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Palli Karma-Sahayak Foundation

Feasibility Study Report

Resilient Homestead and Livelihood Support to the Vulnerable Coastal People of Bangladesh (RHL)

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List of acronyms and abbreviations

ACF	Action Against Hunger, Bangladesh (Action Contre La Fame)
ADP	Annual Development Plan
ADB	Asian Development Bank
ASL	Above Sea Level
ASP	Adaptive Social Protection
BARI	Bangladesh Agricultural Research Institute
BCCRF	Bangladesh Climate Change Resilience Fund
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BDT	Bangladeshi Taka
BMD	Bangladesh Meteorological Department
BRRI	Bangladesh Rice Research Institute
CBA	Community-Based Adaptation
CCA	Climate Change Adaptation
CCC	Climate Change Cell
CCCP	Community Climate Change Project
CCIKM	Climate Change Information and Knowledge Management (CCIKM)
ccGAP	Climate Change and Gender Action Plan
CCTF	Climate Change Trust Fund
CDMP	Comprehensive Disaster Management Programme
CECD	Center of Education and Community Development
CIF	Climate Investment Funds
CLP	Chars Livelihoods Programme
CEDAW	Convention on the Elimination of All Forms of Discrimination Against Women
CRA	Community Risk Assessments
CRIM	Climate Resilient Infrastructure Mainstreaming
DFID	Department for International Development
DDM	Department of Disaster Management
DoE	Department of Environment
DRR	Disaster Risk Reduction
DRR	Directorate of Relief and Rehabilitation
ECCCP-Flood	Extended Community Climate Change Project- Flood
ERD	Economic Relations Division (ERD)
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GCM	General Circulation Model
GED	General Economics Division
GDP	Gross Domestic Product
GIS	Geographic Information System
GMSL	Global mean sea level
GoB	Government of Bangladesh
HYV	High Yielding Variety
ICZMP	Integrated Coastal Zone Management Project
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KICT	Korea Institute of Civil Engineering and Building Technology
LCD	Low Carbon Development
LDCF	Least Developed Countries Fund
LDRRF	Local Disaster Risk Reduction Fund
LDDRF	Local Disaster Risk Reduction Facility
LGI	Local Government Institutions
MoEFCC	Ministry of Environment, Forest and Climate Change

MoFDM	Ministry of Food and Disaster Management
NAPA	National Adaptation Programme of Action
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NEC	National Economic Council
NGOs	Non-government Organizations
NPDM	National Plan for Disaster Management
PKSF	Palli Karma-Sahayak Foundation
PPCR	Pilot Programme for Climate Resilience
PPEPP	Pathways to Prosperity for the Extremely Poor People
PECM	Poverty, Environment and Climate and Mainstreaming
PIP	Project Implementing Partner
REOPA	Rural Employment Opportunities for Public Assets
RRAP	Risk Reduction Action Plan
RVCC	Reducing Vulnerability to Climate Change
SLR	Sea Level Rise
SP	Social Protection
SRDI	Soil Resource Development Institute
SST	Sea Surface Temperature
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WARPO	Water Resources Planning Organization
WB	World Bank
WDP	Women's Development Policy

1 INTRODUCTION

1.1 Context

1. Bangladesh is one of the most climate vulnerable countries in the world[1]. For the past two decades and more, Bangladesh has been continuously facing the adverse impacts of climate variability and change that threaten Bangladesh's economic growth and sustainable development. The challenges posed by climate change made the lives and livelihoods of millions increasingly complex and vulnerable. Bangladesh is heavily exposed to various types of natural disasters such as riverine floods, recurrent flash floods, tropical cyclones and storm surges, droughts, salinity intrusion, sea-level rise, riverbank and coastal erosions. The aggravating climate change is causing the duration, magnitude and frequency of such natural disasters to worsen, making the poor communities around the country increasingly more vulnerable. Despite being the ground zero of the impacts of climate change, Bangladesh has been working persistently to tackle its high level of vulnerability and at the same time, pursuing development objectives for improving the socio-economic conditions of its vulnerable communities. Over the last decade, Bangladesh has played a significant and strong leadership role in Adaptation to Climate Change. Bangladesh has not only introduced innovative approaches to adaptation in vulnerable communities, but the nation has also actively mobilized resources as far as possible to tackle the challenges.

2. The critical geographical location i.e., surrounded by the Himalayan in the north and the Bay of Bengal in the south makes it susceptible to climate change variabilities and extreme events. Thus the lives and livelihoods in the country are facing a new challenge. The country's coastal zone is particularly vulnerable to climate change effects being affected by sea level rise, salinity intrusion and cyclone. The average elevation of the southwest coastal zone ranges from 1-2 meters from the average sea level. Analysis of tidal water over 30 years shows trends of water level in the Ganges tidal floodplain of 7-8 mm year^{-1}. On the other hand, the trend is 6-10 mm/year in the Meghna Estuarine flood plain and 11-21 mm year^{-1} in the Chittagong coastal plain areas. So, it has been found that the overall trend in the coastal zone in the last 30 years has been 6-21 mm year^{-1} [2]. The trend obtained from this study corresponds to the trend cited by SMRC[3], where the trend is lower in the Ganges followed by medium-range values in the Meghna and highest values in the Chittagong coastal plain. In addition to similarities regarding rising trends, this study reveals that the sea level has risen at a higher rate than in the past, thus consolidating the notion of rising sea level. The trend derived from the global tide gauge data found that the long-term trend in GMSL is 1.7 [1.5 to 1.9] mm year^{-1} between 1901 and 2010 for a total sea level rise of 0.19 [0.17 to 0.21] m. Alternatively, the high-precision satellite altimetry record suggests that between 1993–2012, a GMSL rate was 3.2 [2.8 to 3.6] mm year^{-1}. Therefore, the MSL trend derived from the tidal gauge data along the coast of the Bay of Bengal is much higher than the GMSL trend derived from long-term global tide gauge data and short-term satellite data.

3. The most recent IPCC report (AR6) suggested that the global sea level will be elevated 0.44-0.76 m by 2100 under the intermediate GHG emissions scenario (SSP2-4.5). Even in the low GHG emission scenario (SSP1-2.6), the sea level will rise 0.32-0.62 m by the end of 21st century[4]. In the Bangladesh context, it is predicted that for 45 cm rise in sea level may inundate 10-15 percent of the land by 2050 resulting in over 35 million climate refugees from the coastal districts[5]. Climate variability will reduce long-term rice production by an average of 7.4 percent each year during 2005-2050, primarily by undermining production of the *Aman* (summer rice) and *Aus* (late winter rice) crops[6] due to salinity intrusion and sea level rise. The frequency and intensity of tropical cyclones are increasing day by day. Over the last 50 years, 15 severe cyclones with wind speeds ranging from 140 to 225 km hour^{-1} have hit Bangladesh coastal area of which seven hit in pre-monsoon and the rest in the post-monsoon season[6]. The five ppt

isohaline line will move from the lower tip of Sundarbans to the point of the lower Meghna river at Chandpur by 2100 under an assumed SLR of 88 cm due to global warming by 2^0C by the end of this century. The salinity front will move about 60 km to the north in 100 years. A sea level rise of 27 cm causes a six percent increase in brackish water area compared to base conditions. An additional area of 327,700 ha would become a high saline water zone (>5 ppt) during the dry season due to a 60 cm sea level rise. Furthermore, about six percent of the freshwater area (276,700 ha) will be lost in the monsoon.

4. The IPCC fifth assessment report[7] indicates that vast coastal communities in South Asian countries such as Bangladesh are becoming increasingly vulnerable to the imposing threat of sea level rise. Climate change will increase rate of rising sea levels with subsequent tidal flooding, accompanied by more intense tropical cyclones, storm surges and droughts that will severely impact the country's life and economy. These anomalies are already evident recently with devastating cyclones such as SIDR in 2007 and AILA in 2009, exerting huge economic and social losses. In the coastal zone, more than half (56.37%) of the area is currently threatened by cyclonic storm surges with around 45% area under threat from surges of more than one meter[8].

5. The physical risks associated with these extreme and societal exposure risk levies immense pressure on coastal habitat. Sea level rise is a direct result of the adverse influence of the changing climate upon global tidal patterns. It is ultimately increasing the risks to the vulnerable population and their livelihoods. An application of Brunn's equation[9] already informs about increasing intensity of cyclonic activities (i.e, the anti-clockwise circular cyclonic wind speed) with increasing surface temperature. Most of the houses along the coastal zone in Bangladesh are built of thatched biomass (both as walls and roof), with only half of the houses having roofs made of corrugated iron sheets. Many such households cannot even withstand wind speeds above 40~50km/hour. However, Bangladesh's coastal zone faces at least two category-2 cyclones per year, a category-3 cyclone in every 2 to 3 years, a category-4 cyclone in every 6 to 7 years and a category-5 cyclone (wind speed greater than 200 km $hour^{-1}$) once in every 25 to 30 years. With increasing sea surface temperature, the intensification of cyclonic strength has already been experiencing along the coastal zone of Bangladesh. Any escalation in wind speed due to global warming will tend to blow away weak, primarily biomass-based housing structure[10]. This is the most significant physical risk associated with climate change induced effects along the coastal zone.

6. Apart from being a catastrophe, an abrupt rise in sea level can cause a chain reaction of inimical natural calamities based on cause and effect. Salinity intrusion in the coastal regions will potentially become one of the major effects of sea level rise, which is likely to salinize various existing freshwater sources and also the topsoil, thereby inflicting complications towards maintenance of livelihoods of large number of coastal people already who are poor. The groundwater aquifer system in the coastal zone consisted of shallow and finite lenses, which have already been largely exhausted due to gradual extraction[11]. Meanwhile, the drastic reduction of freshwater flow in the coastal rivers due to commissioning of the Farakka barrage and diversion of dry-seasonal freshwater flows towards India have resulted in increased salinity throughout the southwestern region of the country. As a result, the surface sources of potable water have all been salinized, threatening drinking water security and irrigation for crop production[12]. Sea level rise will have adverse effects on salinization of groundwater through saline intrusion[13]. Moreover, accelerated sea level rise with an accompanied rise in temperature will result in increasing the crest height of storm surge, which in turn will salinize both the top soils and the surface water reservoirs along the coastal zone[14]. The intrusion of saline water will continue as the area under one ppt salinity line is expected to increase by 18.22 percent and the area under five ppt salinity is expected to increase by 24 percent by 2050[15]. Coastal flooding due to tidal surges and huge amount of sediment that is carried by the three major rivers through a steep flow gradient, coupled with the sea level rise results in extensive flooding in coastal regions. The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) stressed

the need to understand, prepare and respond to these emerging challenges so that the wellbeing of the people is ensured[16].

7. The vulnerability of the coastal people is therefore broadly characterized in three ways i.e., 1) Climate sensitive livelihoods, 2) Vulnerable settlement in low-lying areas and 3) Scarcity of safe drinking water. The most coastal peoples are poor, with small and marginal farmer families and shrimp workers. They primarily depend on seasonal subsistence agriculture and agriculture wage labour which are highly climate-sensitive. Besides, this poor coastal community builds houses in low-lying areas which are subject to coastal flooding. Most houses are built with mud and *goal pata* (*Nypa fruticans*) which are severely affected by cyclones & storm surges and high tides. These people have to spend a significant amount of their earnings on repairing houses each year. This is perhaps one of the reasons for which they cannot come out of economic poverty. The climate scientists argue that climate change consequences will further aggravate this situation. The surface and groundwater in the country's coastal zone are increasingly contaminated with saline water due to lack of freshwater flow in the dry season, compounded by sea level rise and cyclonic tidal surges. The coastal people particularly the women collect drinking water far away from their locality spending a productive long time which reduces their opportunities to engage in economic activities[17].

8. Considering salinity intrusion due to climate change, crops and vegetable cultivation are facing growing challenges. The salinity intrusion affects coastal agriculture faster than the research outcome reaches the farmers. However, there are some salinity tolerant varieties including BRRI dhan-47, sunflower, sugarcane etc. but these varieties can tolerate a limited level of salinity i.e., less than 15 ppt. But most of the coastal land experiences more intensive salinity particularly during the dry season (mostly from November to May). Thus technology and practices should consider a salinity-tolerant production system for building the resilience of the vulnerable community. The issues of surface salinization have been experienced primarily in the south-western region (SWR) of the country, where several early interventions have been given trial. Since women are generally more active in the courtyard gardening in rural Bangladesh, non-government organizations (NGO) have promoted a few low-cost practices that help break salinity at the root zones and allow women to grow vegetables in their courtyards[18].

