Water management to address salinity in agriculture in Bangladesh

RESEARCH DOCUMENT

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Wageningen Environmental Research

Table of Contents

Abbreviations

ADB	Asian Development Bank
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BDP2100	Bangladesh Delta Plan 2100
BRRI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
BuZa	Ministerie van Buitenlandse Zaken (Ministry of Foreign affairs the Netherlands)
BWDB	Bangladesh Water Development Board
COASTS	Coastal Opportunities and Agriculture Solutions to Tackle Salinity in Bangladesh
CEGIS	Center for Environmental and Geographic Information Services
DAE	Department of Agricultural Extension
DLS	Department of Livestock Services
DPHE	Department of Public Health Engineering
DOE	Department of Environment
DOF	Department of Fisheries
EKN	Embassy of the Kingdom of the Netherlands
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
IRRI	International Rice Research Institute
IWM	Institute of Water Modelling
JICA	Japan International Cooperation Agency
KU	Khulna University
LGED	Local Government Engineering Department
NFP	Netherlands Food Partnership (in the Netherlands)
NSU	North South University
NWP	Netherlands Water Partnership (in the Netherlands)
Ppt	parts per thousand, indication of salinity
PSTU	Patuakhali Science and Technology University
RVO	The Netherlands Enterprise Agency
SAU	Sher-e-Bangla Agricultural University
SLR	sea level rise
SRDI	Soil Resources Development Institute
WARPO	Water Resources Planning Organization
WB	World Bank
WMO	Water Management Organization
WUR	Wageningen University and Research

List of figures

List of tables

Summary

Global food security faces significant challenges due to limited freshwater availability and increasing salinity intrusion. The increasing of water and soil salinity is a complex issue, with expectations that it further increases in the future, negatively impacting food security. The factors that influence these challenges include climate change, population growth, and human activities.

Bangladesh is among the most vulnerable countries due to climate change and development challenges (geographic position, poverty levels and high population density). Effective water management and agricultural practices are important in increasing food security in this context. However climate change together with salinization of the coastal region add to the complexity of ensuring food security. The complexity also lies in that existing salinity is not constant throughout the year. Salinity levels in Bangladesh are dynamic; the levels peak in May/June, just before monsoon rains and increased river discharges and heavy rainfall mitigate them significantly. However, practices such as groundwater over-extraction during the dry season, saline aquaculture, and the reduced inflow of fresh water, increase soil and water salinity in coastal areas.

Local farmers are applying strategies to deal with these saline conditions, using methods such as the raised beds (sarjan system), using salt-tolerant seed varieties, and mulching to limit evapotranspiration and the salinity increase in the root zone. Nevertheless, high salinity levels decrease agricultural yields and reduce arable land availability, particularly in coastal Bangladesh where water scarcity is a primary constraint on farming.

In this region, home to over 139 polders, managing saline water intrusion into these polders is critical. This is achieved through the careful operation of control structures within the polder embankments, a key measure in maintaining agricultural productivity in the face of salinity challenges.

This study elaborates on the Coastal Opportunities and Agriculture Solutions to Tackle Salinity in Bangladesh (COASTS) approach, and provides a reflection on how water management aspects could be addressed when tackling salinity in agriculture, using spatial scale (field to regional) and temporal scale (now to future) to map innovations.

The analytical framework used for that in in Figure 1.

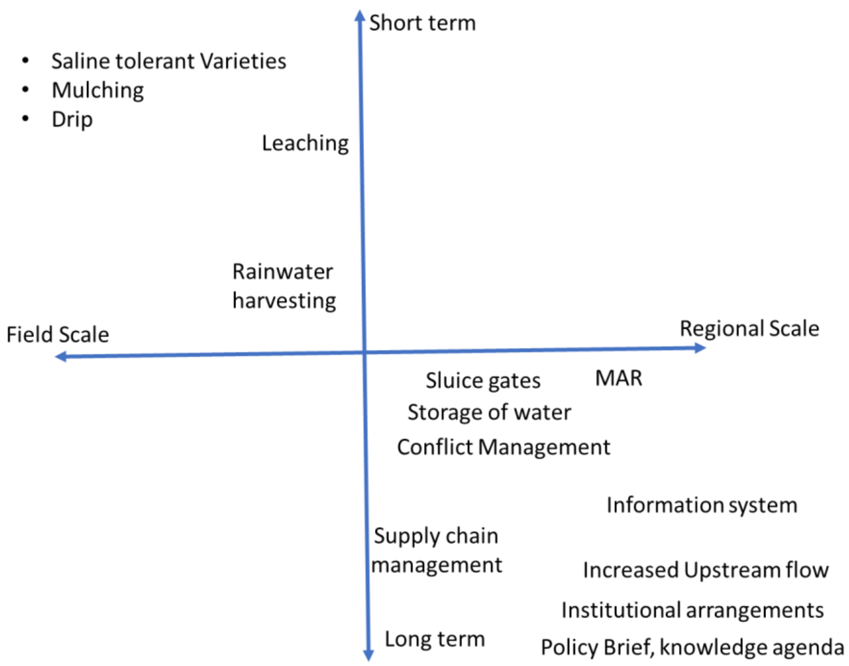

Figure 1: Overview of potential solutions in agriculture practices and water management addressing salinity at different spatial-temporal scale

COASTS is an innovative project, working through a consortium of an NGO (Cordaid), Private sector company (Lal Teer Seeds), a knowledge institute (Bangladesh Agricultural University, BAU) and government agency (Soil Resource Development Institute, SRDI), with farmers addressing salinity at field scale level, and training Farmer Business Advisers (FBAs) as local advisors on salinity tolerant seeds and for measurement of salinity in the soil. Under COASTS project, field scale interventions such as saline tolerant vegetables, mulching, raised beds, rainwater harvesting, and drip irrigation are employed to increase productivity in a water scarce saline region. Other projects, addressing water management, like Sustainable Agriculture, Food Security, and Linkages (SAFAL)- Integrated Water Resource Management (IWRM) and Blue Gold project, re-excavated drainage canals to reduce flooding and to increase storage of fresh water at sub-polder scale. These improve the field conditions and agricultural production.

Communities are engaged in COASTS, SAFAL-IWRM and Blue Gold project to sustain the proposed solution even after completion of the project, but often this is not automatically happening. In the case of COASTS, the link with FBA is expected to be continued after the project, in the case of SAFAL-IWRM the value chain activities and in the case of Blue Gold the water management organizations are expected to be continued. Along with these polder/sub-polder scale activities, institutional arrangements are required at regional scale level (government involvement).

For upscaling in COASTS, the promising results at field scale need to be operational at regional scale level to have meaningful impact on agricultural production and food security. The field level water management of COASTS needs to be connected with water management at the landscape/regional level. Farmers of Cordaid need to connect with the water management group (WMG)/water management organization (WMO), farmer field school (FFS) and farmer groups. The government institutes such as Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC), Local Government Engineering Department (LGED) need to be engaged as well.

It will support progress if policy makers and donors like Embassy of the Kingdom of the Netherlands (EKN)/ The Netherlands Enterprise Agency (RVO)/ Ministry of Foreign Affairs the Netherlands (BuZa) can assist in connecting the spatial and temporal scales when addressing salinity impacts and by connecting policy interventions with generated knowledge and experience. For instance, linking the interest and vision of financing organizations such as World Bank, Asian Development Bank (ADB), Japan International Cooperation Agency (JICA) and government of Bangladesh with field level experiences of consortia like in COASTS. Private sector parties both from the Netherlands and Bangladesh can assist with their interest in finding operational business models addressing complex issues, co-creating and co-funding knowledge to find solutions and the implementation of the solutions. Netherlands Food Partnership (NFP)/ Netherlands Water Partnership (NWP) could assist facilitating parties focusing on new innovations and their applications related to water management, salinity and food production where storage and supply chain will be carefully considered. Locally lead, locally produced, involvement of local communities and local knowledge need to play a role when considering to inspire the adoption of application of the technologies.

The steps are summarized below, including concrete examples for the way forward:

Step 1: Create a vision together with stakeholders for common goals using structured approach such as Food System Approach (Verhagen et al., 2021);

> Example: Organizing a brainstorming event/workshop with stakeholders like the Ministry of Water Resources and the Ministry of Agriculture, but possibly also the Ministry of Planning, representatives from Local Government Institutions (LGI), private sectors and NGOs to develop vision for the future regarding water management and agricultural practices to address impact of salinity.

Step 2: Formulate transition pathway and policies for the perceived future, involving relevant stakeholders;

> Example: Facilitate interaction between the Ministry of Water Resources and Ministry of Agriculture to formulate transition pathway and required policies to achieve the envisioned future.

Step 3: Define responsibilities for stakeholders and government agencies;

Example: BWDB to maintain water infrastructure, DAE to promote climate smart agricultural practices, Ministry of Planning to ensure adequate interaction between the government agencies, LGIs to facilitate conflict resolution at field/local scale, CBOs to operate the gates and canals of polders to drain the polders when needed and store access water for further usage, private sectors to provide the seeds and equipment to achieve food production goals, NGOs such as Cordaid to provide information to the farmers and to connect WMOs and FFS.

Step 4: Create a platform to work together;

Example: Explore setting up a platform where Ministry of Water Resources, Ministry of Agriculture, representatives of LGI, private sector and NGOs interact with each other. EKN could possibly facilitate, Cordaid can also potentially provide such a platform, where they can also interact with regional and national scale stakeholders who might wish to avail their services to reach field level stakeholders.

Step 5: Explore source of funds to implement the project, including mechanisms such public-private-partnership (PPP);

Example: Cordaid can potentially interact with Ministry of Agriculture to showcase their success and ability to effectively work with field scale stakeholders, so this model can be replicated in future projects, e.g. as under World Bank funded 'Partner' project. Possibly Cordaid could play a role in this, providing services.

Step 6: Present and carry out pilot cases showcasing the successful implementations and their impact with a plan to upscale on spatial and temporal scale;

Example: Similar to COASTS project, pilot field applications to address the impact of salinity in water management and agriculture can be carried out. To ensure upscaling, private sectors and local stakeholders involved in water management and agriculture could be involved from the beginning. The upscaling potential and a pathway should be prepared at the initiation stage.

Step 7: Monitor, adapt, learn and share the experience gathered from the project;

Example: Learning in the COASTS project can be documented and shared, and thus may lead to engagement in follow up activities of the partners.

Step 8: Think and explore together on future challenges and activities.

Example: Similar as to step 1: Once a platform exists, different parties will have a role - Local/field scale stakeholders and regional/national scale stakeholders interact within such a platform to explore future challenges and activities. Stakeholders can formulate future plans can be formulated at local/regional scale. Interaction between local and national level will need facilitation. An NGO, like Cordaid, can act as a facilitator for such interactions having the unique experience doing so in their current programmes in which they interact with local and national level stakeholders and transfer knowledge across different scales.

1 Introduction

The Netherlands Enterprise Agency (RVO) requested Wageningen University and Research (WUR) to support with knowledge and expertise on water management in saline agriculture in Bangladesh as part of the Impact Accelerator of the sustainable development goal (SDG) Partnership Facility (SDGP).

The assignment is a desk study, including interaction with stakeholders, addressing improved water management in saline agriculture, focusing on water related challenges in scaling up strategies in situations where salinity is an issue. It analyses possible intervention strategies, at different levels, a.o. farmers (field level, including e.g. mulching, agroforestry, cover crops) and polder / river basin, addressing main actors in the water and agriculture sectors such as farmers, communities, government, knowledge institutes, NGOs, and the role of private actors (both in Bangladesh and the Netherlands), possible options for financing and the type of financing, taking into account the actors and scale of interventions and knowledge and information that might be required by the different actors.

The following activities are undertaken in this study:

- Prepare an inception report to develop a workplan based on the specific needs of the COASTS partnership and the Netherlands Embassy.
- Prepare a report (research document) with recommendations by reviewing relevant literature, policy documents and the responses received in interviews and workshops.
- Prepare a PowerPoint presentation of final findings and organize an on-line session to share findings and receive feedback[1].

We have consulted with the Netherlands Enterprise Agency (RVO) (Ella Lammers and Michiel, Slotema), Embassy of the Kingdom of the Netherlands (EKN) (Neeltje Kielen, Dr. Md. Shibly Sadik and Dr. Mohammad Assaduzzaman), Coastal Opportunities and Agriculture Solutions to Tackle Salinity in Bangladesh (COASTS) (Abul Kalam Azad, Arun Ganguly, Muhammad Imran and Zainal), World Bank, talked with the farmers involved in COASTS and conducted a workshop as a part of International Conference on Water and Flood Management (ICWFM) with a session titled "Salinity, looking towards the future: Transition pathways in water management and agriculture, addressing salinity" with 43 participants of whom 12 were from government agencies and 31 were from knowledge institutes of Bangladesh and abroad.

