often operate in the same high-risk locations, such as the Gabura union, sometimes providing overlapping benefits to the same beneficiaries without a unified tracking system.
- **Redundant Technical Solutions**: Many projects independently promote the same set of interventions - such as rainwater harvesting, pond sand filters, and salt-tolerant varieties - without sharing data or coordinating supply chains.
- **Fragmented Institutional Mandates**: Management is often hampered by "fragmented institutional mandates". Agencies like the BWDB and LGED often have overlapping spatial mandates regarding canal re-excavation and rural infrastructure, leading to fragmented water management within the same polder. The lack of a unified authority for community-centered water governance remains a primary hurdle to scaling success stories like Polder 31 (Amin & Salahuddin, 2025).

6 Recommendations and Way Forward

The salinity crisis in Bangladesh is a long-term, complex, and multidimensional environmental hazard that currently affects approximately 53% of the coastal region. It is driven by an intricate combination of natural processes - such as sea-level rise and cyclones - and human interventions, including shrimp aquaculture and upstream water diversion. These factors have led to severe degradation of soil and water quality, significantly threatening the country's food security and the livelihoods of over 30 million people.

The findings of this scoping study highlight that virtually every component of the coastal food system - from rice production and homestead gardening to livestock and fisheries - is being negatively impacted. The health consequences are equally devastating, with millions at risk of hypertension and cardiovascular diseases, while coastal women face a unique reproductive health crisis due to the use of saline water for menstrual hygiene.

6.1 Opportunities for Strengthening Partnerships

Strengthening partnerships for salinity management involves bridging sectoral divides and scaling local successes through coordinated action. Based on the sources, here are the key opportunities:

a. Strategic Policy and Institutional Integration

- Bridge the Water-Agriculture Divide: Create joint platforms and formal agreements between the Ministry of Water Resources (BWDB) and the Ministry of Agriculture (DAE) to align infrastructure operation with cropping needs.
- Implement BDP 2100 Locally: Facilitate mechanisms to translate the Bangladesh Delta Plan 2100 into actionable polder-level plans, using the Ministry of Planning as a central coordinator.
- Define Clear Responsibilities: Establish a framework where BWDB maintains infrastructure, DAE promotes climate-smart practices, and LGIs facilitate local conflict resolution.

b. Public-Private and Financial Synergies

- Develop Sustainable Business Models: Engage private companies (e.g., Lal Teer) to co-create and co-fund research for salt-tolerant inputs and low-cost desalination, ensuring solutions continue after project funding ends.
- Coordinate with Global Donors: Align field experiences from projects like COASTS with the investment interests of the World Bank (e.g., the "Partner" project), ADB, and JICA.
- Supply Chain Support: Strengthen Farmer Business Associations (FBAs) to improve the access and commercial viability of locally produced salt-tolerant seeds.

c. Community-Led Governance

- Unify Local Organizations: Formalize interaction between Water Management Organizations (WMOs) and Farmer Field Schools (FFS) to create inclusive polder-scale water management plans.

- Empower Women in Decision-Making: Ensure women are involved in resource allocation and healthcare planning, as they are most affected by water salinity and hygiene challenges.

d. International and Knowledge Sharing

- Lateral Learning: Use platforms like the Netherlands Food Partnership (NFP) to share adaptive strategies between global mega-deltas facing similar salinity threats.
- Global Advocacy: Present local successes in international frameworks, such as the Global Framework on Water Scarcity in Agriculture (WASAG), to inspire global policy shifts.

6.2 Strategic Entry Points for the SW & FS Country Approach

To strengthen the Saline – Water & Food Systems (SW&FS) Partnership's trajectory in Bangladesh, several strategic entry points have been identified to bridge the gap between field-level adaptation and regional water management. These entry points focus on integrating sectors, scaling innovations, and aligning policies to create a resilient food system in the face of rising salinity.

a. Bridging the Water-Agriculture Institutional Divide

A primary entry point is the formal integration of the water and agriculture sectors, which currently operate in silos.

- Inter-Agency Coordination: The partnership can facilitate formal collaboration between the Ministry of Water Resources (MoWR/BWDB) and the Ministry of Agriculture (MoA/DAE) to ensure that regional infrastructure, like sluice gates, is operated according to seasonal cropping needs.
- Joint Platforms: Creating a shared platform for these agencies, potentially facilitated by the Ministry of Planning, can help resolve conflicts between different water users, such as shrimp and crop farmers.

b. Scaling Field Innovations to the Regional/Polder Scale

While projects like COASTS have proven successful at the field scale, the partnership provides a pathway to upscale these solutions to affect entire polder systems.

- Polder-Level Management: Entry points include transitioning from individual farm adaptation to polder-based water management, such as coordinated canal re-excavation and freshwater storage.
- Technical Synergy: The approach should combine field-level techniques like mulching and drip irrigation with regional solutions like Managed Aquifer Recharge (MAR) and controlled tidal management to dilute salinity over a larger area.

c. Strengthening Public-Private Partnerships (PPP)

Engaging the private sector is essential for ensuring that salinity-tolerant technologies remain commercially viable beyond the life of specific projects.

- Seed Supply Chains: Partnering with private companies (e.g., Lal Teer Seeds) can improve the availability and distribution of salt-tolerant vegetable and rice varieties.

- FBA Business Models: Strengthening the role of Farmer Business Advisers (FBAs) as local entrepreneurs can provide farmers with ongoing access to salinity testing services and technical advice.

d. Policy Alignment and Localized Implementation

The partnership serves as a vehicle to translate high-level national strategies into local action plans.