9. However, surface salinization of water bodies has offered a salinity-based livelihood that is alternative to salinity-affected agriculture. People found that, wild crab thrive well in saline waterbodies. NGOs have promoted nurturing and fattening of wild crablets as an alternative livelihood in the SWR[19] . Adult (and nurtured) crabs are not accepted in the society as a seafood due to religious practices. On the other hand, mature crabs has a thriving market outside the country, making crab export a profitable business for both the growers and the seafood export industries. However, there exists a legal issue: wild crab is considered as an endangered animal and the current legal regime does not allow wild crabs to be taken out of nature. Despite the fact that crab fattening cycle requires limited efforts and financial resources for the poor crab farmers, due to the illegal poaching of crablets from nature, crab fattening is an illegal activity – not to be promoted at all as an alternative livelihood in salinity affected regions[20]. However, if reproduction of crabs is done in hatchery conditions and the freshly hatched crablets are nurtured by poor people that open up new livelihood opportunities in the saline affected coastal areas, especially in the SWR and also in the south-central region of the country. In this context, crab fattening is a potential resilient livelihood for the poor coastal community.

1.2 Objective and methodology of Feasibility Study

1.2.1 Objective

10. The objective of the study is to identify and assess the feasibility of coastal resilient-building practices in Bangladesh.

1.2.2 Methodology

11. The feasibility study report has been prepared mainly based on literature review and consultation process. The literature includes National Communications of Bangladesh, Bangladesh Climate Change Strategy and Action Plan[15], National Adaptation Programme of Action[21], feasibility study on “Enhancing adaptive capacities of coastal communities, especially women, to cope with climate change-induced salinity”; feasibility study on “Improving resilience of vulnerable coastal communities to climate change in Vietnam”; Perspective Plan, 8th Five Year Plan and several published articles and unpublished research reports . We have also carried out consultation workshops at the national level and community level.

2 PHYSICAL SETTINGS OF BANGLADESH COASTAL ZONE

2.1 Introduction to Bangladesh Coast

12. Bangladesh consists of 19 coastal districts along a coastline of 710 km. The coastal zone (Figure 1) extends over 47,150 km^2 and has a population of 38.52 million[22]. The coastal zone is quite distinct from the rest of the country and has been delineated based on three characteristics: level of tidal fluctuations; salinity condition (surface and groundwater); and risks of the cyclone, storm surge and tidal influence. The 19 coastal districts have been further divided into the interior (7 districts, 48 upazilas) and the exposed (12 districts, 99 upazilas) zones, with regards to distance from the coast or the estuaries, under the Integrated Coastal Zone Management Project (ICZMP) of Water Resources Planning Organization (WARPO).

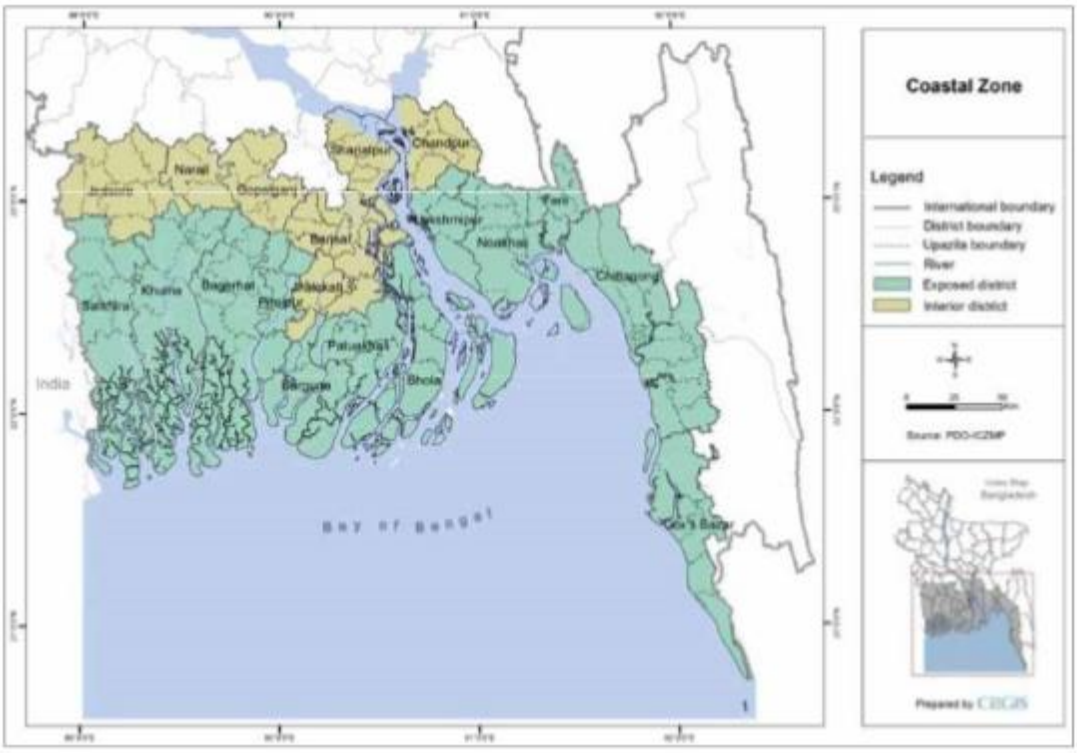


Figure 1: Delineated Coastal Zone based on Distance from Sea

2.2 Physiography

13. The zone is characterised by a vast network of rivers and channels, the enormous discharge of water with a huge amount of sediments, many islands, the Swatch of No Ground (underwater canyon located 45 km south of the Sundarbans in Bangladesh), shallow northern Bay of Bengal, strong tidal influence and wind actions, tropical cyclones and storm surges.

14. The country is in the Bengal Basin, a low-lying very flat delta. About 80 percent of it, is floodplains, with shallow mean elevation above the sea level. The average elevation of the southwest coastal zone ranges from 1-2 m and in the southeast coastal zone 4-5 m (Figure 2). The flat topography, active delta and dynamic morphology play a significant part in its vulnerability to sea level change.

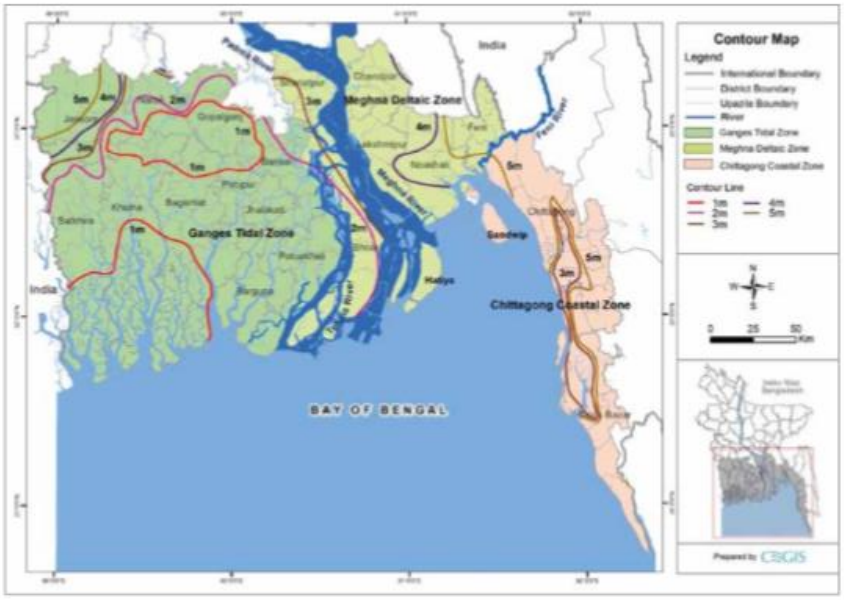


Figure 2: Physiography of Bangladesh coast

2.3 Geomorphology of the Coastal Zone

15. Throughout the centuries, the coast of Bangladesh has undergone massive changes due to the dynamic processes of erosion and accretion along with the coastline and estuaries. Based on the hydro-morphological characteristics, the coastal zone has been delineated into three regions: (i) the Ganges Tidal Plain or the Western Coastal Region, (ii) the Meghna Deltaic Plain or the Central Coastal Region and (iii) the Chittagong Coastal Plain or the Eastern Coastal Region[23]. The coastal districts covered by these three regions are shown in Figure 3.

2.31. The Western Coastal Zone or Ganges Tidal Plain

16. The Western Coastal Zone or the Ganges Tidal Plain extends from the Bangladesh-India border in the west to the Tetulia River in the east. It is mainly covered by the Sundarbans mangrove forest, greater Khulna and part of Patuakhali district. The Sundarbans is the feeding and breeding ground for fish, shrimps and other aquatic species. The zone is relatively stable because of the mangrove forest which acts as a natural barrier against cyclones, storm surges and soil erosion. Swamps, tidal flood plain and natural levees are found with numerous tidal creeks. The topography is low with an elevation between 0.9 to 2.1 m above mean sea level (Iftekhar and Islam, 2004). This zone is a semi active delta mostly composed of silty loams or alluvium washed down from the Himalayas[24] .

2.3.2 The Central Coastal Zone or Meghna Deltaic Plain

17. The Central Coastal Zone or Meghna Deltaic Plain starts from the Feni River estuary to the eastern corner of the Sundarbans, covering Noakhali, Barisal, Bhola and Patuakhali (part) districts. The high amount of silt is deposited through a huge volume of discharge from the Ganges-Brahmaputra-Meghna River system. This is why the sediment load is mainly composed of silt (70%) and 10 percent sand. This zone is a very active delta with high erosion and accretion rates. Many islands including the country's only island district Bhola are located here. Islands have formed and disappeared through the processes of accretion and erosion[25].

2.3.3 The Eastern Coastal Zone or Chittagong Coastal Plain

18. The Eastern Coastal Zone or Chittagong Coastal Plain extends from Teknaf upazila (the southern tip of the mainland) to Mirsarai upazila along the estuary of the Feni River[26]. It is the most stable part of the Bangladesh coast and storm surge is less effective here. The Naf River separates Bangladesh from Myanmar. The soil is mostly composed of submerged sands and mudflats[27]. This submerged sand forms the 145 km long sandy beach from Cox's Bazar towards Teknaf. The beaches of Patenga and Cox's Bazar are situated in this zone.

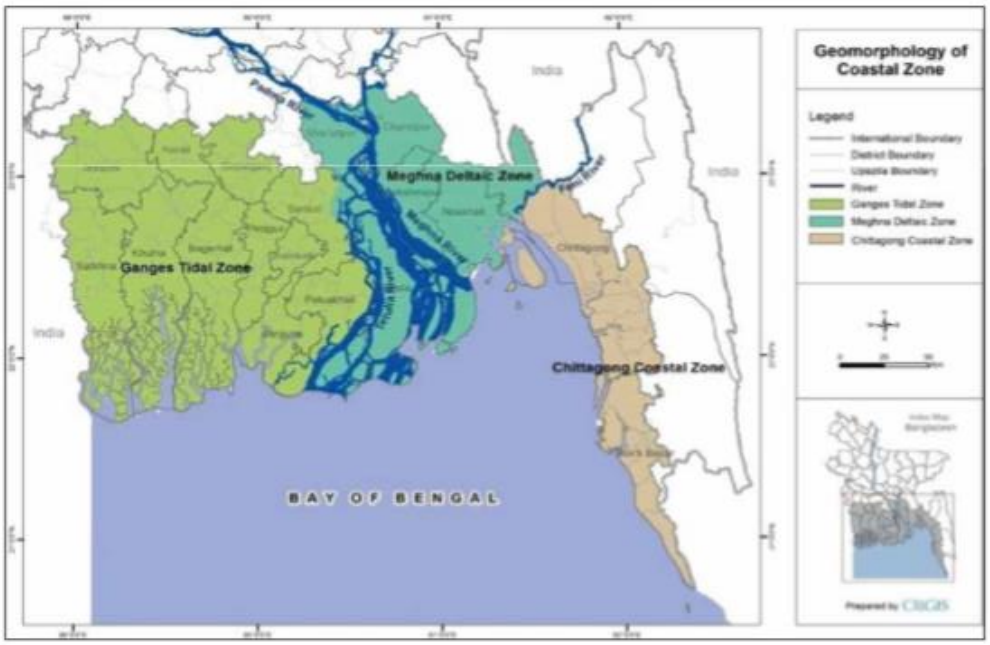


Figure 3: Geomorphology of Bangladesh coastal zone

Proposed project area

19. The project area has been selected based on exposure to sea, intensity of salinity intrusion, tidal surges and feasibility of crab hatchery. Based on these criteria, seven districts have been selected which are Satkhira, Bagerhat, Khulna, Barguna, Patuakhali, Bhola and Cox's Bazar. The following figure 4 shows the proposed project areas:

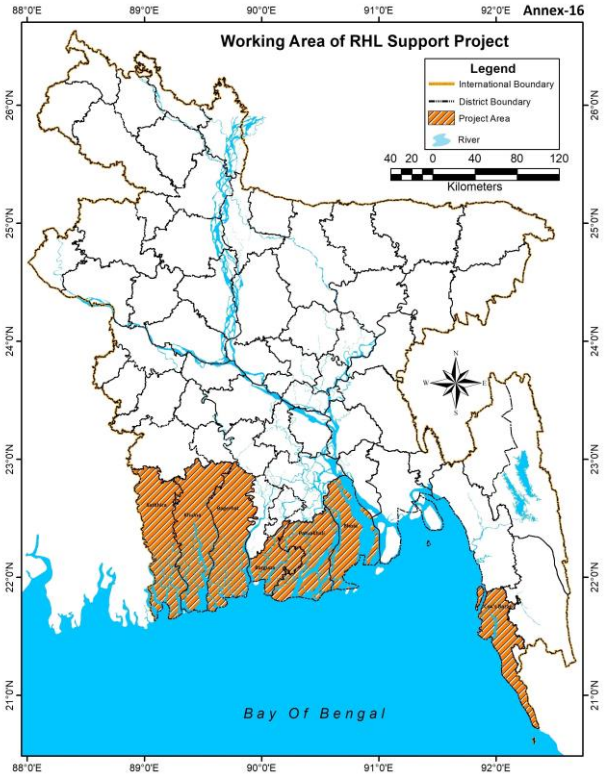


Figure 4: Proposed project area

20. Total area of these seven districts is 24,691km^2 and total population is 12,275,996. Average poverty rate is 26.13 percent which is higher than national average which is 24.30 percent[28]. Dependency ratio is also high in these districts which is 68.59 (detailed in table 1).