This research document has been prepared to share a reflection on the findings from COASTS project reports (as far as shared with the team), selected and scientific literature and policy documents with regard to water management and salinity in Bangladesh, to provide recommendations on improving water management in saline agriculture in Bangladesh to COASTS project, EKN/RVO/BuZa and platforms like the one on salinity coordinated by Netherlands Food Partnership (NFP)/ Netherlands Water Partnership (NWP).

[1] On 6 Feb the findings were also shared at the WaterProof meeting, organized by RVO-PvW, in the session on salinity

2 Background and Approach

Background

The shortage of fresh water and salinity stress on agriculture is challenging global food security. Increasing population and climate change exacerbated the situation in the future (Khondoker *et al.*, 2023). Water and soil salinity had an increasing trend for the last few decades and both water and soil salinity is projected to increase in the future (Russ *et al.*, 2020; Hassani *et al.*, 2021). Increased water extraction, poor water and irrigation management, agricultural practices, sea level and climate change are a few of the major drivers for increasing salinity in water and soil (Hassani *et al.*, 2021; Snethlage *et al.*, 2023). Increasing salinity in water and soil threatens global agricultural production and is a major global challenge (Russ *et al.*, 2020; Snethlage *et al.*, 2023). Over 1 billion hectares of land globally is affected by salinity in more than 100 countries (Russ *et al.*, 2020). Hassani *et al.* (2021) reported that between the year 2000 and 2013, agricultural production equivalent to 124 trillion kilocalories is lost annually which to their estimation would have been enough to feed more than 170 million people daily, every year. Drivers of salinity vary globally, which is depicted by Snethlage *et al.* (2023) who identified the drivers for arid and semi-arid areas, deltas and small island developing states. Bangladesh was one of the study areas as part of deltas. In Bangladesh rice contributes to 70% of agricultural area and 80 percent of the irrigated land. Salinity intrusion is affecting rice production in the coastal region (Terwisscha van Scheltinga *et al.,* 2023). Increasing salinity level in Bangladesh is caused by both natural and anthropogenic changes. Reduction of freshwater flow from upstream, extraction of ground water, land subsidence, sedimentation, sea level rise, dike breach and saline aquaculture are listed as primary drivers of salinity in Bangladesh (Snethlage *et al.,* 2023).

Salinity in Bangladesh varies spatially and temporally. During the dry season, salinity is the highest in the southwestern part of Bangladesh. Salinity is considerably lower in the eastern side of the coastal areas. During monsoon season when there are enough water flows from upstream to push salinity intrusion towards the sea and heavy rainfall, salinity is the lowest across the coastal regions. Soil salinity and water salinity differ as well. Salinity in surface water interacts with sea water and changes with tides and seasons. Salinity in ground water and soil largely depends on land use, water extraction and agricultural practices. Salinity not only varies spatially and temporally but also varies in surface water, ground water and soil, making it a complex phenomenon.

Water management has a substantial impact on salinity. Numerous salinity issues around the world are related to water management. Inadequate field drainage, inappropriate disposal of the drainage water, inefficient irrigation and lack of sound irrigation management plan result in increasing salinity (van Schilfgaarde, 1993). Similarly, increase of salinity in soil and water of coastal region of Bangladesh is the result of human interventions and management which altered the coastal, fluvial and geomorphological systems (Feist *et al.*, 2023). Anthropogenic changes in water management such as reduction of freshwater flow from upstream, over extraction of ground water, disruption of interaction between flood plain and monsoon flow due to construction of dike and, saline aquaculture led to increasing soil and water salinity in coastal Bangladesh (Snethlage *et al.,* 2023).

Approach

We first review relevant scientific articles and published reports on water management for salinity in agriculture in Bangladesh to explore current options and practices to address salinity related issues (in short mentioned below, more details in chapter 3.1). Subsequently, we map the interventions/solutions on a temporal scale (short term to long term) and a spatial scale (field scale to regional scale) (Figure 2). Then we list on-going and completed relevant projects (3.2), policy documents (3.3) and stakeholders (3.4) using salinity and scale as attention points. Followed by analysis of insights from workshops, conference and interviews (4.1), analysis of opportunities (4.2) and provide policy recommendations on improving water management in saline agriculture are provided to COASTS project, EKN/RVO/BuZa and NFP/NWP using the reviewed literatures, policy documents and reports and experience of previous and on-going projects (chapter 5).

Salinity and agricultural practices

a. Saline tolerant varieties (field scale)
b. Drip irrigation (field scale), can be field scale solution but creating issues for the future
c. Mulching (field scale)
d. Rainwater harvesting (field scale)
e. Sarjan method (field scale)
f. Alternate wetting and drying (AWD) in rice cultivation (field scale)

Water management and salinity

a. Sluice gate management (regional scale)
b. Store water in canals, ponds and low elevation areas (regional scale)
c. Managed aquifer recharge (MAR) (regional scale)
d. Leaching salinity with freshwater irrigation (field scale)
e. Provide relevant information to the farmers (regional scale)
f. Increased upstream flow (regional scale)
g. Institutional arrangements (regional scale)
h. Conflict management, water management groups/organization (WMG/WMO) (regional scale).

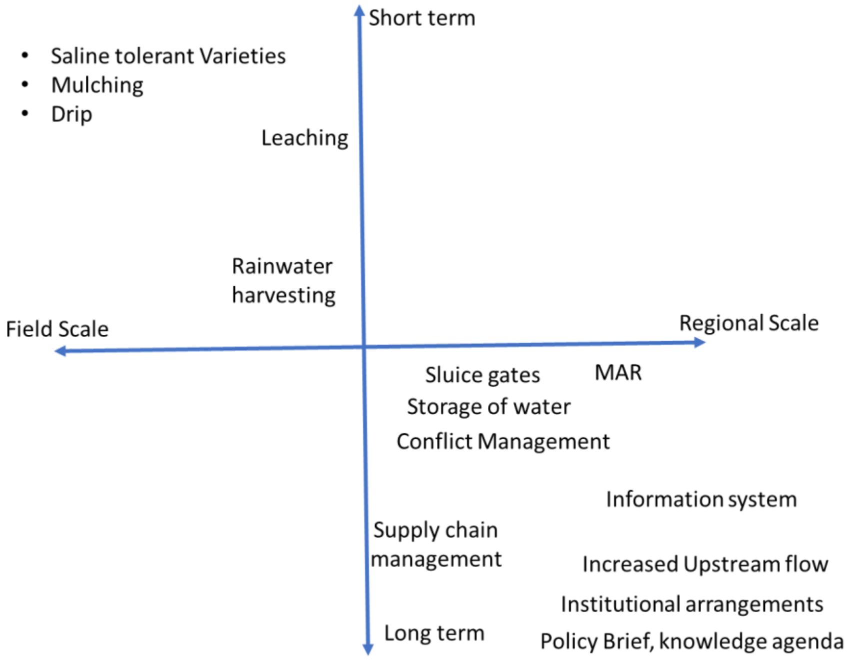

Figure 2: Overview of potential solutions in agriculture practices and water management addressing salinity at different spatio-temporal scale

3 Review of current practices, research and policies on water and salinity in agriculture

In this section an overview is provided regarding water management, agricultural practices and salinity based on literature review (3.1), ongoing and completed projects (3.2), policy documents (3.3) and stakeholder mapping (3.4).

3.1 Literature on current practices to address salinity and potential solutions

Increased salinity is affecting agriculture in Bangladesh. Water and soil salinity show an increasing trend globally for last few decades (Russ *et al.*, 2020 and Hassani *et al.,* 2021). Coastal region of Bangladesh is about 32% of total landmass and home to about 30 million people (Feist *et al.*, 2023 and Islam *et al.,* 2023). Saline effected soil have increased from 0.833 million hectares in 1973 to 10.56 million hectares in 2009 (Islam *et al.,* 2023). Farmers of coastal region are effected by increasing salinity in some cases leaving the land fallow during dry season which is reducing the crop production of the region (Mongabay, 2023). By 2050 saline soil can increase by 39% resulting in 10% loss of food production (Feist *et al.*, 2023 and Islam *et al.,* 2023). To reduce impact of increasing salinity, initiatives are taken by government and non-government (NGOs) agencies. Both field based and non-field based measures are being implemented. The primary objective of field based measures is to reduce impact of salinity on agricultural production. Non-farming dependent livelihoods are focused on by the non-field based measures (Rabbani *et al.*, 2013). Field based measures include saline tolerant crops, storage of fresh water in canals, ponds and tanks, efficient water usage with drip irrigation and management of soil salinity with mulching, flushing of rice fields with fresh water, repairing or reconstructing irrigation channels, managed aquifer recharge, field testing of saline water and soil and adjusting cropping pattern accordingly and providing information to the farmers (Rabbani *et al.*, 2013). All these are mostly applied at field scale, some of them as part of different projects focusing on specific areas of the coastal region but no field level activities have being upscaled across the coastal region yet. For a complex issue like water management and salinity, one solution will not be able to address all, there is a need for multiple solutions at different spatial and temporal scale. Bangladesh Agricultural University (BAU), as part of the COASTS consortium, did upscale by making education curricula and also prepared advices for the farmers.

Agricultural Practices

<u>Saline tolerant varieties</u>

Salinity in coastal region of Bangladesh is increasing reducing and restricting crop production throughout the year, especially during the dry season. Salt tolerant rice, wheat and vegetable varieties are being used by the farmers.

Rice

The salinity tolerance threshold of traditional boro rice is 4-5 dS/m (Islam *et al.*, 2021b). In 2009 about 10.56 million hectares of coastal land accounting for 3.5% of the total coastal land was salt effected and about 69% of the salt effected land had salinity higher than 4 dS/m which led to loss of food production (SRDI, 2010). Several salt tolerant varieties are developed by Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Rice Research Institute (BRRI), Bangladesh Agriculture University (BAU) and Cereal systems initiative south Asia-Bangladesh (CSISA-BD) (Ahmed *et al.*, 2021). Salinity tolerance threshold for new varieties ranges between 8 to 10 dS/m (Islam *et al.*, 2021b). Even though the saline tolerant varieties provides opportunities to the farmers the adoption of these varieties are low especially among the marginal and small hold farmers (Ahmed *et al.*, 2021). Ahmed *et al.* (2021) indicated that medium and small farmers being risk adverse, their inability to offset crop loss, lack of education and access to information about new technologies are among the causes for low adoption of new varieties.

Wheat and pulses

Wheat is slightly more salt tolerant than rice with salt tolerance of 6 dS/m (Asana, 1965). The salt tolerance of Mung bean, a type of pulse planted in coastal Bangladesh, is 1.8 dS/m which is quite low compared to wheat (Minhas *et al.*, 1990). A project titled "Incorporating salt-tolerant wheat and pulses into smallholder farming systems in southern Bangladesh" of Australian Centre for International Agricultural Research (ACIAR) with the objective of "increasing small-holder household incomes through improved productivity and profitability of dry-season crops on non-saline land, and with pulses and wheat with improved salinity tolerance on saline land in Southern Bangladesh" developed 3 salt tolerant wheat varieties and established several de-husking mini mills for mung bean for small hold farmers. The project provides the farmers opportunity to have positive economic return from pulse cultivation and confirmed that a targeted trait-based breeding approach can be an effective strategy to improve salt tolerance and subsequent yields of wheat grown in challenging saline environments. The new wheat varieties are likely to have about 20% more yield in saline environment compared to the current varieties, but will require further development. The challenge of upscaling of cultivation of mung-bean in dry season was connected to difficulties of managing cattle grazing and movement after the harvest of *aman* rice in the field (Erskine *et al.*, 2023).

Vegetables

Department of Agricultural Extension (DAE) of Bangladesh is promoting vegetable production and intake to ensure sustainable income and nutritional intake through the project "Establishment of Family Nutrition Gardens in Uncultivated Fallen Lands and Backyards". The project aims to create 4.88 lakh gardens across the country, which will provide 2.18 lakh tonnes of vegetables per year. The salinity tolerance of tomato, potato, squash, cabbage, broccoli, cucumber and eggplant, the most widely produced vegetables in Bangladesh, are 2.5 dS/m, 1.7 dS/m, 3.2 dS/m, 1.8 dS/m, 2.8 dS/m, 2.5 dS/m and 1.1 dS/m. In general the salinity tolerance of vegetables are relatively low. Coastal Opportunities and Agriculture Solutions to Tackle Salinity (COASTS) a project funded by Dutch government implemented by Cordaid in the coastal areas of Bangladesh introduced saline tolerant vegetable varieties and provides information of saline tolerance of crops and vegetables to farmers. Cordaid trains the farmers on saline agricultural practices and at the moment 10,000 farmers have been provided training.