- BDP 2100 & NAP Integration: A critical entry point is aligning the partnership's activities with the Bangladesh Delta Plan 2100 and the National Adaptation Plan (NAP), ensuring that regional investments are informed by field-level evidence.
- Actionable Data: Using high-resolution climate downscaling to create specific, polder-level action plans provides a clear technical entry point for future investments.

e. Inclusive, Community-Led Governance

Empowering local communities to manage their own water resources is a cornerstone of the country approach.

- Unified CBOs: The partnership can help unify different community-based organizations, such as Water Management Groups (WMGs) and Farmer Field Schools (FFS), under a single polder-governance umbrella.
- Gender-Sensitive Interventions: Addressing the unique health and hygiene crises faced by coastal women - such as uterine infections and fresh-water fetching hardships - provides an entry point for integrating health into food system planning.

6.3 Risk Management Strategies

The following priorities have been identified to manage the "moving line" of salinity intrusion:

1. **Integrated Infrastructure & Nature-Based Solutions -** Rather than just building walls, the strategy emphasizes making existing structures work harder and smarter:
    - **Polder Rehabilitation:** Strengthening and rehabilitating coastal polders and embankments to ensure they can withstand higher sea levels and more intense climate events.
    - **Integrated Polder Management:** Coordinating water management both inside and outside the polders to maintain functionality as sea levels rise.
    - **Greenbelt Extension:** Utilizing "natural infrastructure" to provide a buffer against the sea, offering the dual benefits of climate adaptation and carbon mitigation.
2. **Strategic Freshwater Augmentation -** The most critical recommendation is the **augmentation of freshwater flow** across local, national, and basin scales. This is viewed as a primary defense against:
    - The escalating drinking-water crisis.
    - Saltwater intrusion into agricultural lands.
    - The degradation of sensitive coastal ecosystems.
3. **Addressing the "Boundary-Shifting" Risk -** The simulations highlight a future where the **1–5 ppt (parts per thousand) salinity footprint** moves significantly inland. This creates a "boundary-shifting" risk that changes the map of coastal Bangladesh:

- **New Risks for Inland Districts:** Areas previously considered safe are projected to cross the 1 ppt marker under high-end sea-level rise scenarios. This indicates a more intensive risk-averse planning approach should be followed by the policy makers and implementing agency
- **Dynamic Planning:** Stakeholders must accept that the line where "fresh" water ends and "brackish" begins is no longer fixed. This shifting reality must guide all future agricultural decisions and water-supply investments. The forecasting and hindcasting processes need to be considered into planning so that the initiatives for salinity management and adaptation can be more flexible and robust.

One of the most important planning messages from the analysis is that freshwater augmentation is not just a coastal adaptation measure. It is a delta-wide resilience strategy. The further inland the salinity front moves, the more valuable upstream freshwater becomes for protecting irrigation, domestic water services, and ecological function in downstream and intermediate districts. In that sense, salinity management is as much about basin-scale water governance as it is about local protective infrastructure.

Taken together, the whole analysis shows the way salinity intrusion should be read in this study. They show not only that salinity becomes more intense under higher SLR scenarios, but also that its geography becomes broader and more inland. The **coastal zone remains the core hotspot**, especially the exposed districts directly connected to the estuarine system. However, the future risk pattern does not remain confined there. The modelling suggests a progressive shift toward **interior coastal districts** and then, under higher SLR, toward a new set of **non-coastal districts**. This is the key message that responds directly to the review comments: salinity intrusion in Bangladesh should be understood as a **regional and evolving deltaic process**, not only as a static coastal-zone issue.

From a human perspective, this means the problem is quietly redrawing the map of water security. A district does not need to sit on the shoreline to feel the effects of sea-level rise. If it is connected to the delta’s river network, estuarine channels, or tidal waterways, it may gradually find that the water it once treated as fresh is no longer reliably so. The analysis shows where future pressure may emerge, where adaptation planning needs to start earlier, and why the boundary between coastal and inland water risk is becoming less rigid over time.

6.4 Way Forward

From this scoping study, some key takeaways for future action are:

Integrated Management: Effective salinity management requires bridging the current institutional divide between water management (e.g., BWDB) and agricultural extension (e.g., DAE) to ensure that regional infrastructure supports field-level needs. This integration would be key in addressing the local-level issues, aided by the scientific and data driven technical analysis and local-level footprint of the implementing agencies.

Scalable Solutions: While individual adaptations like salt-tolerant varieties and mulching are successful at the field scale, they must be upscaled to the polder and regional levels through coordinated investment and policy support. For example, the supply chain for these modern agricultural management equipment and techniques, as well as the value chain for the alternative salinity-resilient crops / products needs to be there for making the upscaling successful.

Partnership and Policy: The Saline Water & Food Systems (SW&FS) Partnership provides a critical platform for Dutch and local stakeholders to co-create sustainable business models and transition pathways that align with national strategies like the Bangladesh Delta Plan 2100. This sort of platforms function as the bridge between innovative concepts and research ideas from the academia and actionable solutions for the implementing agencies. These partnerships need to be supported and promoted for finding and implementing solutions to a seemingly everlasting problem.

Addressing Gaps: Success depends on closing technical gaps through long-term water-soil-salt relationship models and ensuring that future policies are gender-sensitive and locally responsive.

Ultimately, moving toward a resilient delta will require removing political and economic barriers to environmental stewardship while advancing solutions that center the needs of the most socially vulnerable communities.

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