Table 1: Area, population and poverty ratio of the selected districts

Name of district	Area (km^2)	Population (2011)	Poverty situation (2016)	Dependency Ratio (%)
Satkhira	3,358.33	1,985,959	18.6%	56.58
Khulna	4,394.46	2,318,527	30.8%	54.07
Bagerhat	5,882.18	1,476,090	31%	62.77
Cox's Bazar	2,491.86	2,289,990	24.1%	85.63
Barguna	1,939.39	892,781	25.7%	65.99
Bhola	3,403.48	1,776,795	15.5%	83.28
Patuakhali	3,221.31	1,535,854	37.2%	71.83
Total	2,4691.01	12,275,996	Avg.=26.13%	68.59

3 CLIMATE CHANGE IN BANGLADESH

3.1 Climate Change: Observed and projected climate variability and change

3.1.1 Temperature rise - Observed changes at national level

21. Bangladesh has been experiencing a constant rise in mean annual temperature since years. A trend analysis on the available temperature data recorded by the Bangladesh Meteorological Department (BMD) at its 35 stations shows temperature rise by 0.0056^0C year^{-1} during 1961-2014[29].

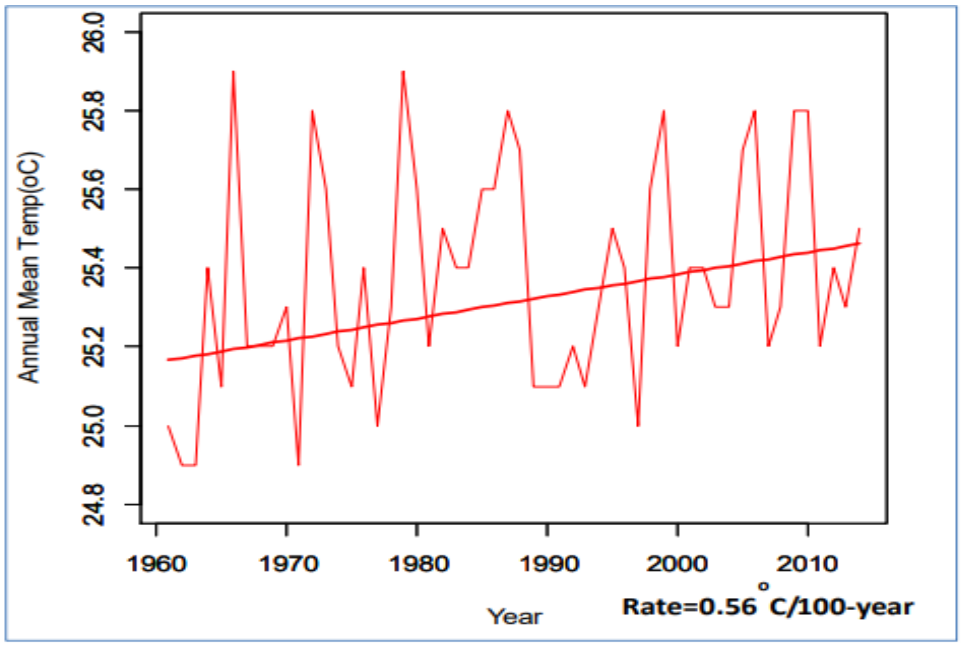


Figure 5: Observed trend in the rise of temperature over a period from 1961 to 2014

21. Since 1950 the land surface temperature rose by approximately 0.74°C[30], with a higher increase during the drier periods. Other study reported increasing trends in the country's average minimum and maximum temperature at the rate of 0.0094 and 0.007° C year^{-1} respectively from 1961-2004[31]. By the end of this century, the minimum temperature rise is projected to about 2-2.5°C and 5°C, respectively, under RCP 4.5 and RCP 8.5 emission scenario of the IPCC53[32].

3.1.2 Temperature- Future trend

22. The trend in the rise of surface temperature increase approximately 0.74^0C has been expected to continue in the future as demonstrated by four general circulation models (GCMs) used to model temperature changes under the A1B scenario[33,34,35,36].The GCM models projected temperature rise between 1 and 2^0C by 2050 in two divisions (Barisal and Khulna) the intended project locations (Figure 6). The PRECIS model (Providing Regional Climates for Impacts Studies) also predicted that annual maximum and minimum temperatures will follow an increasing trend.

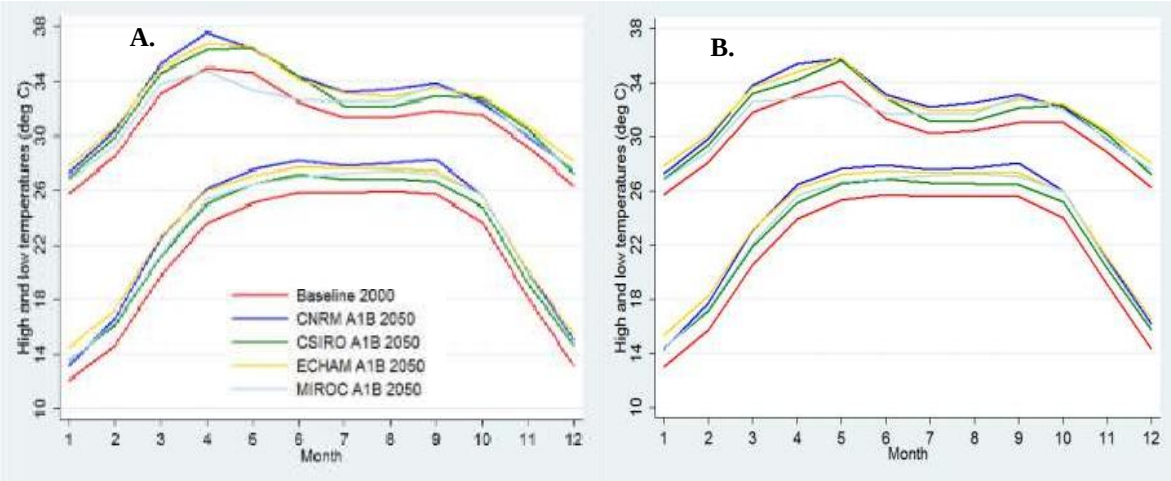


Figure 6: Maximum and minimum temperature in Khulna and Barisal Divisions as predicted by four GCMs

3.1.3 Precipitation rise - Observed changes

23. Precipitation in Bangladesh is predominantly influenced by the monsoon wind. Estimated about 75 percent of the annual rainfall occurs during the monsoon months (June-September). IPCC indicated an increase in both average and extreme precipitations for the Indian summer monsoon and longer duration, especially an earlier onset[37]. Increased monsoon rainfall - even in a 1.5°C scenario - may lead to a more frequent occurrence of high-intensity floods and early flash floods, which may then affect additional geographical areas with prolonged inundation. In addition an increase in the mean seasonal rainfall in all the seasons is also reported [38]. In the pre-monsoon season, the precipitation has been increasing in a range between 2.0mm and 7.4mm per year, with the highest increase (4-7.4mm per year) in the north-western and south-eastern regions[39, 41]. It is predicated a rise of average monsoon rainfall of 11 percent by 2030 and 28 percent by 2050, with a corresponding temperature increase of 0.7 and 1.1°C. Winter temperature would increase by 1.3°C (2030) and 1.8°C (2050) with respectively 3% and 37% decrease in rainfall[40,41].

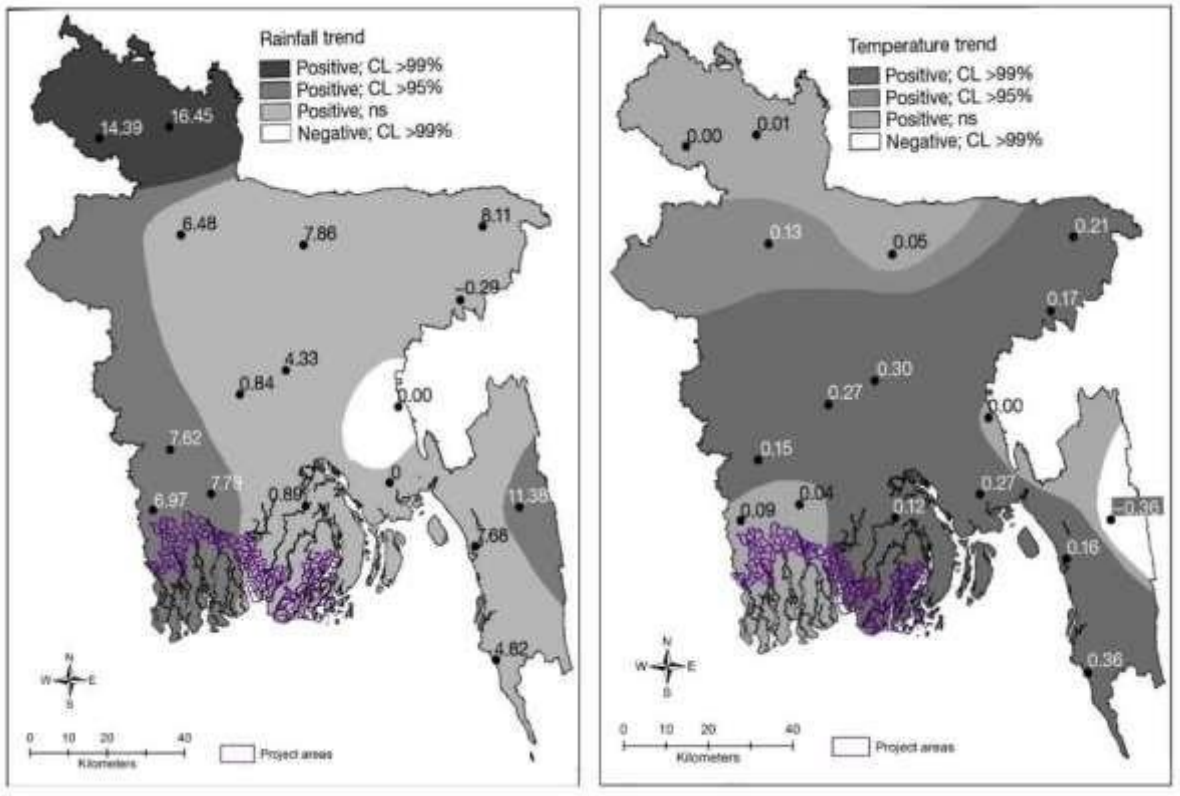


Figure 7: (a) Annual rainfall trends (mm yr^{-1}.) (b) Temperature trends (^0C $decade^{-1}$) in Bangladesh, 1958–2007. White numbers: significant (see legend for level of statistical significance). CL: confidence - not significant.

3.1.4 Precipitation pattern-Modelled future change

24. The future change in the volume of precipitation has been estimated against the temperature changes. The estimation showed the participation in winter (in December, January and February) will gradually decrease in different timelines with the corresponding rise in the mean average temperature. In contrary to this the monsoon months (June, July and August) will experience more precipitation, while also will increase the risk of coastal flooding and sea-level rise. The lesser rainfall in the winter months will potentially increase surface desiccation leading to a phonological drought in Bangladesh, particularly the western parts of the country[42].d

Table 2: Temperature and precipitation scenarios in different timelines

Timeline	Mean Temperature Change (°C)			Mean Precipitation Change (%)			Sea Level Rise (cm)
	Annual	DJF	JJA	Annual	DJF	JJA	
2030	1.0	1.1	0.8	5	-2	6	14
2050	1.4	1.6	1.1	6	-5	8	32
2100	2.4	2.7	1.9	10	-10	12	88

25. General Circulation Models (GCM) are employed to calculate variations in flood discharges and the model results shown that temperature rise at 2^0C, the probable maximum change in precipitation may be 13 percent and 10.20 percent respectively in the Ganges and Brahmaputra basin. The mean annual discharge of the respective rivers will be increased by 21.1% and 6.4% as a result of an increase in precipitation[43]. A study represents that monsoon rainfall in the country increases very gently as 2.65 mm/year and the probability of all types of flood events (low, medium and high) increased while the temporal change of the return period decreases

over years. From the study, it can be concluded that the changing phenomena in rainfall and flooding scenario in Bangladesh are consequences of the probable impact of climate change [44].