Drip Irrigation

Drip irrigation is a type of micro-irrigation system that allows water to drip slowly to the roots of plants, either with surface irrigation or sub-surface irrigation. The efficiency of drip irrigation is usually higher. Vegetables are most suitable for drip irrigation. Drip irrigation is most useful where water is scarce and of poor quality such as high salinity. The rate of irrigation depends on soil type, for clay soil the rate is slower than the sandy soil. In Bangladesh the commercial vendors of drip irrigation provide pump, pipes, emitters/drippers, controllers and other equipment. However, in the COASTS project locally made drip irrigation system with earthen pitchers with perforated bottom and ropes made of jutes are used to reduce cost. In the Chittagong hill tracks, farmers engaged with "The Leadership to Ensure Adequate Nutrition (LEAN)" project funded by the European Union are re-using the plastic water bottles for drip irrigation to reduce cost and water consumption. The installation and, operation and maintenance of drip irrigation are usually costly, especially for marginal and small farmers. As lower amount of water than flood irrigation is applied, leaching of salts from root zone depth is not ensured which may result in salt accumulation over the years especially when enough leaching doesn't happen during the rainy season. This can potentially impact agriculture productivity negatively in the future. If the irrigation water is not clean, has algae, dissolved chemical and fertilizer deposits, the emitters of drip irrigation system can become blocked and a filtration unit will be required which will increase the cost of operation.

Mulching

Mulching is a practice with which soil surface is covered by various materials to reduce loss of moisture, weed population and increase crop yield. Mulches has been widely used for vegetable production throughout human history (Iqbal *et al.*, 2020). Application of Mulches can increase water use efficiency at field scale and reduce salt accumulation at the root zone level as evaporation and the upward movement of salts are reduced. Both organic material such as crop residues, straw, grasses, and farmyard manure etc. and inorganic/synthetic materials such as polyethylene sheets, gravels etc. can be applied as mulch (Abd *et al.*, 2016). Mulching is been used in coastal Bangladesh for vegetable production especially in the saline and water scarce region. It was observed during the recent field visit to Lal Teer's experimental center in Rampal and in the fields of farmers supported by Cordaid through COASTS project. Even though mulching has several advantages, there are drawbacks as well. One of the major challenge for mulching is additional cost which can prove to be a large stumbling block for the small and marginal farmers. The mulching materials should be carefully selected as inorganic materials such as plastics which are flammable and might have negative impact. Moreover, some organic material which can be carrier agents of many weed seeds and pathogens might increase pathogens and weed infestation (Iqbal *et al.*, 2020).

Sarjan method

Sarjan technology can increase agriculture intensity in areas which are water logged or regions with tidal flooding or where agriculture production is feasible only for certain part of the year. In Sarjan method the banks of ponds, ditches can be utilized for planting the crops especially vegetables which grows beyond the bank or dry land on top of the flooded area with the help of small structure usually made of bamboo or wood (Figure 3). Digging trenches and raising land with the material can also be applied to Sarjan. The ditch or waterbody can be used for aquaculture as well. It is already applied in several locations across the Bangladesh delta. The method provides opportunities to the farmers facing adverse conditions. However, it requires considerable initial investment to setup the structure. The agricultural production will still be impacted in case of saline water intrusion and lack of availability of fresh water. This method is useful where water logging and flooding occurs for a long time. For a non-flooded region with this method the crops at planted different might compete for resources and resulting in reduction of yield. Sarjan method requires specific training. However, as several locations of southwest Bangladesh are facing prolonged water logging, this method can increase food productivity and improve socio-economic conditions.

Figure 3: Sarjan Method being applied in the field (Awal, 2014)

Alternate wetting and drying (AWD) in rice cultivation

Alternate Wetting and Drying (AWD) is a water-saving technology that farmers can apply to reduce their irrigation water consumption in rice fields without decreasing its yield. The field is periodically dried and flooded with irrigation in AWD, without stressing the plants and reducing the yield. In AWD, irrigation water is applied when the water level drops a certain level below the ground level. The water depth is allowed to gradually decrease after irrigation due of evapotranspiration, seepage, and percolation. Water level is monitored through a small bore whole or inserted PVC pipe in the field. Irrigation is applied again when the water level becomes 15-20 cm below the surface. This method can reduce water use up to 38% for rice cultivation (Rejesus *et al.*, 2011). As water consumption is less, the cost regarding irrigation and pumping are lower. AWD also leads to reduction of methane (CH_4) emission. However, the release of nitrous oxide (N_2O) increases (Lagomarsino *et al*., 2016). This method requires training as water and moisture need to be monitored and water need to be applied at a specific time. Inadequate application of AWD can lead to reduction of yield. Moreover, pest control is challenging for AWD. The applicability of AWD depends largely on soil type and weather conditions. Therefore, it is not universally applicable.

Water management

Rainwater harvesting

Rainwater harvesting (RWH) is referred to as to manage, control and store rain water for future usage. It is a practice that dates back to prehistoric times, and still forms an integral part of many domestic and agricultural systems in arid and semiarid regions as well as coastal regions (Linderhof *et al.*, 2020). Rainwater can be stored in ditches, canals, deep tillage, contour farming and in tanks. Large amount of rainfall during monsoon and household construction material make rainwater harvesting an attractive option for coastal Bangladesh (Ghosh and Ahmed, 2022). In coastal regions of Bangladesh, rainwater is being stored in the polders under Blue Gold project. In the Safal-IWRM project several canals are dredged to increase drainage and water storage capacity to hold access water especially. Rainwater harvesting (RWH) has been applied to households as well. Donor agencies and NGOs are assisting implementation of rainwater harvesting. Government agencies such as the Department of Public Health Engineering (DPHE) has launched various projects to promote household and community-based RWH systems and Pond Sand Filters (PSF) (Ghosh and Ahmed, 2022). In several cases, the stored water is used for agricultural practices with the combination of water efficient irrigation such as drip irrigation. Storing rain water in ditches and canal has challenges as well. The challenges include loss of stored water through evaporation and leaching. High ground water table or high surface water level with high salinity can impact the quality of the stored water. Furthermore, canals where water is stored are most accessible to and useful for adjacent farmlands and farmers, and fields located further away from the canal don’t enjoy similar benefits. Moreover, storing water in a tank for long can have water quality challenges and the quantity of water to be stored in tanks is limited. Both of these techniques are costly and might be challenging for the small and marginal farmers which was affirmed by the farmers during recent field visits to the coastal region of Bangladesh.

Sluice gate management and storing water in canals

The control structure and sluice gates of polders of Bangladesh are constructed to ensure drainage of the areas inside and reduce flood risk. The control structures can also be operated to regulate flow of fresh and salinity water inside the polders. In general the control structures are operated and maintained by Bangladesh Water Development Board (BWDB). Recent survey by BWDB indicates that large portion of the control structures require maintenance to remain operational. The ownership and funding for operation of sluice gates are not always readily available, as informed by BWDB during recent interviews and workshops. Conflicting interest of stakeholders involved in agriculture and saline aquaculture adds to the complexity of polder and operation of the gates. The World Bank funded projects Coastal Embankment Improvement Project (CEIP)-I and CEIP-II have invested in improving the polder dikes and control structures in the coastal region. Under the Blue gold project co-funded by the Government of the Netherlands and the Government of Bangladesh and implemented by BWDB and DAE, water infrastructure were rehabilitated for 22 polders and Water Management Groups (WMGs) and Water Management Associations (WMAs) were formed for water management inside the polders. Water management in these polders were carried out by WMGs and WMAs to store rainwater and fresh water in canals along with other activities. SAFAL for Integrated Water Resource Management (IWRM) project aims to sustainably store and use ground and surface water and canals of 80 micro-watersheds in the southwestern districts namely Jashore, Narail, Satkhira, Khulna and Bagerhat. These 80 canals will be rejuvenated to achieve the goal. SAFAL-IWRM is a project funded by Ministry of Foreign Affairs, Netherlands.

Managed aquifer recharge (MAR)

Managed aquifer recharge (MAR) is applied to store excess water in the shallow aquifers to be used during dry season when fresh water is scarce. MAR has been developed and implemented mostly to address shortage of domestic and drinking water. UNICEF, in collaboration with Department of Public Health Engineering (DPHE), Dhaka University, Acacia Water (Netherlands) and seven local NGOs introduced and scaled up MAR implementation in three coastal districts (Khulna, Satkhira, Bagherat) of Khulna Division since 2009 focusing on drinking water and rural water supply. Until now the application of MAR in agriculture (Agri-MAR) has not been developed at large scale. MAR can be applied at field scale as well as at larger scale. It can provide water when its needed most and by storing excess water from rainfall it can play its part in flood risk reduction as well. However, the quality of water to be stored needs to be inspected and maintained as the overland flow can potentially accumulate chemicals from agricultural practices and pollute the aquifers. Application of MAR largely depends on soil and aquifer properties whether water can be stored or not. Even at small scale, implementation of MAR requires large investment which can be a challenge for small and marginal farmers. It requires community involvement as well, as this can impact a larger area and can be used by multiple stakeholders. MAR for agriculture (Agri-MAR) was tested at the research and development center of Lal Teer seed in Rampal of southwestern Bangladesh. Acacia Water constructed and operated the Agri-MAR system for the irrigation of crops. The fresh water stored in ponds during rainy season was stored underground to be used during dry season for irrigation. Considerable amount of infiltrated freshwater was lost due to mixing with saline ground water. The recovered fresh water was mixed with brackish surface water to irrigate salt tolerant crops with water of constant low salinity. The cost of installation was 4500 euros with yearly operation cost of 620 euros which could irrigate 0.32 ha of land. To operate the Agri-MAR, the farmers will need to earn enough revenue from utilizing the recovered water. The earning of farmer is largely depends on the crop type and market value of the product. As the investment costs are large, it was recommended that for upscaling the farmers will require loans or grants as well as technical assistance. Private sector and famers association might be interested to be involved in Agri-MAR but will require investment loans or micro finance. Suitable institutional arrangement will be required as well for MAR, in order to ensure sustainable use of groundwater.

Leaching salinity with fresh water irrigation

During monsoon, Bangladesh receives large amount of rainfall which reduces the salinity in both soil and water. Farmers in the southwestern coastal areas also irrigate to leach out the salt. However, leaching of salt requires large quantities of non-saline water of good quality which might not be available everywhere round the year. Moreover, there is risk that the leached solutes might reach deeper aquifers and result in ground water pollution.

Provide relevant information to the farmers

With relevant information farmers can take early action and make decisions which might be economically beneficial. Weather Impact together with DAE and Bangladesh Meteorological Department (BMD) has worked on producing weather forecast, early warning and relevant action points and bulletins to the Mango farmers under sub-seasonal to seasonal (S2S) forecast information for Bangladeshi farmers. S2S is a project which is part of the larger AMISDP programme (agro-meteorological information systems development programme). In the larger programme, providing weather forecast and producing agriculture bulletin have the potential to be implemented at larger scale and assist numerous farmers. The challenges include the lead time for forecast, uncertainty and reliability of the information, acceptability to the end users, method of information dissemination and accessibility of the information. The AMISDP project was funded by World Bank (WB) up till December 2023 and is expected to continue in Phase 2 in (near) future. S2S forecasts are sub-seasonal to seasonal forecasts, which are weather forecasts with 4 weeks lead time. These provide an indication of the weather on a weekly time scale. BRAC, a renowned NGO is providing weather related information directed to the farmers as well.

Increased upstream flow

The southwestern part of Bangladesh delta is receiving less fresh water from upstream due to human intervention and morphological changes at the inlet of the Gorai River which is the primary supplier of fresh water for this part (Islam *et al.*, 2021a). As a result, the river beds are silting up and salinity front is moving further inland (Rahman *et al.*, 2017 and Islam *et al.*, 2021a). Increased fresh water flow from upstream will reduce the salinity level of the southwestern delta of Bangladesh (Rahman and Navera, 2018). A feasibility study was conducted in 2017, for the construction of a barrage on Ganges River 36 km downstream of inlet of Gorai River at Pangsha. The objectives were to increase fresh water flow towards the southwestern region, reduce salinity intrusion, increase agricultural production, improve inland navigation and drainage. The same feasibility study, indicates that the project will have positive impact on environment, agricultural production and economic development (Mahmud *et al.*, 2017) but could not be followed up due to lack of funds and manpower.