26. The predicted changes in seasonal temperature and rainfall pattern will have implications on the lives and livelihoods of people. Increased monsoon rainfall may lead to the frequent occurrence of high-intensity floods over the floodplains. Monsoon flood duration will be prolonged by a significant number of days and inundation area, and inundation depth will be increased.

4 CLIMATE CHANGE IN COASTAL AREAS OF BANGLADESH

4.1 Precipitation changes in the project areas

27. 40 years of rainfall data from five coastal stations of Bangladesh (Khulna, Mongla, Barisal, Patuakhali and Khepupara) and one in West Bengal (Canning) was analysed. The study found both spatial and temporal variations in the coastal zone. The annual precipitation was found to vary spatially, which is decreasing from more than 2000 mm in the east (Khepupara and Patuakhali) to 1800 mm in the west (Canning). Similar spatial variation was found in the number of rainy days, changing from 123 days in the east to 100 days in the west. This implies that the eastern part of the coastal region generally experiences longer and wetter rainy periods. In addition, lower latitudes were found to have larger amounts of total precipitation, as seen by comparing Khepupara with Patuakhali, and Mongla with Khulna. Overall, the precipitation generally increased from west to east, and from north to south (1853 mm in Khulna and 2783 mm in Khepupara) within the study area [45] .

28. The study also observed, a very small amount of rainfall occurs during the dry season (December to February). The precipitation is comparatively higher between March and September, with average slopes of approximately 15 mm per day at Khepupara and Patuakhali, and 11 mm day^{-1} for the other stations. The total annual precipitation can reach up to 2000 mm at Canning (West Bengal) in the west and 3000 mm at Khepupara in the eastern coastal region. The annual rainfall differed in different five-year periods, with the period 2008-2012 being the driest at all stations, with a reduction of about 20 percent compared to the other three periods. The reduction is attributed to reductions in extreme rainfall events during that period.

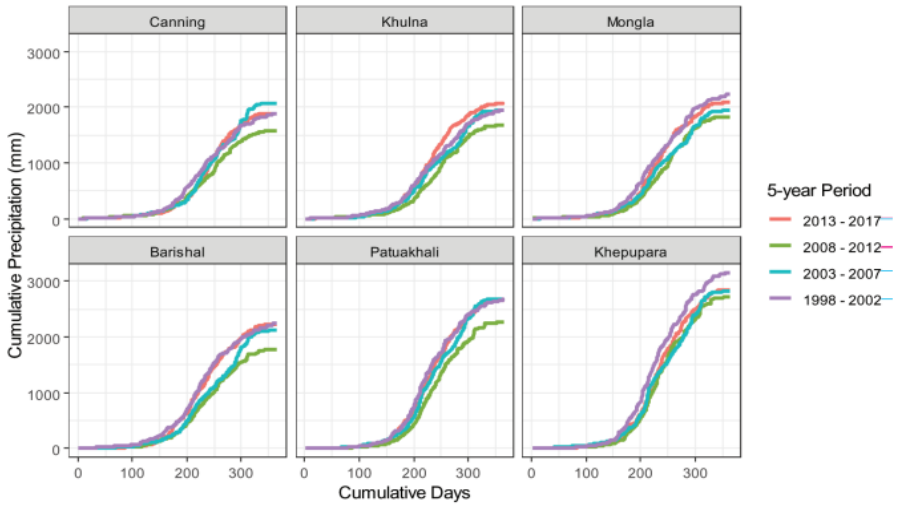


Figure 8: 5-year average of annual cumulative precipitation at 6 observatories between 1998 and 2017

29. A ten-year return period of extreme rainfall was analysed. An average of 28 percent reduction in annual maximum 5-day precipitation was found in the south of the coastal zone (Khepupara, Patuakhali) between 2010 and 2017, which indicates the reductions of extreme rainfall events in the recent years[46].

30. The following figure shows three other features of extreme rainfall events. The most significant events were observed at Khepupara, which recorded maximum precipitation more than 450 mm in 5 consecutive days. At Patuakhali, maximum precipitation up to 400 mm was recorded in 5 days. The extreme events occurred at the other stations were from 250 to 300 mm[47].

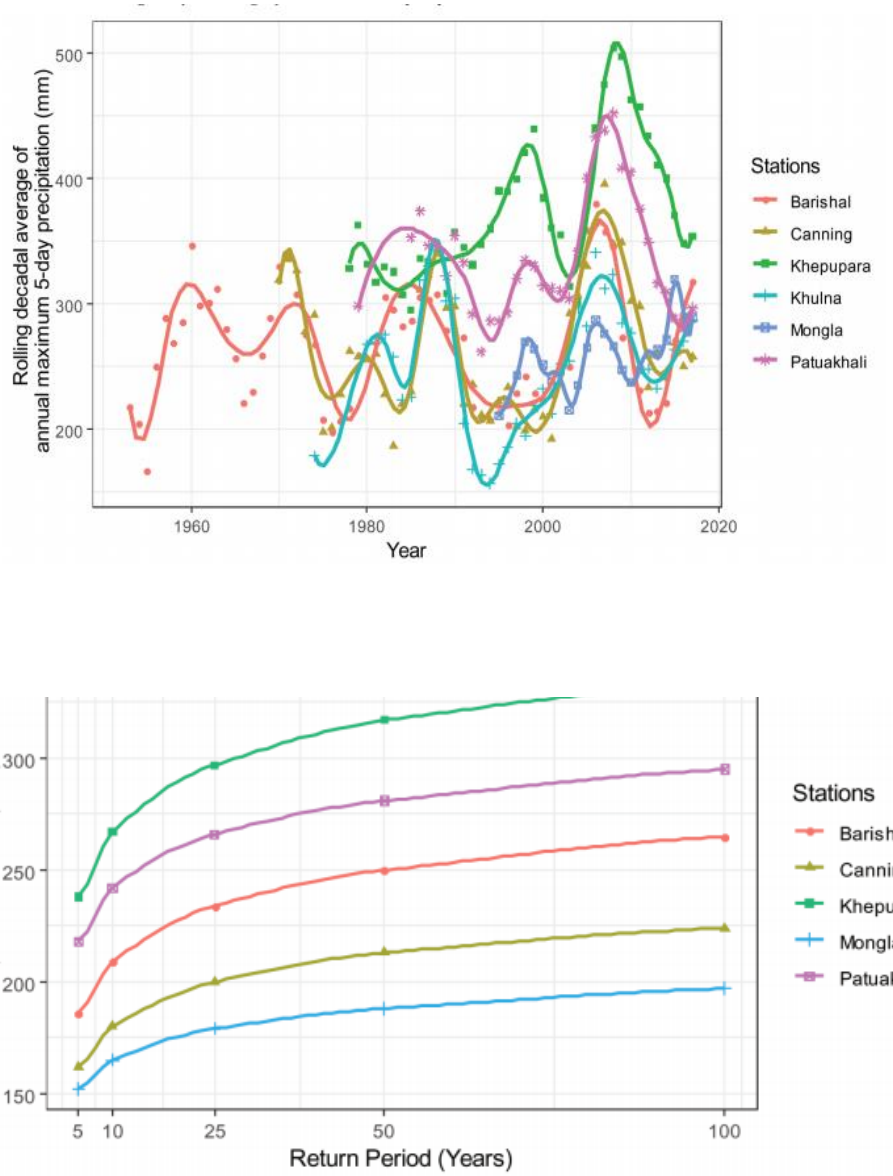


Figure 9: Rolling decadal average of annual maximum precipitation for 5 consecutive days at 6 observatories

31. At a return period of 5 years, one-day maximum precipitation was generally larger than 150 mm. Extreme one-day precipitation reaches approximately 230 mm day^{-1} in the west and 350 mm day^{-1} in the east at a return period of 100 years. The monthly minimum and maximum rainfalls were 0 and 254 mm, respectively, in the study area from December to March, during the rabi season crop growing period.

4.2 Changes in temperature

32. The annual average daily maximum temperature increased at all stations, with average rates of 0.01°C year^{-1} at higher latitudes (Khulna and Barishal) and 0.028°C year^{-1} or more at lower latitudes (Mongla, Patuakhali and Khepupara). The trend was statistically significant at all 5 stations in Bangladesh. Stations at lower latitudes in the east, Khepupara and Patuakhali, have longer summer seasons (SU25), increasing at a rate of 0.35 days year^{-1}, and their ranges of daily temperature (DTR) are also rising at 0.03°C year^{-1}, indicating a large temperature

difference over a day .Overall, annual maximum precipitation and daily temperature generally increased over the years in the coastal zone[48].

4.3 Sea level rise and associated risks

33. Bangladesh is predominantly flat and low-lying. Most of the southwest coastal belt is less than two meters ASL with a significant area less than one meter ASL. The average elevation of the southwest coastal zone ranges from 1-2 m and in the southeast coastal zone 4-5 m ASL[49]. The low-lying flat topography and dynamic morphology of the zone significantly contribute to its vulnerability to sea level rise (SLR).

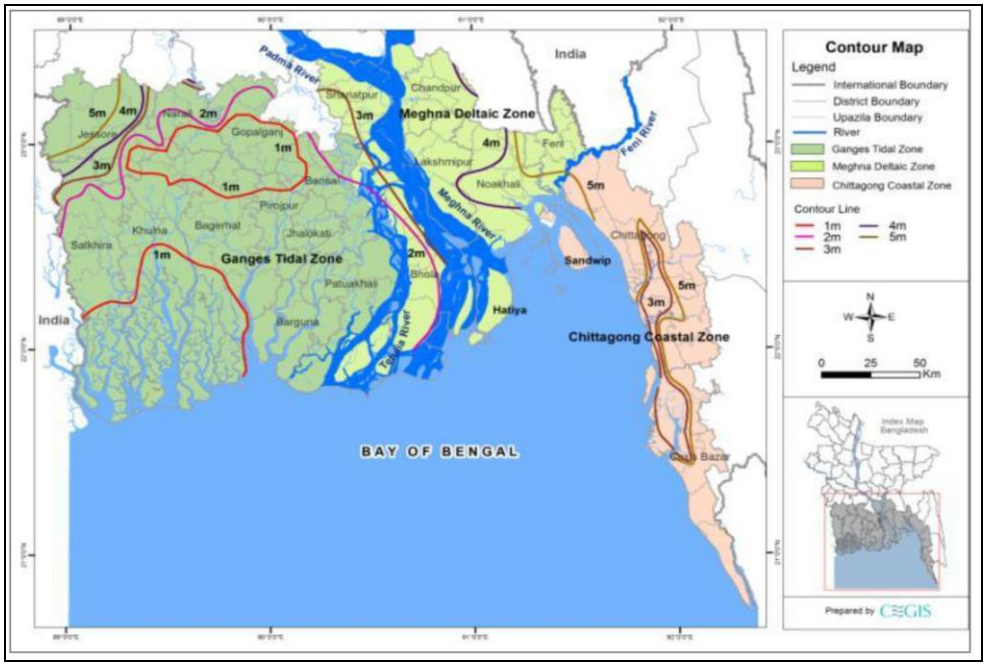


Figure 10: Map showing coastal elevation

34. Analysis of tidal water over 30 years shows increasing trends of water level in the Ganges tidal floodplain of 7-8 mm year^{-1}. On the other hand, the trend is 6-10 mm year^{-1} in the Meghna Estuarine flood plain and 11-21 mm year^{-1} in the Chittagong coastal plain areas. So, it has been found that the overall increasing trend of sea level rise (SLR) in the coastal zone in the last 30 years has been 6-21 mm year^{-1}. The trend obtained from this study corresponds to the trend cited by SMRC[50], where the trend is lower in the Ganges followed by medium-range values in the Meghna and highest values in the Chittagong coastal plain. In addition to similarities regarding rising trends, this study reveals that the sea level has raised at a higher rate than in the past, thus consolidating the notion of rising sea levels. The trend derived from the global tide gauge data found that the long-term increasing trend in global mean sea level (GMSL) is 1.7 [1.5 to 1.9] mm year^{-1} between 1901 and 2010 for a total sea level rise of 0.19 [0.17 to 0.21] m. Alternatively, the high-precision satellite altimetry record suggests that between 1993–2012, a GMSL rate of 3.2 [2.8 to 3.6] mm year^{-1} was observed[51]. Therefore, the MSL trend derived from the tidal gauge data along the coast of the Bay of Bengal is much higher than the GMSL trend derived from long-term global tide gauge data and short-term satellite data.

35. IPCC's sixth assessment report stated with high confidence that Asian coastal countries are likely to incessantly experience relative sea-level rise and it will result in the coastal flooding of many low-lying areas. Bangladesh is considered a hotspot for the sea level rise impact as mentioned in several scientific studies. Increasing sea level rise is one of the most critical climate change issues for coastal areas of the country. Because of the low topography in these

coastal areas, about 50 percent typically become inundated during the annual monsoons. A study by SMRC through observing tidal gauge records between 1977-1998, found that the tidal levels in Hiron Point, Char Changa, and Cox's Bazar rose by 4.0 mm year^{-1}, 6.0 mm year^{-1}, and 7.8 mm year^{-1}, respectively. The trend is almost double in the eastern coast than that of the western coast. CEGIS and the Department of Environment (DoE) have analysed 30 years of tidal gauge data for estimating observed sea level change in the Bangladesh coastal zone without considering any land-sea interaction i.e., sedimentation, subsidence, erosion, accretion, etc. It shows that water level change in the Ganges tidal floodplain is 7-8 mm year^{-1}. On the other hand, the trend is 6-10 mm year^{-1} in the Meghna Estuarine flood plain and 11-21 mm year^{-1} in the Chittagong coastal plain areas. Sea level in the 37 coastal stations of Bangladesh is predicted to rise between 0.53-0.97m by 2100 , while IPCC states in AR6 that under the intermediate GHG emissions scenario (SSP2-4.5) global sea level will elevate 0.44-0.76 m by 2100. These figures are supported by the NASA sea level projections tool (https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool) which suggests the under SSP2-4.5, by 2100, sea level at Hiron Point will rise by 0.42-0.91m and sea level at Cox's Bazar will rise by 0.24-0.73m (see Figure below). It is predicted that a 45 cm rise in sea level may inundate 10-15 percent of the land by the year 2050 resulting in over 35 million climate refugees from coastal districts. Sea level rise may also influence the extent of the tides (currently the lower one-third of the country experiences tidal effects) and alter the salinity quality of both surface and groundwater.

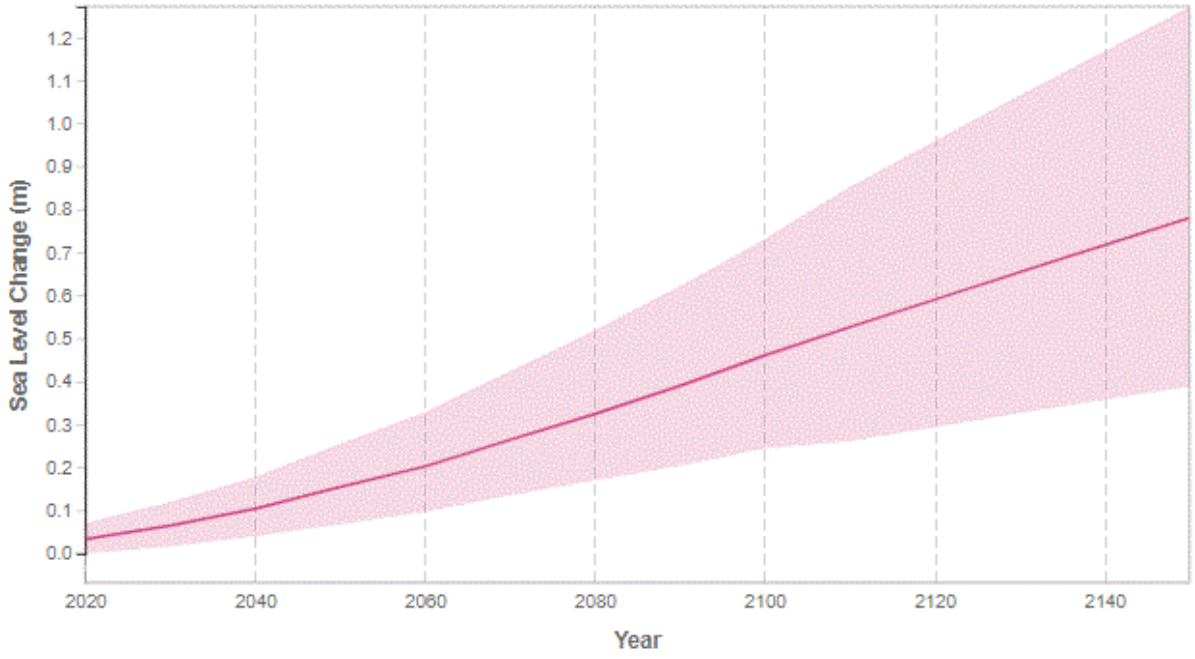


Figure11: Sea level projections for Cox's Bazar. Projections are for 2100 relative to a 1995-2014 baseline, under future scenario SSP2-4.5. The bold line shows the median projections and the shading represents the 17th-83rd percentiles.

36. The IPCC[52] reported that by the year 2050 approximately 27 million people in the coastal areas of Bangladesh will be at risk due to sea level rise. By 2080, assuming a sea level rise of 62 cm, up to 17 million, 12 million and 14 million people are expected to be at low, medium and high risk, respectively[53]. Therefore, the southern coastal districts not only house a higher percentage of poorer people than the rest of the country, but they are also those most likely to suffer a wider range of and intensification of impacts from climate change. Impacts in the coastal region include SLR and increased storm surges from cyclones and tropical storms, in addition to the increases in temperature which will be experienced over the whole country. All three of these impacts increase the salinity of land and freshwater sources, through increased

inundation of sea water and evaporation of fresh water. As a result, further stress on populations who rely on both surface and groundwater for drinking and agricultural increases, causing people (often women) to travel further to source safe and potable drinking water and for agriculture to shift to more saline resilient activities. It is reported that saline incrustations in the Chittagong coastal belt is causing immense suffering for people by making the underground water saline and undrinkable. Furthermore, salinity in the coastal belt is also causing numerous health problems for the inhabitants[54].

4.4 Observed and future changes of salinity intrusion

37. One of the immediate and long term threats of climate change is the ingress of salinity into the surface (i.e., river water) and groundwater systems and in the soil. Salinity intrusion in the coastal areas occurs owing to several factors such as the reduction of freshwater flows of the Ganges river during the peak dry season, intrusion of saline sea water due to subsurface hydrological movement owing to a rise in sea level, saline inundation due to increased wave interaction and occasional storm surge, the latter being compounded by lack of ability of the sluice gates to facilitate discharge as a consequence of increased siltation. A study found that salinity increased from two ppt to 20ppt at Mongla (south-western coastal regions) in the Passur River from 1962 to 2008[55]. However, much of such rapid increase in salinity can be attributed to the diversion of freshwater flows from the Ganges beyond the borders of the country[56]. Soil Resource Development Institute[57] periodically estimates soil salinity for coastal regions of Bangladesh. The Third such report in a row was published in 2010. The study findings suggest that total soil salinity prone areas have increased by about 1.056 million hectares from 0.8333 million hectares in about four decades. As of 2010 out of about 1.689 million hectares of coastal land 1.056 million hectares (about 63 percent) were affected by soil salinity of various degrees. About 0.328, 0.274, 0.189, 0.161 and 0.101 million hectares of land are affected by very slight (S1; 2 – 4 dS m^{-1}), slight (S2; 4.1 – 8 dS m^{-1}), moderate (S3; 8.1 – 16 dS m^{-1}), strong (S4; >16 dS m^{-1}) and very strong salinity (S5) respectively. A comparative study of the salt-affected area from 1973 to 2009 showed

that about 0.223 million ha (26.7percent) of new land is affected by various degrees of salinity during the last four decades.

38. The surface and groundwater salinity, combined with the soil salinity have serious negative impacts on agricultural productivity and production. SRDI periodically estimates soil salinity for coastal regions of Bangladesh. The third such report in a row was published in 2010. The study findings suggest that total soil salinity has increased to about 1.056 million hectares from 0.8333 million hectares in about four decades. As of 2010 out of about 1.689 million hectares of coastal land.

Table 3: Soil salinity in coastal Bangladesh

Region*	Salt affected area (000 ha)			Soil salinity: degree and area (000 ha)												Salinity increase over 4 decades	
				S12 – 4 dS m^{-1}			S24.1 – 8 dS m^{-1}			S3**8.1 – 16 dS m^{-1}			S4>16 dS m^{-1}			Area (000 ha)	%
	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009	1973	2000	2009		
1	374	417	432	48	93	87	255	119	102	52	161	169	20	48	68	57	15
2	78	78	76	18	24	25	53	27	19	3	19	27	0	7	1	-	-
3	100	106	106	25	16	21	31	33	29	24	46	50	19	72	6	6	6
4	0	26	33	0	10	22	0	5	8	0	1	2	0	0	0	33	100
Bangladesh	833	1020	1056	287	289	238	426	307	274	79	336	351	36	87	101	222	26

**1 - South-western regions (Khulna, Bagerhat, Satkhira)*
2 Central coastal regions (Laxmipur, Feni, Noakhali)

3 South-eastern regions (Chittagong, Cox's Bazar)
4 Mature delta regions (Jessore, Narail)
*** S3 = S3+S4; S3 = 8.1 -12 dS m^{-1}; S4 = 12.1 – 16 dS m^{-1}. Survey conducted in May 2009.*

39. About 1.056 million hectares (about 63 percent) were affected by soil salinity of various degrees. About 0.328, 0.274, 0.189, 0.161 and 0.101 million hectares of land are affected by very slight (S1; 2–4 dS m^{-1}), slight (S2; 4.1–8 dS m^{-1}), moderate (S3; 8.1–16 dS m^{-1}), strong (S4; >16 dS m^{-1}) and very strong salinity (S5) respectively. A comparative study of the salt-affected area from 1973 to 2009 showed that about 0.223 million hector (26.7 percent) of new land is affected by various degrees of salinity during about the last four decades (Table 3).

40. Alongside soil salinity, river water salinity in the Southwestern region is rising. In a study, it was mentioned that water salinity in Alaipur Khal in the Bagerhat district has increased gradually between the year 2000 and 2014[58]. Likewise, a study conducted in the Assasuni Upazila of Sathkhira district showed that chloride concentrations of the groundwater samples vary between 18 and 4545 mg L^{-1}, which exhibits that the highest saline tube-wells possess close to 25% seawater[59]. Almost all the people of three southwestern coastal districts i.e., Satkhira, Khulna, and Bagerhat are bearing the brunt of increased salinity[60,61]. Under climate change, the five ppt isohaline line will move about 96 kilometers northward from the current locations, which will severely affect agriculture. Since it does not rain appreciably during the *Boro* rice growing period (February till end of May)[62], with increasing surface temperature under climate change and associated desiccation from the root zones of standing Boro crops, the primary staple will not be able to sustain with increasing salinity. A study suggests that, by 2050 under moderate climate change scenario (equivalent to SST 1 and 2) the *Aman* growing areas in monsoon season will also be shrunk by 40 percent, which will have severe food insecurity related consequences[63].

4.5 Observed and future changes of tropical cyclone and storm Surges

41. The coastal areas of Bangladesh are frequently hit by cyclones formed in the Bay of Bengal. Annually, almost 12-13 depressions form in the Bay of Bengal and one or two of them transform into powerful cyclones. Notwithstanding, Bangladesh receives about two-fifths of the total impacts of global storm surges, particularly during November and May[64]. These devastating events result in massive damage to the coastal communities of Bangladesh. Statistics show that about 45 colossal cyclones formed and attacked coastal Bangladesh during the timeline of 1970 to 2015[65].

42. Bangladesh Delta Plan, 2100 reported that between 1961 and 2013, a total of 61 cyclones hit Bangladesh. The spatial distribution of these cyclones presented in Table 4 shows that the south-western coastal zone was hit by more cyclones (28 per cent) compared to the south-central coastal zones (16 percent) during the observed period[66].

Table 4: Distribution of land-falling cyclones to different coastal regions during 1961-2013

Coastal region	No. of tropical cyclones hit the coast	% of the total number of tropical cyclones
South-eastern coast (Southern Chittagong, Cox's Bazar and Teknaf)	18	29.5
Sundarban coast (Satkhira, Khulna and Bagerhat)	17	27.9
Meghna estuary, east central coast (Eastern Bhola, Noakhali and Chittagong)	16	26.2

Central coast (Borguna, Potuakhali, Pirozpur, Barisal, Bhola)	10	16.4
Total	61	100

43. The Sixth Assessment Report of IPCC (AR6) stated that the amount of intense tropical cyclones is assumed to increase (High Confidence). However, it is narrated with medium confidence that the total number of cyclones throughout the world might decline or remain constant[67]. In AR6, IPCC has firmly stated that coastal hazards in Asian countries will rise throughout the 21st century. In addition, it is asserted with high confidence that anthropogenic climate change results in increased heavy precipitation and accompanying tropical cyclones. However, it is unlikely to ascertain the trends in the frequency of all-category tropical cyclones due to the unavailability of authentic data[68].

44. Tropical cyclone often would result in devastating storm surge with as high as 6m to 10m tidal height having the potential of devastating coastal flooding, a notable effect of sea-level rise[69]. So far, a storm surge of 13m was reported in Bangladesh and 6 to 21 mm year^{-1}[70], thus significantly faster than on global average. World Bank[71] projected 30 cm (2030) to 50 cm (2050) of sea-level rise. It is estimated that sea-level rise may lead to the displacement of almost seven million people by 2025 and 13 million by 2050, with 25,500 km^2 of inundated land, if the population growth continues at a rate of 1.40 percent and if no massive corrective action is taken noted that further rise as predicted by one meter by the end of this century would cause permanent inundation of 22,000 km^2 of the coastal belt[72,73].