Supply chain and storage management

The production of food requires land, water and resources. Loss of food is becoming a global issue through which water and resources used to produced food are wasted. If food is wasted, it basically means that precious water is wasted. About 1.3 billion tons of produced food is lost globally every year. Post-harvest loss is estimated to be about 22 to 44% of produced food in Bangladesh (Hassan *et al.* 2010). The post-harvest loss of food is due to lack of infrastructure, storage facilities and supply chain management. This indicates that improving supply chain management and storage capacity can have positive impact on reducing water and food loss. This is essential for the coastal region of Bangladesh where availability of fresh water to produce food is already scarce. Vernooij *et al.* (2021) studied the food supply system in Bangladesh and suggested that the quality of the product needs to be improved, development of skills to be facilitated to handle food post-harvest is required, need to develop collaborative food value chain and create awareness, investment is required in infrastructure development, storage facilities and increase institutional capacity for monitoring and regulation to reduce food waste. Reducing food to turn bad will save water.

Governance

Institutional arrangements

Institutional arrangements for water management and adaptation to climate change are complex and involves numerous organizations. The management of water resources is shared between state water agencies, users of water involved in agriculture, government agencies involved in industry, commerce, water supply, sewage, public health, inland water transport, fisheries, forestry and the environment. In Bangladesh, the Ministry of Water Resources is responsible for flood management, irrigation, drainage control, erosion protection, land reclamation, integrated management of coastal polders, river flow augmentation, water sharing from transboundary rivers and wetland conservation through coordinated programs with all the ministries dependent on water resources such as the Ministry of Agriculture (MoA) and Ministry of Water Resources (MoWR). However, more care needs to be taken to assess the impact of constructed structure on different catchments than the one for which it was built. Moreover, the coordination among agencies needs to be improved (Chowdhury, 2010). An interagency task force was formulated in 1999 comprising officials from both Ministry of water resources and Ministry of agriculture. The Master Plan for Agricultural Development in the Southern Region of Bangladesh, 2012 by MoA recommended development of Inter-Ministerial Implementation Coordination Committee (IMICC) and Inter-Ministerial Implementation Committee (IMIC) to increase co-ordination among the government agencies. It was stressed that to implement National Water Act 2013, interagency co-operation between the Ministries of Agriculture (MoA), Local Government, Rural Development & Cooperatives (MoLGRD&C), Ministry of Industries (MoI), Ministry of Textiles & Jute (MoT&J) and Disaster Management & Relief (MoDM&R) and Ministry of Water Resources. It was suggested that Water Resources Planning organization (WARPO) should have the capacity to involve the agencies under different Ministries to make the Water Act 2013 effective in different sectors. Several approaches were explored in different projects to increase co-operation between different agencies such as Memorandum of Understanding (MOU) and Cooperation through Full Partnership. Under the Blue Gold project, the Ministry of Agriculture (MoA) and the Ministry of Water Resources (MoWR) coordinated with each other. The Ministry of Agriculture (MoA) played an influential role in policy-level decisions alongside the ministry of Water Resources (MoWR).

Bangladesh Agricultural Development Corporation (BADC) which is an autonomous corporate body under the Ministry of Agriculture, operates small scale irrigation projects along with other agricultural development activities. BWDB which is part of Ministry of Water resources have agricultural research officers as well. As BWDB is one of the major organization which manages water resources and MoA is the major user of water resources, these organizations should co-operate better.

Using the National Water Policy (NWPo) of 1999 and Guidelines for Participatory Water Management of 2001, BWDB developed water management groups (WMGs), water management associations (WMAs) and Water Management Federation (WMF) under Blue Gold project for community participated water management. It was planned that through a signed agreement between BWDB and WMGs the responsibilities will be sorted. WMGs will be responsible for routine maintenance and operation of the structures. WMGs can also assist in conflict resolution among different stakeholders such as farmers and fisherman through consultation.

At local level, besides water management groups, there are various groups organized through the agriculture sector. However, these groups do not necessarily work together. For instance, DAE utilizes farmer field school (FFS) as community based organizations (CBOs). Initially FFS was used for integrated pest management (IPM) and now these are being used for various purposes, like integrated crop management, climate change adaptation, etc. Through FFS, farmers are informed and trained which builds their capacity as well. Similar to BWDB and DAE, better cooperation is required between CBOs such as WMGs and FFS.

Conflict management

There are multiple land uses and stakeholders with different livelihood and usage of water in a polder which sometimes lead to conflicts. One such conflict is between shrimp farmers and rice farmers. Shrimp farmers bring saline water inside the polder by cutting embankment or using low lift pumps. This affects salinity balance inside the polders and causes damage to crops in surrounding fields which sometimes leads to confrontation and violence.

Moreover, land elevation inside the polder is not uniform. There are high lands, as well as low lands with different demand-supply regimes for water. Those who control the sluice gate also control the water according to their own convenience and benefit. When high lands are irrigated, low lands are submerged under deep water and crops are damaged. When water is drained out for the benefit of low lands, high lands suffer. In many villages, farmers of low-lying areas have to make their own internal dikes to protect their crops from inundation, while the high land farmers do the same to retain water.

Sometimes polder dwellers utilize the local smaller canals inside the polder for fish culture and construct dams across the canals for aquaculture. This obstructs the flow and results in drainage congestion and loss of access to water for other which leads to conflicts.

Community based water management with water management groups (WMGs) has been set-up in different polders under projects like Blue Gold. During several workshops, conferences and interviews, Bangladesh Water development Board (BWDB) informed that they work with Water management Group/organization (WMG/WMO), Department of Agriculture extension (DAE) works with farmer field school (FFS) and local government engineering division (LGED) with farmers group. These groups include representatives from different parts of the community but their focus are different. Polder or sub-section of a polder water management is the primary focus of the WMG/WMO, whereas the FFS and farmers groups are more focused on agriculture and includes small and marginal farmers. These community based organizations (CBOs) provide potential platform for conflict resolution through discussion and consultation. A participatory water management is required for the coastal regions of Bangladesh. However, a mechanism for different CBOs such as WMGs and FFS to interact with each other is not available at the moment. As the WMGs maintain water management and FFS are the largest user of water, it is essential for these groups to interact and deduce an inclusive water management and agricultural production plan for the polders.

3.2 Ongoing and completed relevant projects

Here we discuss the projects relevant to salinity, water management and agriculture. Three project were reviewed: COASTS, SAFAL-IWRM and Blue Gold.

COASTS Project

COASTS stands for Coastal Opportunities and Agricultural Solutions to Tackle Salinity in Bangladesh. The COASTS project, funded by Netherlands Enterprise Agency (RVO), started on 01 July, 2020 and is a public-private partnership project, mainly focused on saline agriculture. Partners are 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 . In this project Cordaid has the main role of partner coordination, donor compliances, farmers' mobilization and reporting. The objective of the project is to contribute to sustainable agriculture and food-system development on farmland affected by varying salinity levels. More general information on the project in Annex 1.1.

In April 2023, the mid-term review (MTR) report of COASTS was available. The findings from the mid-term review, summarized below in a table prepared by the authors of this report, indicate that the project is performing well and on its way of achieving its objectives.

Overview of COASTS' Mid Term Review points

- The average income of the respondents of the MTR has increased compared to baseline.
- About 5003 farmers are involved in COASTS project and more than half of the respondents were women.
- 12 salt tolerant varies were provided by COASTS.
- The respondents stated that their production has increased substantially.
- 20% of the respondent farmers tested their soil and water salinity from FBA (Farm Business Advisors) and 90% of the respondent farmers used pheromone trap as part of integrated pest management practices. Approximately 87% of the farmers have gained knowledge about good agricultural practices.
- As the seeds performed well, farmers are now buying the prescribed seeds directly from local sources like retailer, dealer, FBA etc.
- Farmers adopted new climate resilient technologies at field level related to growing salt tolerant vegetable like applying gypsum, mulching with straw, applying organic fertilizer and ridges and Furrow method (growing crops on ridges, prepared prior to planting of vegetables). All these are DAE/SRDI suggested and tested technologies.
- The collection points setup by the project accounts for 18% of total sales across the region and 71% of the farmers sold products through local traders.
- Project developed 20 Farm Business Advisors, 50% of whom are women, as a local level extension and business agent who is providing fee-based advisory services like soil and irrigation water salinity testing followed by advisory support on saline agriculture technologies and cropping pattern.

With specific reference to salinity and water management, the MTR recommended that:

- The access and supply chain of salt tolerant vegetable seeds for commercial vegetable production needs to be improved.
- Improve the services provided by FBA by providing appropriate materials to the farmers and FBAs which has already been address as informed by Cordaid.

During the discussion of the draft report, Cordaid opined that the technology provided to the farmers to counter the impact of salinity might be adequate but the availability of fresh water is the primary hurdle and a proven and replicable business model is required. Cordaid staff indicated that there are hardly any farmers involved in the COASTS programme who are also member in a water management group (local level). Also at national level, and related to scaling up, Cordaid staff are actively looking to engage with institutions and CBOs in water management. According to Cordaid staff, these organizations, involved in water management, should work together to deduce a plan to improve water availability.

SAFAL IWRM Project

SAFAL for Integrated Water Resource Management project is a project funded by Ministry of Foreign Affairs, Netherlands. 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. More information on 6 water management pilots in 2022 (Mornout *et al*., 2022) and in Annex 1.2.

With regard to salinity and water management it may be observed, that 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. It may be noted that there are multiple organizations involved in water management such as BWDB, LGED and BADC. SAFAL-IWRM project operates more or less at a lower field scale level, apparently with no formal link so far with these organizations. Also assessment of water availability, water management, water quality and salinity at catchment scales does not seem to be part of the activity, which are important to understand the impact of re-excavation of canals at the regional (polder) scale level.

Blue Gold Project

Water management groups (WMGs) were formed under Blue Gold project for water management. More information on the project is provided in Annex 1.3.

One of the aspects under this project with particular relevance to water availability improvement was, that canals inside the polders 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, also included in the project, remained working mainly through their CBOs in FFS. However, in the reporting, the interaction between the WMGs and FFS is not featuring much, leaving the impression that this could have been improved to have more inclusive polder water management and integrated with agriculture planning.

3.3 Policy documents

Policy documents were reviewed and highlights of them regarding water management, agriculture and salinity is presented here. In this section we reflect on 4 policy documents: Bangladesh Delta Plan 2100 (BDP2100), 8th Five Year Plan (8FYP) 2020 – 2025, National Adaptation Plan (NAP) and Bangladesh Water Act 2013

Bangladesh Delta Plan (BDP) 2100

BDP 2100 addresses the whole nation as 'delta', encompassing 'all districts of Bangladesh because they face numerous weather and climate change risks related to their location either around the sea, around major rivers or in water scarce zones.' (GoB, 2018). A larger summary with some general details about the plan has been included in Annex 2.

With regard to salinity, water and agriculture, it is important to note that the plan does see the importance of food security and is not only focusing on water. For instance it highlights that 'The soil and water combination of Bangladesh makes it a highly fertile land with multiple cropping opportunities. Bangladesh has wisely combined this natural advantage with seed-fertilizer-irrigation technology to intensify land cultivation and expand food production, primarily rice.

BDP2100 recognizes salinity of soil and salinity intrusion in ground and surface water as complex challenges. The coastal zone is listed as one of the hotspots. And it indicates that with development, climate change and sea level rise, salinity will increase in the future. Salinity is listed as one of the challenges for the coastal zone. Additionally, it observes that inadequate regulation of shrimp culture in the coastal belt has contributed to increased soil salinity, and that an increased soil salinity level will reduce and limit the cultivation of many crops in coastal areas. Higher salinity is negatively impacting production of livestock as well. Reduced upstream fresh water flow and increased silt deposition on the river channels are causing salinity intrusion in water. Effective management of existing polders, maintaining flow in the rivers, reclaiming new land in the coastal zone and conservation of the Sundarbans are proposed to counter the challenges posed by storm surge and salinity intrusion through. Revival and improvement of the regional rivers and channels are proposed for drainage improvement. However, in polder water management it is not highlighted. Moreover, strategy to reduce or tackle the increasing soil salinity is not included even though its recognized to have negative impact on crop production in coastal areas. However, the conflict between land uses such as saline shrimp culture and agriculture in the coastal areas is included in the baseline study of BDP2100. More details about BDP2100 is provided in Annex 2.