45. Aside from stronger cyclones the frequency of rough sea events is also rising. A trend analysis on the occurrence of Tropical Cyclones over the past five decades confirmed the rise of rough weather events in the Bay, which is attributable to rising sea surface temperature in the Bay of Bengal[74]. An annual average from 5.48 to 7.94 has been identified, resulting from the rise of sea surface temperature by 0.30-0.48°C during the period from 1958 to 2009 (CPRD, 2012)-65[75]. Such rise of the rough weather events, which was unlikely even a few years ago, are directly affecting the only means of livings of 3.5 million coastal fishers[76]. It indicates that coastal flooding could become an everlasting phenomenon in Bangladesh instead of a non-traditional natural hazard.

46. The primary damage from cyclones is caused by storm surge flooding, and if the cyclones make landfall during high tide, surges are higher. While the number of deaths caused by the usually occurring extreme events (e.g. tropical cyclones in Bangladesh) seems to be reduced due to different disaster management programmes, still they are causing substantial economic losses while exposing an increased number of people under the risk scenario. Currently, an estimated 8.3 million Bangladeshis live in cyclones high-risk areas. This figure is expected to grow to 20.3 million people by 2050 due to climate-induced intensification of cyclones[77]. Table 5 presents an account of loss and damages caused by the major cyclonic events;

Table 5: Loss and damages caused by the major cyclones

Disaster events	Date of Occurrence	Strength / Extent	Loss of human lives	Loss and assets and properties
Cyclone - Bhola	Nov 13, 1970	225 km/h	500,000+	86.4 million US dollar
Cyclone - Marian	April 29-30, 1991	240 km/h	139,000	One million cattle died; 74,000 acres of crops were destroyed; and another 300,000 acres of cropland were damaged by saltwater flooding; 2.07

Disaster events	Date of Occurrence	Strength / Extent	Loss of human lives	Loss and assets and properties
				billion US dollar[78].
Cyclone - "One Bravo"	May 19, 1997	230km/h	100	250,000 household were damaged[79].
Cyclone - Sidr	Nov 15, 2007	260 km/h	3400+	1,928,265 household were damaged; 2,007,226 acres of crops were damaged; 1.2 billion US dollar[80,81].
Cyclone - Aila	May 27-29, 2009	120 km/h	190	100,000 livestock dead; 350,000 acres of crop land were damaged; 270 million US dollar[82].
Cyclone-Mahasen	May 16, 2013			94,000 household were damaged; and over 1.2 million people were affected; 35.2 million US dollar[83].
Cyclone - Roanu	May 21, 2016	100km/h	27	31.8 million US dollar[84].
Cyclone - Fani	May 4, 2019	250km/h	14	155,662 acres of crops were damaged; 21,033 household were damaged; 175 livestock dead; and 21.95 km embankment were damaged; 4.6 million US dollar[85].
Cyclone - Amphan	May 21, 2020		17	330,667 houses were damaged; 14.7 billion US dollar[86].

47. World Bank estimates that under the baseline scenario, the damages and losses stand at 4.6 billion US dollar from a single cyclone/storm surge of a ten years return period. With climate change, the damages and losses would be increased to 9.16 billion US dollar, including 4.5 billion US dollar attributable to climate change[87].

48. Housing sector will be experienced the worst damages and losses due to cyclonic storms accounting for 43 percent of the total damages and losses. The tourism sector comes next with 26 percent, followed by agriculture with 20 percent. Damages and losses due to tropical cyclones and storm surges that accounted for 0.30 percent of the GDP under the baseline scenario would rise to 0.06 percent in 2050.

4.6 Future changes in cyclones, storm surge, and inundation

49. The Bay of Bengal, as one of the most rapidly warming large marine ecosystems, is currently warming up at 0.04°C year^{-1} [88]. IPCC reported that rising sea surface temperature also leads to significantly higher wind speeds[89]. A 21 percent and 49 percent storm surge increase

with the corresponding rise of sea surface temperature rise of SST by 2^0C and 4^0C is also projected[90]. The Sixth Assessment Report of IPCC stated that the amount of intense tropical cyclones is assumed to increase (High Confidence). However, it is narrated with medium confidence that the total number of cyclones worldwide might decline or remain constant[91]. In AR6, IPCC has firmly stated that coastal hazards in Asian countries will rise throughout the 21st century. In addition, it is asserted with high confidence that anthropogenic climate change results in increased of heavy precipitation and accompanying tropical cyclones. However, it is unlikely to ascertain the trends in the frequency of all-category tropical cyclones due to the unavailability of authentic data[92].

50. There will be a significant increase in the frequency of the highest storm surges for the Bay of Bengal[93], even if there is no substantial change in the frequency. Increased of intensity of tropical storms by 2100 for the North Indian Ocean is also projected[94]. Another study modeled cyclones storm surge impacts and inundation of the coastal areas by 2050 at a 27cm rise in sea level, a ten percent increase in wind speed, and landfall of cyclones during high tide [95]. The model predicted inundation of an additional 15 percent of the coastal area of Bangladesh by storm surges by 2050 (table 6, Figure 12). Several coastal districts e.g., Khulna, Bagerhat and Satkhira will be severely affected by sea-level rise and tidal surges of a three meters height that will inundate 69 percent more land area than they do at present (Figure 12).

Table 6: Vulnerable Area Estimates (km^2)

Inundation Depth	2050 Without Climate Change (km^2)	2050 with Climate Change (km^2)	% Change
More than 1m	20,876	23,764	+ 14%
More than 3m	10,163	17,193	+ 69%

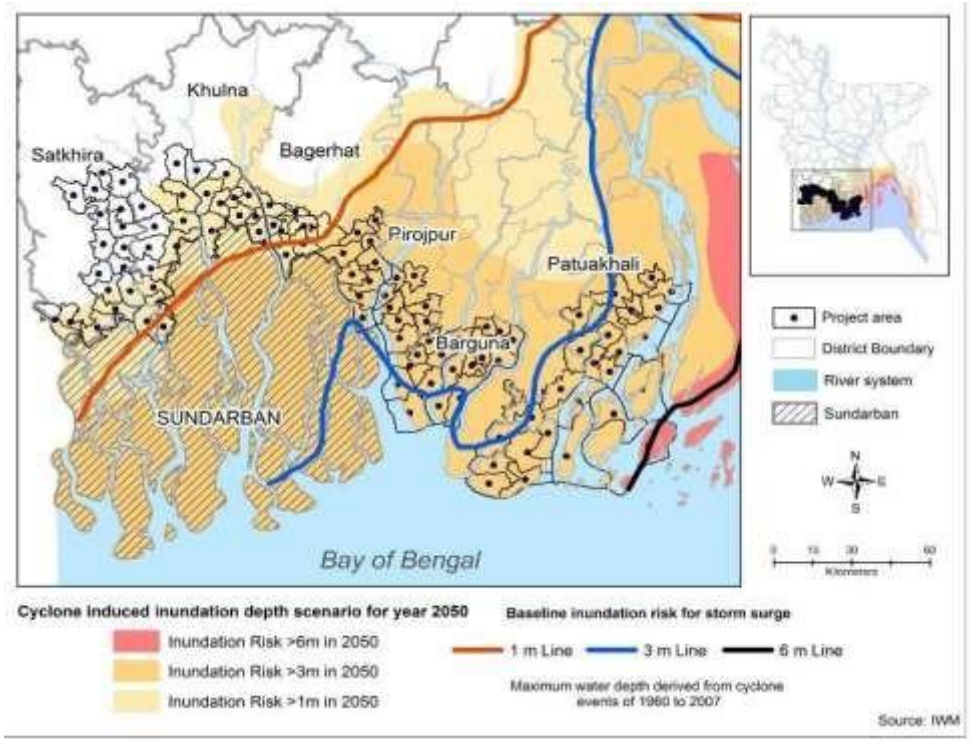


Figure 12: Cyclone inundation map in 2050 under a climate change scenario

51. Historical cyclonic tracks in the Bay of Bengal (BoB) area was analysed, where the largest delta is located on the tip of the BoB area. All the cyclones including severe cyclonic storms are brought under analysis occurring between 1970 and 2014 in the BOB region. There is an increasing trend in the occurrence of post-monsoon cyclones in the BOB during the past three decades. The analysis also reveals that there has been a substantial rise in Power Dissipation Index (PDI) and Accumulated Cyclonic Energy (ACE) in the most recent decades compared to the past decades. The two indicators represent intensity of cyclones occurring in the BoB region. The analysis suggests that the decadal variability of PDI has increased almost by a factor of six times in the past four decades[96]. Figure-13 presents decadal variability and trends of PDI and ACE in relation to occurrence of cyclones in the BoB region.

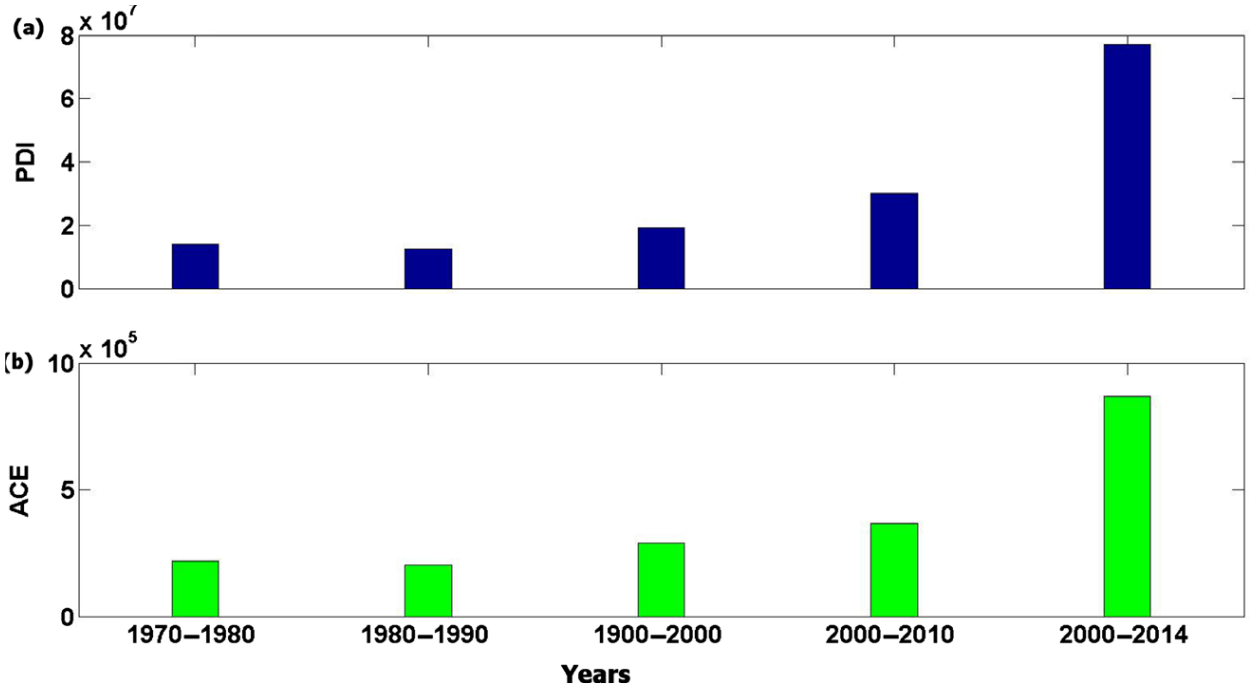


Figure-13: Decadal variation of (a) PDI and (b) ACE for tropical cyclones occurring in the BoB

52. The tidal surge will cause profound damage to coastal infrastructures like dams, embankments, and polders, etc. And the destruction of polders will allow the intrusion of saline water into the agricultural land, increasing soil salinity with the prolonged waterlogged situation. The situation would likely make agriculture and other livelihood activities nearly impossible. Figure 14 shows the number of polders in the region that risk being overtopped by 2050 under changing climate conditions.

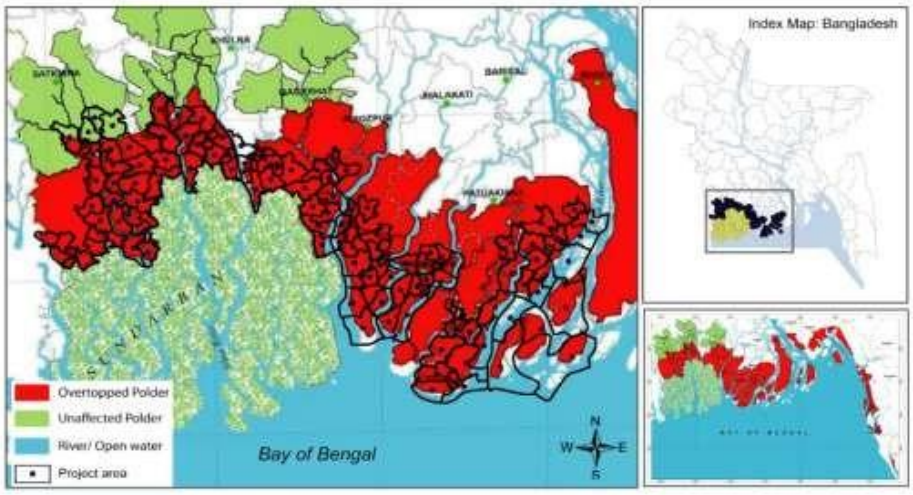


Figure 14: Overtopped polders by cyclone storm surge in 2050 under a changing climatic condition

53. Furthermore, cyclones and associated storm surges could result in coastal flooding which is also a growing disaster in the country. Coastal flooding is a notable effect of sea-level rise[97], which could become an everlasting phenomenon in Bangladesh instead of being a non-traditional natural hazard.

54. In 2018, the government of Bangladesh agreed with KfW Development Bank (Germany) worth 40 million US dollar to implement “Climate Resilient Infrastructure Mainstreaming (CRIM)” project in Bangladesh. The project aims to develop and refurbish cyclone shelters and construct the critical access road. Furthermore, the project intends to ameliorate urban infrastructure, protect vulnerable city inhabitants, and establish a "Center of Excellence for Climate Resilience Infrastructure" to disseminate and direct the future infrastructural development. The estimated budget of the CRIM project is 82.75 million US dollar, and out of the total cost, Green Climate Fund (GCF) will channel the approved 40 million US dollar as a grant through KfW.

4.7 Impacts of increasing salinity on agriculture-based livelihoods

55. Two-thirds of Bangladesh is less than five meters above the mean sea level, making these coastal regions particularly susceptible to tidal surges and incremental impacts, such as erosion and salinity intrusion. Bangladesh could experience a sea-level rise of 14 cm, 32 cm and 88 cm by 2030, 2050, and 2100, respectively[98,99]. The current rate of SLR in the country ranges from 6 mm/yr. to 21 mm year^{-1}. Observations of tidal levels in Hiron Point, Char Changa, and Cox’s Bazar between 1977, and 1998 indicate a rise of 4 mm year^{-1}, 6 mm year^{-1}, and 7.8 mm year^{-1}, respectively[100]. Sea level rise along with climate change induced increased wind speed will be the primary drivers of coastal inundation, with saltwater amplifying current trends of salinity intrusion in the ground and surface water aquifers and soils. This significantly impacts agricultural productivity and freshwater availability in the coastal belt. These impacts will be intensifying by extreme weather phenomena like cyclones. Livelihood options particularly, that of the poor community, are gradually shrinking. Since higher salinity levels on top soils will restrict farmers to continue to grow paddy, the national staple, people will have limited choice to find other agricultural livelihoods under high salinity. Their dependency on coastal natural resources (particularly on the Sundarban mangrove forest) is increasing at an alarming rate. This puts tremendous pressure on Sundarban causing loss of biodiversity, extinction of flora and fauna, and degrading the overall coastal ecosystem. In addition, increasing population pressure enhances the exploitation and degradation of the coastal ecosystem.

4.7.1 Impacts of salinity intrusion on agriculture

56. At least one million hectares of cultivable land in the country are affected by salinity intrusion caused by slow and rapid-onset events including sea-level rise, cyclones & storm surges and consequential coastal flooding[101]. As a result, net cultivated area in Satkhira district decreased by about seven percent from 1996 to 2008 and production of rice decreased from about 0.3 million tons in 2008 to 0.2 million tons in 2010.

57. Under a moderate climate change scenario, crop losses due to SLR-induced salinity intrusion have been estimated to be approximately 200,000 metric tons[102]. Other studies support this projection, estimating climate-induced increases in the salinity (+5 ppt) of irrigation water will lead to reduced farm productivity by up to 50 percent[103,104]. Irrigated *Boro* rice yields are predicted to reduce with low fertilizer regardless of cultivar and planting month, though with potential increases under high fertilizer and optimal cultivar and planting month. Rained *Aman* rice is predicted to increase only under low fertilizer with optimal cultivar and planting months in Barisal and other divisions. However, higher levels of salinity in the SWR will further restrict the production potential of rainfed Aman paddy, which will have severe food insecurity related consequences.

58. Both the Khulna (i.e, south-western region) and Barisal (central-southern region) divisions of the country have already experienced a relatively higher percentage of females with respect to male population in comparison with elsewhere in the country, which is indicative of migration of a large number of adult males in other regions/districts. Although the direct causal effects are yet to be determined, there are speculations that much of the 'male only' migration is attributable to diminishing livelihood opportunities in the two Divisions. Climate change induced salinity, particularly its effect on agriculture and loss of livelihoods is forcing the lacklustre people to leave their families behind in search of gainful employment (Ahmed and Neelormi, 2008)-97[105].

4.7.2 Impacts of salinity intrusion on livelihoods

59. The Sundarbans, the world's largest mangrove forest with considerably high biodiversity, is under threat because climate change. World Bank, using different aquatic salinity scenarios in 2050 predicted that salinity increases will negatively affect 14 mangrove species (especially the most valuable Sundari tree[106]. In turn, this will impact the livelihoods of poor communities who depend on the mangrove forest. It was projected that "the greatest negative impacts will be on the poorest upazilas (sub-district) via loss of standing timber value and honey production, as well as increased risk of human-wildlife conflicts." Similarly, salinity intrusion is also expected to have severe impacts on freshwater fish species[107]. It was reported that salinity has caused the reduction of 75 percent indigenous rice varieties in Paikgacha sub-district of Khulna[108].

4.7.3 Impact of climate change on housing

60. The housing of coastal areas is mainly affected by cyclones & storm surges coastal flooding and salinity. Nationwide, 70.31 percent of households in disaster-prone areas have *katcha* (mud) houses and 17.44 percent have semi-*pucca* (brick) houses. These houses are vulnerable to heavy rainfall, flooding and storm surge as they are made with mud and straw or *gol pata* (traditional leaf, found in Sundarban). This means, around 88 percent of households are vulnerable to climate change and associated disasters in the country. The recent cyclone Amphan in May 2020 destroyed 55,667 houses completely and about 162,000 houses partially in the southwest coastal zone of Bangladesh. Cyclone Mahasen on 16 May 2013 damaged 150000 houses[109]; Cyclone Aila in May 2009 damaged 500000 houses[110] and Sider in November 2007 damaged 600,000 houses in the coastal areas of Bangladesh. These damages are expected to be increased in the future with the increasing frequency and intensity of cyclones & storm surges.

4.7.4 Impact of salinity intrusion on drinking water

60. Tube wells or groundwater is the primary source of drinking water for 73 percent of the population living in rural areas of Bangladesh. Most of the groundwater used on the coast is pumped from upto 150 m depth, but much of it is saline. Another data source indicates that groundwater salinity in the potential project areas is beyond the limit for drinking and irrigation use (>2500 uS cm^{-1}) and surface water is beyond this limit in Satkhira and parts of Khulna Districts[111].

61. Salinity intrusion affects the sources of drinking water, hampers health, agriculture, fisheries and the ecosystem. Though the results of the local community's perception reveal the awareness of safe water scarcity due to salinity, the socioeconomic factors affect the ability of local people to adapt, and they have their adaptation technologies to deal with the problem.

Loss and Damage by very recent super cyclone 'Amphan'

Cyclone Amphan affected over a million people in nine districts in the Khulna and Barishal divisions (our working area belongs to these two divisions) of Bangladesh on 20 May 2020. UNDP reported that:

- *26 people were killed*
- *55,667 houses were completely damaged, and around 162,000 were partially damaged*
- *approximately 149,000 hectares of agricultural lands and fish farms worth about BDT 3.25 billion were damaged*
- *millions of trees were uprooted*
- *150kms of protection embankments were washed away at 84 points in 13 districts*
- *200 bridges and culverts and 100km of roads were damaged*
- *about 15 million clients lost electricity*
- *many freshwater ponds inside forests were flooded with seawater*
- *approximately 18,235 water points and 40,894 latrines were destroyed in most impacted districts*
- *preliminary estimates of the total cost of damages caused by the cyclone are BDT 11 billion*

62. The coastal regions comprise 32 percent of the total landmass and 28 percent of the total population in the country. The zone is experiencing slow in social and economic development due to scarcity of safe drinking water, waterlogging, soil salinity, high arsenic content in aquifers and various forms of pollution. As a result, GoB defined the coastal zone as an 'agro ecologically disadvantages region, where the expansion of agriculture is significantly hampered due to salinity intrusion and tidal flooding. From the 1960s to 1980s, the World Bank and other development organizations helped the country boost rice production through large-scale polderization[112]. But in the long run, this polderization made the southwestern region highly unsuitable for agricultural practices, and high salinity facilitated the option for shrimp farming as well. Land use for agricultural practice has drastically fallen between 1980 and 2010 while aquaculture has risen in recent years as a result of both adaptation and maladaptation practices based on its salinity levels.

63. In particular, shrimp culture has had some noteworthy negative impacts on the coastal ecology, especially on women who are the most affected by the ownership of agricultural enterprises. Since shrimp farming increases the salinity level, and the activity itself further escalates the soil salinity levels.

64. In the 1980's Coastal Embankment Project was initiated with a mission to the dominant use of the land for agriculture with 68.42 percent used for rice cultivation. Low lands were mainly used for conventional shrimp farming during this period. A radical shift was made in 1995 towards shrimp farming, which was partly attracted due to the high prices both nationally and globally. As a result, the areas for shrimp cultivation increased with the pace of time, and it was 2.34 percent in 1980 while it was 31.51 percent in 1995. The outcome is the expansion of shrimp farming areas from 51,812 ha in 1983 to 137,996 ha in 1994 and to 141,353 ha in 2008 due to massive revenue generation.

65. Given the context, rapid growth in shrimp culture is observable before the period of 2010 that attracted even small farmers to involve in such farming activities and wide scale of deforestation occurred in the coastal areas as a consequence. However, a huge loss in shrimp farming was caused by a virus outbreak and other factors in 2010. The country underwent a worse situation and economic downfall when European economies banned shrimp imports from Bangladesh. After that, the country started the use of HYV rice and vegetables. A notable shift in land use patterns is apparent over the years, and for instance, agriculture was the most dominant farming practice in entire southwestern coastal areas, including Satkhira, Khulna, and Bagerhat Districts in 1980. But a major change in land use pattern from agriculture to shrimp farming started in 1995 in the southwestern coastal belt. Over these 15 years from 1980 to 1995, agricultural land use is reduced from 68.42 percent to 42.53 percent. Figure 15 exemplifies the make-shift of land use from agriculture to shrimp farming from 1975 to 2005, where shrimp culture in 1975 is almost zero and more than 60 percent in 2005, while in the contrary, agricultural land dropped 80 percent to a little under 20 percent for the same period. Finally, the lives and livelihoods in Satkhira District were most extreme because of such changes in land use patterns[113,114]. It is to be highlighted here that, the complete transformation was pushed beyond a tipping point starting 1990, as observed in the figure 14 below, when the then agreement on sharing of the peak dry seasonal flows of the Ganges river expired (in 1990), resulting into unilateral withdrawal of the flows by neighbouring India, until the two countries had entered into a Ganges Water Sharing Treaty in December 1996. By that time, the reduction of flows wreaked havoc along the distributaries of the Ganges River inside Bangladesh territories, with a resulting increase in soil and water salinity and a proliferation of shrimp areas on prime crop agricultural lands.

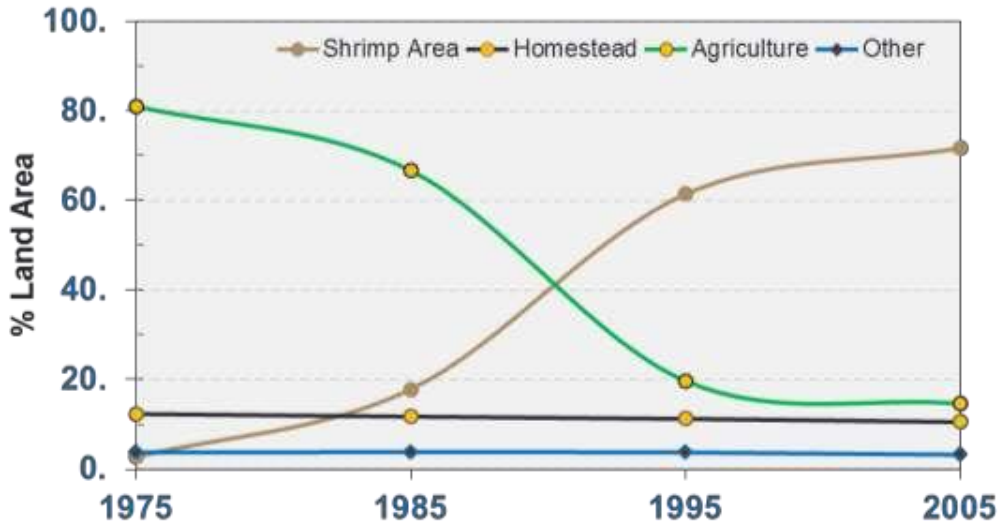


Figure 15: Pattern of land use changes in Satkhira

66. Agriculture and aquaculture are the prime economic activities that govern livelihood patterns in coastal areas. The cultivable lands are mostly suitable for wet season cropping as soil salinity is high during the dry season. Pulses, oilseeds, betel nuts, potatoes and other winter vegetables are the main types of crops produced in the coastal zone with an average net agricultural land of 1.95 million hectares. Besides, the country exports a substantial amount of shrimp trade in the global market and ranks second biggest foreign exchange earner. However, the land use for shrimp culture can no longer support the cultivation of other crops and vegetables. Moreover, shrimp farming ponds must be kept in saline, that ultimately aggravates the soil salinity condition through leaching salts from land into groundwater and adjacent lands. This can bring devastating effects to farmers by preventing them from carrying out farming activities in their agricultural lands.