8th Five Year Plan (8FYP) 2020-2025

The 8th Five Year Plan 2020 – 2025 (8FYP) compiles the main areas of interests where developments and improvements are required. For the agricultural sector concrete plans and strategies are developed for marine and fresh-water fisheries, livestock, crop sector and for the agricultural sector in general. Emphasis on all these domains is to further increase production while halting or reducing pressure on natural resources with thus a main focus on sustainable production. Also addressing effects of climate change is a main priority topic of this plan

With regard to salinity and water management, one of the priorities of 8FYP is to initiate the implementation of the Bangladesh Delta Plan (BDP2100). The 8FYP Strategy includes prioritizing BDP2100 private investment programme (PIP) in favour of addressing irrigation, flood control, waterlogging and salinity problems. The first phase BDP2100 investment programme during the 8FYP calls for integrated water resource management to lower salinity along with other objectives. The projected allocation for BDP2100 investment programme will increase from 1% of GDP in fiscal year 2019 (FY19) to 2% of GDP by fiscal year 2025 (FY25). The 8FYP proposes the introduction of saline tolerant varieties for southern Bangladesh is included in the strategies for Crop Sub-Sector. Re-excavation and rejuvenation of Rivers and canals, extent, repair and construction of irrigation facilities and construction and maintain coastal of embankments are the activities proposed to reduce salinity along with other challenges such as flooding and water logging. Climate Smart Integrated Coastal Resource Database (CSICRD) is also being setup. However, the interaction between water management, salinity and agricultural production is not included in 8FYP. Furthermore, the role of CBOs and the interaction between them are not included as well. More details about 8FYP is provided in Annex 2.

National Adaptation Plan, 2019

One the goals of National Adaptation Plan (NAP) is to develop climate-resilient agriculture for food, nutrition and livelihood security. Agriculture is one of the most vulnerable sectors and climate change will adverse impact agricultural production challenging food security and livelihoods. Salinity will increase due to sea level rise and storm surge induced cyclones which will reduce agricultural production. Increasing salinity will damage traditional crop varieties, reduce yields and reduce suitable irrigation water. As a result cropping pattern will change, scope for agricultural production will reduce leading to loss of livelihoods and internal displacement. Reduction of risk and vulnerability of agriculture to climate change will be reduced by incorporating climate-resilient and smart agriculture, fisheries, aquaculture and livestock, and managing a sustainable value chain for agricultural production in climate vulnerable regions. Cultivation of salinity tolerant varieties are proposed as a potential solution. Management of freshwater resources and monitoring of salinity for reducing vulnerabilities in existing and potential salinity-prone areas is recognized as high priority for medium to long duration and cost of adaptation is listed as 516 billion BDT in total. Among the proposed activities listed below DAE is proposed as the lead for the first one regarding agriculture and BWDB is proposed as lead organization for the management of water resources. DAE and BWDB will be supported by Government institutes(LGED, BMD, Roads and Highways Department (RHD), Department of Environment (DoE), Bangladesh Forest Department (BFD), Department of Fisheries (DoF), Department of Disaster Management (DDM), Department of Livestock Services (DLS), DPHE, Local Government Division (LGD), Department of Youth Development (DYD), Department of Social Services (DSS), Department of Women Affairs (DWA), Bangladesh Space Research and Remote Sensing Organization (SPARRSO), WARPO, Department of Bangladesh Haor and Wetland Development (DBHWD), Survey of Bangladesh (SoB), Ministry of Land (MoL) and Public Private Partnership Authority (PPPA)), research institutes (National Agricultural Research System (NARS) institutes, Bangladesh Forest Research Institute (BFRI), Bangladesh Livestock Research Institute (BLRI) and SRDI), private sector, NGOs. More details on the NAP may be found in Annex 2.2.

Regarding salinity and water management, proposed activities are:

- Research and development saline tolerant varieties and agronomic practices to reduce stress and extension through training, field-level demonstrations and input supplies
- Monitoring and mapping of soil and water salinity through in situ low-cost testing instruments at the field level and GIS mapping at the planning level
- Large-scale reservoir development and dredging of rivers for freshwater flow augmentation in coastal rivers
- Excavation or re-excavation of dighi, pond, reservoir or construction relevant infrastructure for freshwater harvesting
- Construct heightened dikes or freshwater retention ponds to halt salinity ingress due to storm surges
- Community-based, youth-led and gender-inclusive freshwater pond management and rainwater harvesting
- Demarcation of potential saline-prone areas, develop and implement freshwater management plan for smooth transition of freshwater ecosystem to saline water
- Adjusted and adaptive land cover change
- Expand use of deeper groundwater reserves through solar-powered water networks, advanced water storage through small-scale retention structures, and gender-sensitive drinking water points
- Introduce community-based, low-cost desalination techniques and freshwater management for mass-level drinking water supplies
- Expand hydrometeorological observation networks and strengthen forecast and climate information services through data acquisition and monitoring of local climate variables, sea surface temperature, sea-level rise, sediment, land subsidence and salinity intrusion
- Invest in developing, updating, and strengthening climate products and services (data, forecast, analyses, etc.) for emerging climate extremes like heat waves, cold spells, hailstorms, salinity ingress, etc.

NAP includes objectives, activities and funds to address different stresses. However, the mechanism for intra-agency interaction and the role of CBOs are not included. The funding mechanism and source of funds are not included either. Both agriculture and water are addressed in NAP but the interaction between them is not included and it’s not practiced in the field as well.

Bangladesh Water Act (BWA), 2013

Bangladesh Water Act (BWA) includes that in the declared water stressed area priority usages would be in the order where drinking water will have the highest priority followed by domestic usage, irrigation, fish culture, bio-diversity, wildlife, in-stream flow, industry, salinity control, power generation and recreation. Therefore, salinity control was not given the highest priority for water usage. However, irrigation had the third highest priority. The role of water management in combating salinity is not included in BWA. The role of inclusive water and agricultural management through CBOs are not included as well. As limited information is available, no further details are provided in the annex.

3.4 Stakeholder Mapping

The stakeholders were mapped according to spatial scale from local to national and involvement in water management and agriculture (Table 1). Most of the Government institutes are active both nationally and locally. However, the local involvement varies among the institutes with DAE having larger local involvement than other. Research institutes explore for solutions when questions, demands for solution are raised and fund is available. Most of NGOs and CBOs work at local level. Large projects are usually funded by donors like World Bank (WB) or Asian Development Bank (ADB).

Stakeholders mapped in Table 1 include government institutes, research institutes, knowledge institutes, donor agencies and NGOs. This has been indicated in the overview table. Most of the stakeholders mapped are involved in water or agriculture sector, also indicated in the table. From the table it can be seen, that there is a divide among water and agriculture in e.g. knowledge institutes, NGOs and government institutes as well. Only a few government institutes research institutes and knowledge institutes work on both water and agriculture sector. When considering salinity, where typically both agriculture and water are part of the process, this indicates that there is a need for facilitation of interaction among the institutes working on water and agriculture to learn from each other and take collaborative action.

Not all the stakeholders are working at both local and regional scale, though some do. This highlights the need for increasing active collaboration between the stakeholders working at different spatio-temporal scales. Water management is one of the primary driver of salinity levels in coastal region and higher salinity impacts agricultural production. Therefore, to address the challenges posed by increasing salinity, stakeholders involved in water and agriculture sector should collaborate more. At field and regional scales water management and agricultural practices influence the salinity levels in water and soil. The policy level activities at national scale effects the salinity level as well. Therefore, there should be a mechanism for facilitating active interaction between the national level stakeholders and regional level stakeholders. Among the government agencies, BWDB is in the lead for water management and DAE leads the agricultural practices. These two agencies should collaborate with each other both at national as well as at local level. In practise, this does not happen sufficiently. In light of the Bangladesh Delta Plan 2100, where actions at inter-ministerial level are facilitated, a third party such as Ministry of Planning might take a role as a facilitator to ensure effective interaction and collaboration between the two ministries and the agencies involved.

Table 1: List of Stakeholders, their sectors and spatial scale

Stakeholders	Agencies					Spatial scale		Sectors	
	Government	Knowledge Institutes	NGO	Donors	Private Organizations	Local	Regional	Water	Agriculture
Government institutes									
Bangladesh Water Development Board (BWDB)	√					√	√	√	
Department of Public Health Engineering (DPHE)	√					√	√	√	
Water Resources Planning Organisation (WARPO)	√						√	√	
Department of Environment (DOE)	√					√	√	√	
Local Government Engineering Department (LGED)	√					√	√	√	
Soil Resource Development Institute (SRDI)	√					√	√		√
Department of Livestock Services (DLS)	√					√	√		√
Department of Fisheries (DOF)	√					√	√		√

Department of Agricultural Extension (DAE)	√					√	√		√
Bangladesh Agricultural Development Corporation (BADC)	√					√	√	√	√
Bangladesh Agricultural Research Council (BARC)	√						√		√
Knowledge institutes									
Institute of Water Modelling (IWM)		√					√		√
Center for Environmental and Geographic Information Services (CEGIS)		√					√	√	√
Bangladesh University of Engineering and Technology (BUET)		√					√	√	
Bangladesh Agricultural University (BAU)		√					√		√
Khulna University (KU)		√					√	√	
Patuakhali Science and Technology University (PSTU)		√					√		√
Sher-e-Bangla Agricultural University (SAU)		√					√		√
Wageningen University & Research (WUR)		√					√	√	√
North South University (NSU)		√					√	√	
Research institutes									
Bangladesh Rice Research Institute (BRRI)		√					√		√
Bangladesh Agricultural Research Institute (BARI)		√					√		√
International Rice Research Institute (IRRI)		√					√		√
The Food and Agriculture Organization (FAO)		√					√		√
Community based organizations (CBOs)									
Water Management Organizations (WMOs)			√			√		√	
Farmer Field School (FFS)			√			√			√
NGOs									
Uttaran			√			√			√
Cordaid			√			√			√
SOLIDARIDAD			√			√		√	√
Donor agencies									
World Bank (WB)				√			√	√	√
The Embassy of the Kingdom of the Netherlands (EKN)				√			√	√	√
Asian Development Bank (ADB)				√			√	√	√
Japan International Cooperation Agency (JICA)				√			√	√	√

Private sector									
Lal Teer					√	√	√		√
ISPAHANI AGRO					√	√	√		√
ACI					√	√	√		√
SYNGENTA					√	√	√		√

4 Analysis

4.1 Insights from workshops, conferences and interviews

Agriculture and water should be considered together

- Water management and salinity goes hand in hand and both impacts food production at different spatial scale and different time scale. Lack of water and drainage management after heavy rainfall can damage the crops at field scale level and regional scale level. Lack of fresh water and increasing salinity in water and soil are impacting food production and with climate change the impact will be even more severe.
- Water and agriculture need to be considered together. The agriculture transformation (Ahmed et al, 2021) which is the ambition of MoA to be developed in the near future doesn't include water in its concept yet. At FAO's Investment Forum in Rome in 2022, agriculture Minister of Bangladesh Muhammad Abdur Razzaque stated that the agricultural sector of Bangladesh will need to be transformed and this will require substantial investment of 150 billion Bangladeshi Taka (BDT) in the next five years. He urged the developed countries, international banks, donor agencies and private entrepreneurs to invest in Bangladesh's agriculture sector (The daily star, 2022b). On the occasion of the World Food Day 2022, Prime Minister of Bangladesh, Sheikh Hasina, asked all to reduce food waste and to bring all fellow lands under cultivation as well (The Daily Star, 2022a).

Spatial and Temporal variability and connectivity

- Water management at field scale and polder or river basin scale should be interconnected. Operation and water management of the canals and water bodies should benefit farmers and stakeholders living away from the canals.

Complex issue and requires a combination of multiple solutions are required

- Water management and salinity are complex issues and requires a combination of multiple solutions.
- In COASTS experience, there is efficient water use at field level by farmers but not at commercial farmers level. The primary challenge is the availability of non-saline water.
- Water management as well as salinity solutions needs attention.
- Canals inside the polders can potentially store fresh water when available. Fresh water storage areas such as beels, canals and depressions need to be protected. Dredging can be used to make the canals deeper.
- Climate smart agriculture needs to expanded as well. Currently 19 sub-projects in 3 different agencies: BWDB, DAE and Ministry of Fisheries on climate smart agriculture and participatory water management is ongoing.

Inclusive water management and agriculture involving community based organizations (CBOs) in polder governance and conflict resolution

- Water users and relevant stakeholders should be involved in water management. These are on the one hand community based organizations (CBOs), like WMO and FFS. CBOs can provide a platform to address water management and agricultural related conflicts between different stakeholders. WMOs are foreseen to be involved in routine maintenance of polder infrastructure and to be fully in charge of the structures used for water management. Water management should be based on sub-catchment units. For effective water management in the polders, 3 parties need to be involved: CBOs, DAE and BWDB. This is currently not the case.
- The WMOs existing within a polder should consult each other and prepare a water management plan.
- WMOs are formed on the basis of administrative boundary of villages which should be done considering the sub-catchment or sub-polder boundaries regarding canals and waterbodies.
- LGED works with co-operatives which has limitations. The co-operatives need to be registered at the Department of co-operatives which increases complexities. These co-operatives should

be treated specially and separately. Moreover, the co-operative department of LGED should include a water section as well.

- Polder water management should increase food production of the entire polder and benefit all stakeholders. The government can make agreements with the WMO of a polder to buy produced food when collecting for government stocks.
- Fishermen are influential and have muscleman as well, whereas the farmers are poor and don't have enough influence.
- The farmers part of COASTS project live far from the canals. Only 5 to 10% of the farmers live next to the canals and reaps the benefit from it. Irrigation water is not sufficient enough and cannot reach the farmers living further away. Development or engaging WMO was not part of the project as well. But now Cordaid realizes that to manage or achieve the objectives WMO should be engaged but there is no budget in the project for such activities.

Community based organizations need to share the cost of operation and maintenance

- BWDB is in charge of operation and maintenance of the canals. WMO is also participating in maintenance but doesn't have the budget and the capacity to excavate and maintain the canals.

Private sector and commercial farmers need to be engaged to ensure continuity and upscaling of solutions

- At this stage of the COASTS project only small farmers are connected/engaged. Larger and commercial farmers will be engaged in the future to be more efficient. WMOs will be included in the future. To be successful, government as well as farmers believe that better technologies will help larger farmers, like e.g. semi-automated equipment like ploughers and harvesters. Water related technology would then entail drip irrigation. However, this would entail a lot of investment costs, and require specific skills to be used productively for a longer term.
- Involvement of private sector in the concept of COASTS project can ensure continuity and sustainability.

Water availability and impact of adaptation at catchment scale need to be studied and share the information with the farmers

- As farmers require information on water availability more focus should be on catchment scale water management.

Policies should consider water management and agricultural practices together for saline effected regions

- BDP2100 takes only water salinity into account. BWDB is concerned about water salinity whereas SRDI and COASTS are more focused on soil salinity.
- One innovative and inclusive idea is to lease the polder areas to WMGs to produce agricultural product which will be procured by Government of Bangladesh (GoB). At the moment GoB purchases agricultural products such as rice from the millers. The example of sugar cane collection by the Government sugar mills can be used where the mills provide loans to farmers with a guarantee of purchasing the produce from the farmers after harvest. Similarly, SME loans can potentially be provided to the WMGs.

The findings of the stakeholders engagement indicates that water management and agriculture in saline stress region is a complex issue and should be considered together (water and food nexus). Policies should consider water management and agriculture together. Community inclusive water management and agricultural practices are required to tackle the issue regarding polder governance and operation and maintenance of control structures. A combination of multiple solution is required. Better coordination between agencies and CBOs involved in water management and agriculture is required. Water management should be studied at regional scale taking field scale activities into account.

4.2 Framework to analyze opportunities

In order to get an overview of opportunities related to the 3 projects and the various initiatives undertaken in these, we mapped them in graphic way, using the figure provided earlier (see *Figure 2*). We look at different spatial scales (field or more regional or national scale) and linked to short and longer term interventions. For the 3 projects reviewed, we indicate how some of the activities could potentially contribute to solutions, in particular addressing the salinity water management interaction.

The COASTS project suggests and implements several practices some of which are approved by

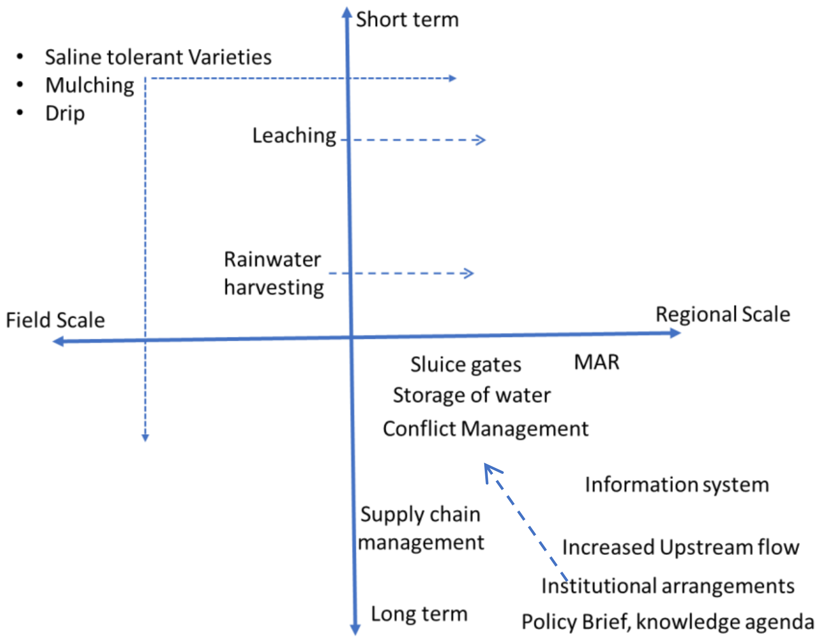

Figure 4: Potential and shifting of solutions with regard to different spatio-temporal scale by Cordaid/COASTS

government agencies of Bangladesh. Some of these solutions have the potential to be scaled up from field scale to larger/regional scale and can have short term to longer term impact (Figure 4). Currently saline tolerant varieties, mulching, drip irrigation, leaching and rainwater harvesting are being applied at the field scale. When most of the farmers of polders will be inspired by the positive results of the field application of COASTS project and adopt the solutions, the scale can change from field scale to regional scale which is being indicated by dotted line and arrow in Figure 4. Currently the COASTS project is more focused on the agricultural practices which perform well, however, it was informed by Cordaid that water availability is one of the primary limitations. COASTS works with farmers associated with FFS, but consulting farmers involved in water management organizations (WMOs) through institutional arrangement to take more inclusive decision with regard to water management at polder scale is needed. WMOs work at a larger scale than field scale yet smaller than national scale which as indicated in Figure 4 with dotted line and an arrow. Currently Cordaid is working at field scale where funding opportunities are available, but to upscale these solutions funding will be required. The adaptation measures practiced by Cordaid within the COASTS project should be shared with DAE and BARC to create vision for upscaling and pursue funds such as World Bank funded "Partner" project. "Partner" project intends to increase crop productivity using adaptive technologies, sharing knowledge and training youth and women farmers and entrepreneurs which aligns well with the activities of COASTS project.

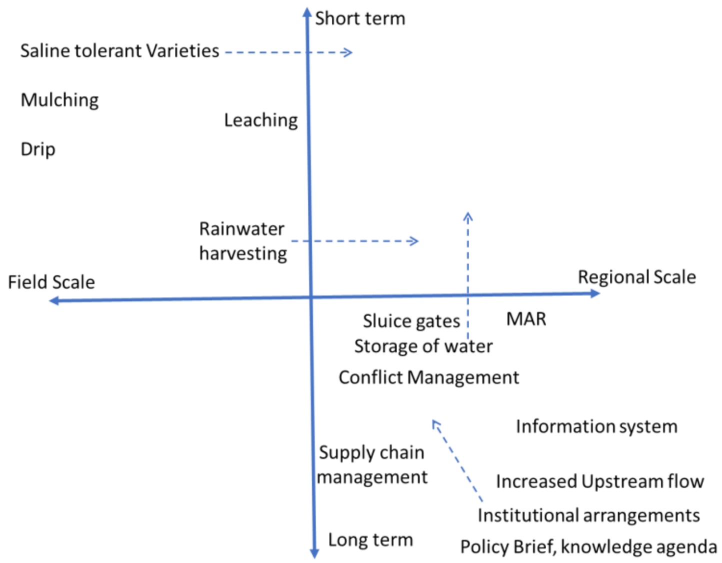

Figure 5: Potential and shifting of solutions with regard to different spatio-temporal scale by SAFAL-IWRM

SAFAL-IWRM focuses on re-excavation of about 80 canals to increase drainage during flood season and to store rainwater in the canals to be used during dry season. The storing of water in canals has the potential to be scaled up from field scale to polder/regional scale especially in regions where fresh water availability is low and impact of salinity is increasing which is indicated by dotted line and arrow in Figure 5. The adoption of saline tolerant varieties by farmer across the coastal region can have regional impact. Under SAFAL-IWRM project the canals are constructed and operated with active involvement of local communities and members of local government. During the interviews of SOLIDARIDAD personal who are involved in the project, it was informed that BWDB was informed about the re-excavation of local canals. However, BWDB officials said that they would like to have more informative interaction as these canals will impact hydrology inside the polders. If such interactive and inclusive model of institutional arrangement is adopted for numerous polders it can have impact at larger scale than field scale and for several years.

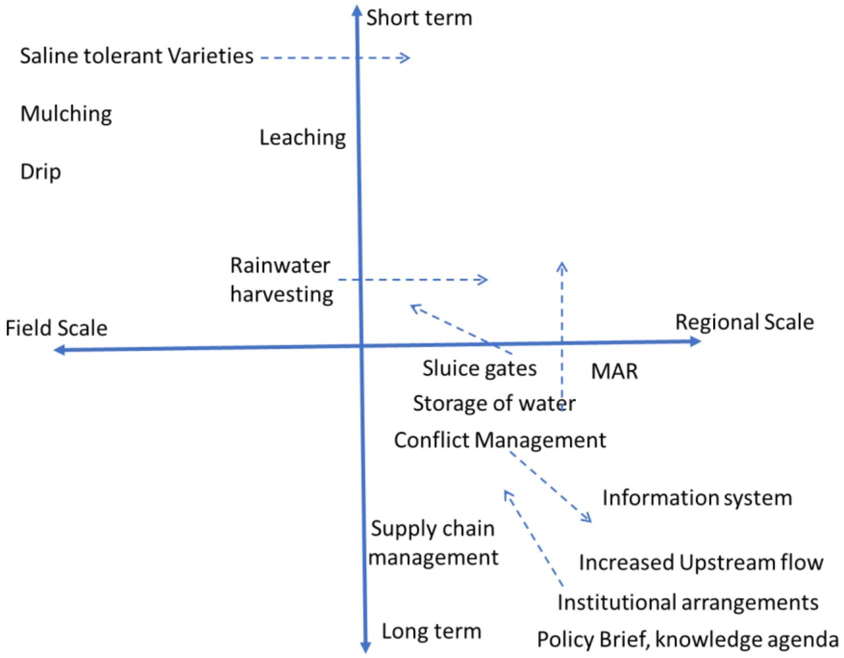

Figure 6: Potential solutions and their shifting with regard to different spatio-temporal scale for Blue Gold project

Water management groups/committee were developed under the Blue Gold project which can also have impact at polder scale and at shorter scale as well. The operation of sluice gates, storage of rainwater in the canals can be operated seasonally or round the year to ensure water safety and availability. These structures of polder dikes are connected with the rivers that are impacted with regional water management as well. The operation the sluice gates can have impact at sub-catchment levels especially during the flood season for drainage and water storage for dry season which are indicated by dotted line and arrow in Figure 6. The institutional arrangement work at polder scale which is smaller than national scale and plan for the year is developed which is shorter than the national plans usually spanning from 5 years to decades. The Blue Gold provides a platform for conflict management among the stakeholder which can potentially be used for numerous polders and even at regional scales.

5 Subject matter policy recommendations

Project Level (COASTS)

COASTS project has a positive impact on the agricultural practices in salt effected soils. Farmers are actively engaged and FAB provide crucial information to the farmers to take decisions. COASTS is applying water management and salt tolerant varieties at field level. To improve field level water management, COASTS stakeholders need to engage with the landscape/regional level. Farmers directly, or facilitated (e.g. by Cordaid) need to connect with the WMG/WMO, FFS and farmer groups. The government institutes such as BWDB, BADC, LGED play an important role, so they need to be engaged as well, and this may be of mutual interest.

Possible action points

- Formulate the problem definition and research question, and engage with knowledge institutes such as BARI, BIRI and the universities etc. by sharing information collected in the field. The research institutes and universities to utilize available resources for research and engage students to address the shared problems and questions and provide answers.
- Create a practical link with BADC, BWDB, LGED and community-based organizations WMO/WMG, FFS who are involved in water management and agricultural practices of the polders and sub-catchments. For instance by FBA's providing their services to WMO/WMG members, but also regarding management of water resources.
- Involve private sector to ensure upscaling and continuation considering both water management and salinity.
- Engage with DAE regarding world bank funded "Partner" project and sharing the successful implementation of adaptation measures to address salinity related issues and possibility of upscaling especially with regard to climate smart agriculture, crop diversification and sustainable production.

Policy level (EKN/RVO/BuZa)

There are limited interaction between the water management and agricultural practices at different spatial and temporal scales. Field level interventions can be developed and implemented relatively shorter time span whereas river basin scale interventions require more time but will have longer impact and reach larger population. The Embassy of the Kingdom of the Netherlands in Dhaka, in close collaboration with the Netherlands Enterprise Agency and the Ministry of Foreigns Affairs in the Netherlands (EKN/RVO/BuZa) can play a major role in connecting the scales. At the moment interventions related to water management and agricultural practices are not clearly linked. EKN/RVO/BuZa can put efforts to link the two worlds and create integrated solutions. The organizations require to develop vision for the future regarding water management and agriculture connecting different spatial and temporal scales, engage relevant stakeholders and together create transition pathways for the future. Private sectors can be engaged to ensure implementation and continuation of the generated knowledge and solutions. Co-creation knowledge, cofounding research and sharing knowledge with private sectors may prove to be socio-economically acceptable and economically beneficial.

Possible action points

- Support practical ways to bridge the water-agriculture divide, engaging BADC, BWDB, LGED and community-based organizations WMO/WMG, FFS, and others.
- Facilitate linking to knowledge institutes such as BARI, BRRI and other institutes.
- Facilitate learning and encourage a wider perspective
- Invest in co-creation of knowledge, research and knowledge sharing with private sectors to ensure implementation and continuation of the generated knowledge and solutions.
- Organize knowledge sharing sessions with WB, ADB and other funding organizations to discuss about implementation of knowledge generated.

- Facilitate developing mechanism to implement BDP2100 at local level and support discussion among BDP focal points of different ministries.
- Guide capacity building regarding water management, agriculture and salinity through Nuffic programmes.
- The Netherlands Enterprise Agency (RVO) to consider agricultural management in the projects funded focused on water management and vice versa.
- Prepare visions for the future and transition pathways together with relevant stakeholders.
- Link policy interventions and generated knowledge.
- Share experience and knowledge generated with deltas around the world and learn together deltas where water management and food production is liked wit and challenged by salinity.
- Engage private sectors both from Netherlands and Bangladesh in identifying complex issues, co-creating and co-funding knowledge to find solutions and preparing a business model to ensure continuation of the implementation of the solutions.

Platforms (e.g. NFP/NWP)

Water is utilized by all and to produce food. But the food loss during transportation, inadequate supply management and lack storage facilities, technologies and knowledge results in waste of water and resources used to produce food. New and innovative solutions can address the complex issue related to water management, salinity and agriculture but lateral learning from existing knowledge and solutions from areas facing similar challenges can increase the social acceptability as it has been applied with positive impact already. Solutions should be locally lead and adaptive to the location.

Possible action points

- New solutions can potentially be connected with supply chain and storage to reduce loss of food, water and resources.
- Locally lead, locally produced, involvement of local communities and local knowledge should be considered more – while linking it to (inter)national level policies and solutions
- Create learning possibilities: Share knowledge from other deltas around the world facing similar challenges and applied solutions.
- Support sharing of local adaptation example such as COASTS project at international level such as in the Global Framework on Water Scarcity in Agriculture (WASAG) to inspire and engage others and to indicate that multiple actors are required even at local level to succeed.

Summary of findings, concluding remarks and way forward

Here we provide highlight of our findings, make concluding remarks and suggest possible steps for the future.

Salinity regarding water management and agriculture is a complex problem and should be considered together. Regarding the water management within the polder, BWDB and DAE should cooperate more and work together better. The CBOs such as WMOs and FFS need to work together under one umbrella which to prepare an integrated and inclusive water management and agricultural plan for the polders.

Salinity level in water and soil is affected by agricultural practices and water management of local/regional stakeholders as well as national level policy interventions. The stakeholder mapping and consultation indicate there are hardly any interaction between the national and regional scale stakeholders. There is a need for a platform and facilitation of increasing interaction between the stakeholders of different spatial scale. When the field scale stakeholders and relevant project personal are consulted, it is evident that there is lack of effective communication and collaboration among the regional stakeholders. For example, the BWDB official expressed their interest to have more information about the canals being re-excavated under the SAFAL-IWRM project. Therefore, coordination in the same level, between levels and at field level needs to be improved.

Till now numerous solutions have been explored to address the challenges regarding water management, agricultural practices and salinity. Previous experiences indicate that the issue cannot be tackled with one solution, instead a combination of multiple solutions is required. Different projects such as COASTS applied multiple solutions. It can be observed from the COASTS project that the adaptations applied with regard to soil management, seed and fertilizer application can assist the farmers of saline region but the availability of water of adequate quality remains the primary limiting factor. However, the amount of available water is finite. Though technologies can ease the impact, they will come at a price (desalinization of water can be done, but is at the moment too costly for agriculture to be profitable). So solutions will most likely not come from expansion of activities (like has been the general strategy in Bangladesh for the last 50 years or so) but from more smart (optimizing) utilization of the existing possibilities and solutions with the actors who are already involved. Practically, this could entail creating a mechanism where government agencies and stakeholders come together and jointly address water management in saline conditions, while including different interests (aquaculture, agriculture, flood management, etc.).

Currently NGOs are mostly working at field scale and funding opportunities are most available at field scale level, but to upscale these solutions funding will be required. The adaptation measures practiced by Cordaid within the COASTS project should be shared with DAE and BARC to create vision for upscaling and peruse funds such as World Bank funded "Partner" project. "Partner" project intends to increase crop productivity using adaptive technologies, sharing knowledge and training youth and women farmers and entrepreneurs which aligns well with the activities of COASTS project. In the past large projects at a regional scale such as CEIP, Blue Gold etc. were funded by WB, ADB etc. Bangladesh's economy is growing and it's gradually moving out of development cooperation which will require exploring of new formats for funding such activities (e.g. as living lab, or as business investment, public private partnership etc.). Though, this could not be elaborated in detail yet as part of this assignment, one could think about the following more general steps, each of which is supported by one or more concrete examples:

Step 1: Create a vision together with stakeholders for common goals using structured approach such as Food System Approach (Verhagen et al., 2021);

> Example: Organizing a brainstorming event/workshop with stakeholders like the Ministry of Water Resources and the Ministry of Agriculture, but possibly also the Ministry of Planning, representatives from Local Government Institutions (LGI), private sectors and NGOs to develop vision for the future regarding water management and agricultural practices to address impact of salinity.

Step 2: Formulate transition pathway and policies for the perceived future, involving relevant stakeholders;

> Example: Facilitate interaction between the Ministry of Water Resources and Ministry of Agriculture to formulate transition pathway and required policies to achieve the envisioned future.

Step 3: Define responsibilities for stakeholders and government agencies;

> Example: BWDB to maintain water infrastructure, DAE to promote climate smart agricultural practices, Ministry of Planning to ensure adequate interaction between the government agencies, LGIs to facilitate conflict resolution at field/local scale, CBOs to operate the gates and canals of polders to drain the polders when needed and store access water for further usage, private sectors to provide the seeds and equipment to achieve food production goals, NGOs such as Cordaid to provide information to the farmers and to connect WMOs and FFS.

Step 4: Create a platform to work together;

> Example: Explore setting up a platform where Ministry of Water Resources, Ministry of Agriculture, representatives of LGI, private sector and NGOs interact with each other. EKN could possibly facilitate, Cordaid can also potentially provide such a platform, where they can also interact with regional and national scale stakeholders who might wish to avail their services to reach field level stakeholders.

Step 5: Explore source of funds to implement the project, including mechanisms such public-private-partnership (PPP);

> Example: Cordaid can potentially interact with Ministry of Agriculture to showcase their success and ability to effectively work with field scale stakeholders, so this model can be replicated in

future projects, e.g. as under World Bank funded 'Partner' project. Possibly Cordaid could play a role in this, providing services.

Step 6: Present and carry out pilot cases showcasing the successful implementations and their impact with a plan to upscale on spatial and temporal scale;

Example: Similar to COASTS project, pilot field applications to address the impact of salinity in water management and agriculture can be carried out. To ensure upscaling, private sectors and local stakeholders involved in water management and agriculture could be involved from the beginning. The upscaling potential and a pathway should be prepared at the initiation stage.

Step 7: Monitor, adapt, learn and share the experience gathered from the project;

Example: Learning in the COASTS project can be documented and shared, and thus may lead to engagement in follow up activities of the partners.

Step 8: Think and explore together on future challenges and activities.

Example: Similar as to step 1: Once a platform exists, different parties will have a role - Local/field scale stakeholders and regional/national scale stakeholders interact within such a platform to explore future challenges and activities. Stakeholders can formulate future plans can be formulated at local/regional scale. Interaction between local and national level will need facilitation. An NGO, like Cordaid, can act as a facilitator for such interactions having the unique experience doing so in their current programmes in which they interact with local and national level stakeholders and transfer knowledge across different scales.

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Annex

Annex 1 Ongoing and completed relevant projects

1.1 COASTS project

COASTS stand for Coastal Opportunities and Agricultural Solutions to Tackle Salinity in Bangladesh. COASTS is funded by Netherlands Enterprise Agency (RVO). COASTS project started on 01 July, 2020. COASTS is a public-private partnership project, mainly focused on saline agriculture where Soil Resource Development Institute (SRDI) is a public partner, Bangladesh Agriculture University (BAU) is an academic partner, Lal Teer Seed Limited is a private company partner and Cordaid is an NGO and lead partner and Netherlands Enterprise Agency (RVO). In this project Cordaid has the main role of partner coordination, donor compliances, farmers' mobilization and reporting. The objective of the project is to contribute to sustainable agriculture and food-system development on farmland affected by varying salinity levels.

The objective of the project is to contribute to sustainable agriculture and food-system development on farmland affected by varying salinity levels. This includes support to increase the availability and commercial viability of locally produced salt tolerant seed varieties, agro-training to farmers in saline agriculture, support to farmers in access to markets, and the endorsement of saline agriculture by local, national and academic institutions. The project aims to increase resilience of stress and shocks of 5,000 ha of farmland and increase productivity of 10,000 farmers with about half of them being women.

There are three impact pathways and 20 performance indicator for COASTS. Impact pathways are

- Pathway-1: Farmer's capacity building and making salt-tolerant inputs available.
- Pathway-2: Strengthening output marketing channel through Collection Points and linkage with buyers
- Pathway-3: Creating an enabling environment for scaling-up saline Agriculture through engaging all the relevant departments like Public, Private, NGO, research, and Academic institutions.

COASTS considers three SDGP for target value and baseline narratives:

1. Gender

The project is termed as "Gender-aware". The project intends to select at least 50 percent female farmers to engage them with saline agriculture as well as to enhance their participation in agriculture and nutrition and increase their decision making power at household level as well as enhancing their knowledge on gender issues through incorporating the issues with planned agriculture sessions.

2. Climate Adaptation

The COASTS project area is in the coastal regions of southern Bangladesh, highly vulnerable to climate change impact such as frequent cyclones, heavy rain, increasing soil salinity due to intrusion of seawater, water logging and lack of fresh water for drinking and irrigation during dry period of the year. From the experience of earlier saline agriculture projects of ICCO Cooperation (The Salt Solution project, STAB_ Salt-tolerant Agriculture in Bangladesh), implemented in the southern coastal districts of Bangladesh, several best practices were identified as beneficial for crop production in salt-affected soil which can be termed as "saline agriculture crop cultivation technologies". The climate resilient crops and crop varieties as well as different agronomic practices such as ridge-furrow method of planting, use of Pitcher irrigation, application of gypsum, organic fertilizers, mulches and use of flying bed/basket method of crop production will be used for adaptation to the soil salinity. Relevant Government extension agencies and Research institutes also approved and accepted those best practices or technologies to scale-up or extend in wider areas. With those proven/ tested best practices/learning from earlier projects (Figure 4), COASTS project has taken those saline agriculture technologies to scale-up in extended areas and communities. The focus of this project is also on the whole value chain and its relevant stakeholders.

3. Transition to a Circular Economy

The technologies COASTS project is recommending and farmers are using, have environmental impact that may lead to a process that are acknowledged as 'circular economy'. Salinisation is an complicated issue and one of the biggest challenge in coastal Bangladesh and climate change will aggravate the situation even more causing flooding and salinity intrusion in water and soil. Prior to COASTS project farmers have mainly tried to combat salt concentrations in the soil. However, Cordaid for COASTS project works on improving irrigation technologies and efficiency, and introducing saline tolerant varieties to ensure productivity in salt effected soil. The salt-tolerant cultivation technologies, proposed by the COASTS project are beneficial for the farmers as well as for the soil and environment, especially in the southern coastal belt where increasing soil and water salinity, decreasing soil fertility or health, decreasing crop cultivation practices by farmers are the key problems. The project interventions have major focus on limiting the use of natural resources (irrigation water, soil) and agri-inputs (seeds, fertilizer). This project intervention also supports reuse and recycle of agri-inputs and products along with reducing the impact of climate change (increasing soil salinity) on crop production.

Under COASTS project 2,000 salinity affected farmers households are selected and being trained. About 1,900 smallholder farmers are trained on saline agriculture technologies who are harvesting on salt effected land and 80 demonstration farms are produced where 10 salt-tolerant vegetables seed varieties validated and demonstrated. Different technologies like pitcher's irrigation, ridge and furrow and poly-bed mulching techniques are being tested and promoted by the COASTS project.Farm Business Advisors (FBA) are being trained as well who measures the soil salinity and suggests farmers on vegetables to be produced depending on the salinity level and the chart of salt tolerance of vegetables from SRDI. During the interviews the employees of Cordaid informed that the test of soil salinity level is preferred by the local farmers even though FBA are paid for services. During field trips and discussion with the farmers, they informed that they test the soil salinity pre-season and mid-season to adjust their agricultural practices accordingly if required. According to employees of Cordaid, local agricultural business and industries are interested to acquire services of FBA to test the soil salinity.

A mid-term review was conducted during March- April, 2023 in 08 severely salinity-affected working upazilas under COASTS project and 430 quantitative survey was conducted.

The Mid-term findings indicate:

The average income of the respondents was Tk.252,630/ annually during mid-term whereas baseline was Tk.206,477 which means 22.35% income increased from baseline. Currently about 5003 farmers are cooperating with COASTS project and all of them cultivates vegetables and 58% of the respondents were women farmers. COASTS supported of 12 salt tolerant vegetable varieties or seeds for cultivation in the project areas. The respondents stated that their production has increased remarkably than before, when they were not tilling the salt-infected areas. Farmers tested water and soil salinity and were interested in advise for appropriate cropping pattern. Among the responders, 20% of the farmers tested soil and water salinity from FBA, whereas 46% farmers selected SRDI laboratory for their soil and water testing. 90% respondents used pheromone trap as part of integrated pest management practices. Approximately 87% of the farmers have gained knowledge about good agricultural practices, and they received training from the project. At the beginning of project, farmers received seeds for free from project as support. As the seeds performed well, farmers are now buying the prescribed seeds from local sources like retailer, dealer, FBA etc. Farmers adopted new salt tolerant vegetable and climate resilient technologies like Gypsum, Mulching with Straw, organic Fertilizer and, Ridge and Furrow method. The collection points setup by the project accounts for 18% of total sales across the region and 71% of the farmers sold products through local traders. Project developed 20 Farm Business Advisors, 50% of whom are women, as a local level extension and business agent who is providing fee-based advisory services like soil and irrigation water salinity testing followed by advisory support on saline agriculture technologies and cropping pattern. These FBAs can play a vital role to sustain COASTS interventions at the ground level after completion of the project. Farmers involved with the COASTS project is interested to continue the practices suggested and farmers who are not involved in the project are also showing interest to implement the suggested practices.

It was recommended to:

Strengthen access to salt tolerant vegetable seeds for commercial vegetable production, strengthen supply chain of Salt tolerant seeds, policy adaptation for saline Agriculture, strengthen FBA services and its delivery mechanism and, provide appropriate materials to the farmers and FBAs.

In late March and early April of 2023, the Netherlands Enterprise Agency (RVO) team with EKN representative visited the farmers and the fields of the COASTS project and during the field trip, extension of another year on a cost neutral basis was discussed. Impact of COVID pandemic and robust preparation of phasing out strategic action were considered as primary reasons for the extension.

1.2 SAFAL IWRM Project

SAFAL for Integrated Water Resource Management project is a project funded by Ministry of Foreign Affairs, Netherlands. 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. Community-based sustainable use, protection and restoration of watersheds for resilient agriculture is promoted in this project. The objective is to improve water and soil efficiency, sustainable harnessing of ground and surface water and improve local governance of water for agriculture at the micro-water shed level. To achieve the objectives water-efficient, climate-smart and regenerative agriculture production systems will be explored and local community lead micro-watershed management and governance will be promoted. 80 canals in 05 districts reaching 90,000 farming household will be re-excavated to drain access water from low elevation areas and to store fresh water when possible over the course of 5 years of the project.

1.3 Blue Gold Project

The overall objective of the Blue Gold Programme was to reduce poverty for 190,000 households of selected coastal polders by creating a healthy living environment and a sustainable socio-economic development. The blue gold project was continued between March 2013 to December 2021. A number of government agencies implemented the programme. The Bangladesh Water Development Board (BWDB) was the lead agency, responsible for protecting the communities from flooding and surges by ensuring the integrity of the embankments and associated structures, and for forming and registering water management organisations (WMOs). The Department of Agricultural Extension (DAE) worked alongside farmers to encourage the selection and cultivation of crops and varieties that are well-suited to the coastal environment and which, as part of an interlinked annual cropping system, form the basis for profitable business. The farmer field schools were conducted for landless – mainly women – farmers to enhance homestead production, both for consumption and sale, increasing incomes and resilience. In addition, the Department of Livestock Services (DLS) and Department of Fisheries (DoF) provided specialist advice for the development of training modules to farmer field schools, and contribute to other project interventions. Local government institutions (LGIs), especially Union Parishads (UPs), were partners in polder development planning, coordination and maintenance. The twenty-two polders selected for interventions through Blue Gold cover around 115,000 ha in the districts of Patuakhali, Khulna, Satkhira and Barguna.

Blue Gold concluded that for WMGs to function effectively in terms of managing water resources within their mandate, it is essential that major water infrastructure is timely rehabilitated and subsequently maintained by other agencies such as BWDB. Farmers with small plot or pond sizes and women were benefited by Blue Gold. WMGs are much appreciated by their members in terms of a focal point for training, as a savings and loans facility and also for generating labour work contracts. There is no evidence of concrete improvements in terms of local water management.

Some WMGs were not established in a (micro-) water catchment or water command area, but rather at village level, so cannot be expected to perform useful water management functions. In other cases, the WMG does not fully represent all water users so part of the catchment area might not be served. WMGs do not have the mandate to carry out other than minor operations or repairs, they only deal with minor operational matters, especially the opening and closing of sluices. Individual WMGs are not allowed to repair or to contract a constructor to carry out repairs, but the WMA (water management association, an association of WMGs) are allowed to do so in collaboration with BWDB.

Agricultural production have increased substantially in the polders where Blue Gold was involved. The increased agricultural production in the beneficiary area has led to increased consumption but reduced sales, contrary to the trends in the control area. Blue gold has improved diversity and nutrition, the role of women in decision-making in agriculture.

Annex 2 Policy documents

2.1 Bangladesh Delta Plan 2100 (BDP2100)

BDP 2100 addresses the whole nation as 'delta', encompassing 'all districts of Bangladesh because they face numerous weather and climate change risks related to their location either around the sea, around major rivers or in water scarce zones.' (GoB, 2018).

The plan highlights that 'The soil and water combination of Bangladesh makes it a highly fertile land with multiple cropping opportunities. Bangladesh has wisely combined this natural advantage with seed-fertilizer-irrigation technology to intensify land cultivation and expand food production, primarily rice.

The plan emphasizes four main challenges: 1. Climate change (temperature, rainfall, etc.), 2. Upstream developments; 3. Water quality; and 4. Water-logging. The plan comprises a vision, mission, goals and strategies (see table 1, for an overview) to address those. Basically, the government aims to ensure long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies and equitable water governance (GoB, 2018).

Vision: Achieving a safe, climate resilient and prosperous delta

Mission: Ensure long term water and food security, economic growth and environmental sustainability while effectively reducing vulnerability to natural disasters and building resilience to climate change and other delta challenges through robust, adaptive and integrated strategies and equitable water governance.

This long term vision needs have been translated into specific goals or targets for its implementation. This is done by combining long term development outcomes in terms of economic growth an poverty reduction in the Perspective of 2041 with targets for reducing long term vulnerability from water and climate change related hazards plus targets for environmental conservation.

BDP 2100 approach to long term **goals**: The BDP 2100 proposes 3 higher level national goals and 6 BDP goals that contribute to achieving these higher level goals.

Higher level goals

Goal 1: Eliminate extreme poverty by 2030

Goal 2: Achieve upper middle income status by 2030; and

Goal 3 : Being a Prosperous Country beyond 2041

BDP 2100 specific goals

Goal 1: Ensure safety from floods and climate change related disasters;

Goal 2: Enhance water security and efficiency of water usages;

Goal 3: Ensure sustainable and integrated river systems and estuaries management;

Goal 4: Conserve and preserve wetlands and ecosystems and promote their wise use;

Goal 5: Develop effective institutions and equitable governance for in-country and trans-boundary water resources management; and

Goal 6: Achieve optimal and integrate use of land and water resources.

The goals are then translated into **strategies**: 2 national strategies, one for flood management and one for fresh water management; and 6 regional specific strategies (coast, Barind (drought prone), Haor (flash flood), CHT (eastern hills), river systems and estuaries, urban), and cross cutting strategies (1.

Sustainable Land Use and Spatial Planning; 2. Agriculture, Food Security, Nutrition and Livelihoods; 3. Transboundary Water Management; 4. Dynamizing Inland Water Transport System; 5.Advancing Blue Economy; 6. Renewable Energy; 7. Earthquakes)

2.2 National Adaptation Plan (NAP)

National Adaptation Plan (NAP) aims at reducing adverse effects from the impact and fluctuation of environmental conditions induced by climate change. The NAP primarily encompasses eight distinct sectors: water resources; disaster, social safety and security; agriculture; fisheries, aquaculture and livestock; urban areas; ecosystems, wetlands and biodiversity; policies and institutions; and capacity development, research and innovation. Infrastructure, water and sanitation (WASH), health, gender, youth, the elderly, persons with disabilities, ethnic communities and other socially disadvantaged groups, and the private sector are cross-cutting issues and part of identifying appropriate strategies aligned with national aspirations. The NAP considered 11 climate stress areas in devising 113 interventions based on developed adaptation pathways and sectoral adaptation requirements. These interventions are aligned with the global Sustainable Development Goals (SDGs) and 52 climate adaptation projects of the Bangladesh Delta Plan 2100 (BDP2100). They ensure the inclusion of women and people with diverse gender identities, the elderly, persons with disabilities, youth, ethnic communities and other socially disadvantaged groups throughout the NAP process. Recommended interventions are envisaged as being implemented in an integrated and coordinated manner through programmatic approaches instead of ad-hoc, project-based, short-term initiatives.

The NAP implementation process will develop and scale up the adaptation practices such as saline tolerant varieties, rainwater harvesting in coastal saline areas; mini-ponds for supplementary irrigation during drought spells; drip irrigation with mulch in raised beds; use of combine harvesters for early harvesting in haor areas to reduce the risk of flash floods; the Kuni method for minor-scale irrigation; the pyramid method for tide-affected lands and vegetables in Gher; floating cultivation and the Sorjan technology as widely practiced in the coastal water stagnant areas; nuts and coffee in the Chattogram Hill Tracts; diagonal jhum cultivation, and introduce four crop-based cropping patterns developed by BARI to increase cropping intensity from 192 to 400 percent. Other areas of focus are increasing water use efficiency through climate-smart agriculture techniques such as alternating, wetting and drying; buried pipes; mulching; smart metering; etc. Field-level demonstrations on stress-tolerant cultivars, mechanization, use of location-based agromet services and early warning systems will be developed on a mandatory basis to support greater agriculture production to ensure food and nutrition security. Management of freshwater resources and monitoring of salinity for reducing vulnerabilities in existing and potential salinity-prone areas is considered as possible interventions in NAP.