67. Climate-induced salinity intrusion significantly impacts the agro-based livelihoods and simultaneously imposes a tremendous risk to the country's agrarian economy. This results in direct loss and damage to crops, freshwater fish stocks, and income intensifying the vulnerability of local communities. A subsequent demand in adaptive responses in livelihood choices and production patterns is seen where salinity intrusion due to climate change already triggers the reduction in agricultural productions in the coastal belt. Salinity has extended over 1.05 million hectares area in the coastal belt of Bangladesh in 2009, which used to be 0.833 million hectares in 1973 which are gradually contracting the cultivable land in the coastal zone[115].

4.8 Climate Change affects men and women differently

68. In Bangladesh, there exists gender differentiated impacts[116], as elsewhere in the developing world[117]. In the aftermath of super cyclone Sidr (2007), the death toll was seven fold higher for women than for men. Since women cannot leave their homestead upon receipt of warnings due to gender differentiated roles and responsibilities, they often cannot safeguard their lives[118,119]. This calls for an immediate intervention for the existence of a stronger house that can withstand higher wind speed in case of a climate-induced cyclone. However, a poor household cannot afford to invest more in an effort to strengthen the house. Since the poor often do not have financial and other capacities to offer collateral, the financial market does not allow them to invest in strengthening of their houses. Cyclone-resilient housing, therefore, is a gender-oriented development agenda under climate change in Bangladesh.

69. The availability of drinking water and agrarian livelihoods are significantly affected due to an increase in surface salinity as a consequence of climate change. In particular, surface salinity affects women most where it imposes threats to their health through saline water consumption, as well as hinders their ability to perform household activities and agricultural livelihood options. Bangladesh holds 142nd position in the Gender Inequality Index[120], which was developed by the UNDP based on some measuring criteria, for instance, the quality of reproductive health, the degree of empowerment, and women's economic status in the country. In the country, the persistent societal and cultural norms retard not only undertaking women's daily activities but also their adaptive capacity to climate change which ultimately results in gender inequality.

70. Moreover, gender disparity is common in coastal areas whereas, women's activities are assigned based on gender roles. Men are generally involved in income-generating activities, and they often move to distant places for searching work. At the same time, women remain in their houses and take care of the domestic spaces. They have to travel long distances to fetch clean drinking water for their family. Women act more as 'reproductive labour' than is opposed to 'productive labour'. Furthermore, women are less empowered role in the decision making process than their male counterparts. This scenario is even seen during the context of any onset environmental hazard while they are often rendered immobile but their husbands and sons move elsewhere for searching work. Though the country has shown remarkable progress in reducing live loss during the cyclonic disasters in the last few decades, women still fall victim more than men. The World Bank estimates show 300,000 victims in total during the Bhola Cyclone in 1971 whereas the female victims outnumber the male victims 14 to 1. This situation is not much changed 30 years later. The death ratio is still five times more among women than men, irrespective of the considerable reduction in death numbers through the construction of cyclone shelters and the expansion of early warning systems in the country[121] .

71. Focusing on women and adolescent girls, a six years project entitled 'Enhancing adaptive capacities of coastal communities, especially women, to cope with climate change-induced salinity was undertaken. The project commenced in July 2018 and is expected to provide support to 0.7 million people residing in disaster-prone areas. Ministry of Women and Children's Affairs is co-financing the project with UNDP to authorize women as 'change agents' so that they can plan, materialize, and administer climate-resilient solutions[122].

4.9 Cost of Adaptation

72. The World Bank (2010c)[123] estimated that, by 2050, adaptation costs in relation to tropical cyclones and storm surges will be 5,516 million US dollar and the annual recurrent cost would be 112 million US dollar, while regarding inland monsoon flooding the cost will be 2,671 million US dollar and the annual recurrent cost will be 54 million US dollar. Adaptation cost for climate-related diseases: Diarrhea, Kalazar, Filariasis, Dengue/Malaria Chikungunya, chronic obstructive pulmonary diseases would be 4.01 billion US dollar for the 15-year period (1915-2030), which is equivalent to 272.1 million US dollar per annum.

73. Bangladesh has already implemented or is implementing some key adaptation activities as urgent and immediate needs of the country. However, the implementation of identified priority adaptation measures is very critical to increase the resilience of the country to climate change. The Green Climate Fund has endorsed a project for the SWR on addressing availability of potable water (UNDP as the AE). Although such small-scale projects (in the order of 33 million US dollar) are useful, the total beneficial effect still appears little compared to the overall demand for financing. It was estimated that Bangladesh would need to invest 44 billion US dollar from 2015 to 2030 to implement identified adaptation measures to address adverse impacts of climate change for a tropical cyclone, monsoon flooding and climate-related diseases.

5 THEORY OF CHANGE

5.1 Climate context

74. As described above, the coastal people of the country are vulnerable to both slow and rapid onset. Sea level rise is evident along the coastal zone with varying degrees. The SLR has both primary and secondary impacts on coastal communities. It primarily inundates farming lands and residences and will be continuing. Its secondary impact is the continuous increase of soil and water salinity affecting agriculture production. Intensive rainfall, along with SLR, causes inundation and damage to homesteads and houses, particularly to poor people. Cyclones and storm surges damage crops and houses and will continue the long run with the changing climatic condition. It also increases the salinity of soil affecting, long term production.

75. The coastal population is mostly poor, small and marginal farm families and shrimp workers. These communities live in highly vulnerable homesteads that put themselves and their livelihoods at risk during every slow and sudden extreme climate event, leading to loss of homes, livestock and arable land and crops. It is not only life threatening but financially catastrophic for these communities. Although the GoB has implemented several settlement projects in coastal areas these are urban housing projects (undertaken by Khulna Development Authority; infrastructure development of Patuakhali municipality*; Climate Change Adapted Urban Development (CCAUD) Programme for Barisal City Corporation* project etc.) and rural poor and vulnerable people do not have access to these projects.

76. On the other hand, the coastal people depend on seasonal subsistence agriculture and agriculture wage labour. Climate resilient livelihoods of the coastal belt is based on the coupling of land and aquatic ecosystem (freshwater and brackish water aquaculture) services which are highly sensitive to climate change and associated disasters. Salt intrusion brought by flooding is expected to continue leading to more losses of productive lands, land productivity and degradation of natural resources. Low elevation and higher salinity levels in coastal zones are already strongly correlated with lower incomes and migration of working-age adults leaving behind women, the elderly and the disabled, who have limited resilience to climate-hazards. Without adaptation, the number of people facing coastal inundation and migration is estimated to grow by 2–7 million by 2070s[124].

77. The vulnerability of the coastal people is characterized in three ways i.e. 1) Climate sensitive livelihood, 2) Vulnerable settlement in low-lying areas and 3) Scarcity of safe drinking water. Majority of the coastal population is poor, small and marginal farm families and shrimp workers. They build their houses in low-lying areas which are subject to coastal flooding. Most of the houses are built with mud and goal pata which are severely affected by cyclone & storm surge and high tides. These people have to spend significant amount of their earning for repairing houses each year. The surface and ground water in the coastal zone of the country are increasingly contaminated with saline water due to seal level rise, cyclone and tidal surge. The coastal people particularly the women collect drinking water far away from their locality spending productive long time which also push back them in poverty.

78. The ideal state is one where rural families and communities can withstand cyclones and storm surges so that there is no loss of life or livelihood; that livelihoods can persist even with slow onset changes to soil salinity and higher temperatures and families are not forced to leave traditional villages for a life of poverty in cities because of financial loss and lack of access to finance. But to get to this state key barriers must first be addressed.

79. The project will take the opportunity of salinity intrusion in the coastal zone, particularly in the project area, instead of projecting salinity intrusion like embankment etc. This requires a salinity based production system. Crab farming could be a very important economic activity to capitalize on this opportunity. For this, the project proposed for establishing crab hatchery by the existing crab traders so that the natural crab stock is not hampered. The partner organisations of PKSF will be continue to finance in this sector. Secondly, the community people are unaware of rising homestead plinths through coastal floods and storm surges inundated them. Therefore, this project will introduce the practice of raising homesteads of the vulnerable coastal community. Through these practices, the community and local institutions will learn how to protect their houses and homesteads from inundation and storms. Moreover, more than 20 local organizations including government and NGOs will learn and adopt similar practice through their engagement in the project during implementation.

5.2 Proposed interventions

80. The proposed project will establish crab hatcheries for promoting crab fattening as a climate resilient livelihood through technology transfer, capacity building and financial services. Almost 13,335 people are collecting crab-lets from natural sources and around 50,000 people are involved in traditional crab fattening. Primarily the proposed project will target these people establish crab hatchery and promote crab fattening. For the establishment of the crab hatchery, the proposed project will follow the proven scientific model of Vietnam.

81. The poor people in Bangladesh including the coastal community rear goats/sheep. Because it requires small space and considerably low cost required to rear. Most importantly, women are mainly involved in sheep rearing because the management of this small ruminants are easier than cow or buffalo. Slatted house of sheep rearing is a new technology in Bangladesh particularly in the proposed seven districts. PKSF has demonstrated several hundred slatted houses under Community Climate Change Project (CCCP) which was completed in 2016. The response of the community to the technology was significant in terms of adaptive capacity and economic benefit. Based on this experience, the proposed project will support 90,000 people for sheep and goat rearing in slatted houses.

82. 52.01% of household of Khulna division is katcha (temporary) and 26.86 percent are semi-pucca[125] which means that more than three-fourth of the households are vulnerable to intensive precipitation, cyclones and storm surges etc. For sustaining the livelihood, the proposed project will provide support to construct climate resilient housing. The concept of climate resilient housing under the project includes raising homesteads plinth above flood or tidal surge level, constructing and/or reconstructing houses with concrete pillars resilient to climate change and associated shocks (i.e. cyclone, storm surge, tidal surge, salinity, coastal flooding etc.), construction of climate resilient sanitary latrines, rainwater harvesting system, homestead gardening system, and tree plantation around the homestead area. The core structure will be made with bricks and reinforced concrete which are locally available. Resilient housing is very important for building resilience of the affected community; because they have to spend much of their income in repairing their houses each year during post-monsoon period. However, the proposed project will support about 3000 most vulnerable people in building climate resilient houses to from the selected community.

83. The local level institutions including government and non-government organisations understand development activities. But there is a gap on integrating climate change in their regular development activities. This is mainly due to lack of understanding causes and

consequences of climate change in relation to conventional development activities. There are many interventions that may be related to climate change adaptation. For example, rain water harvesting for drinking and irrigation, cultivation of resistant varieties etc. But the organisations do not consider present and future climate change while designing the interventions.

5.3 Linkage to climate Change and proposed adaptation solutions

84. Intensive and irregular rainfall, coastal flood, salinity intrusion, cyclone, and storm surges are the major climate change-related threats to the lives and livelihoods of the vulnerable community. More than 42 percent of people in the coastal districts are poor and marginal farm families and fishermen who depend on seasonal subsistence agriculture, agriculture wage labour, and Sundarban resources. All these options are highly vulnerable to the causalities mentioned above of climate change. The proposed project will promote crab farming, a pro-salinity economic activity for the coastal people. The slatted house of goats or sheep protects them from intensive rain, flood, tidal surges, and diseases caused by cold and ammonia gas. Climate-resilient housing will protect the lives and resources of vulnerable communities from frequent and extensive cyclones and storm surges and help them continue their daily activities as usual. It will also support improved sanitation and safe drinking water facilities that are also resilient to these climate variability and shocks.

5.4 Key barriers and challenges

Barrier 1: Lack of climate planning and implementation capacity amongst communities for addressing climate change

85. The local communities experience salinity problems, cyclones, tidal surges, and coastal floods. But they have the least understanding of the long-term impacts of climate change-induced problems. Hence, they seldom take effective measures to address climate change issues. The local level institutions also have limited capacity to address climate change impacts as it is an emerging issue. Climate change is an emerging issue. The local level institutions, including government and non-government organisations understand development activities. But there is gap in integrating climate change in their regular development activities. This is mainly due to a lack of understanding causes and consequences of climate change in relation to conventional development activities. There are many interventions that may be related to climate change adaptation—for example, rainwater harvesting for drinking and irrigation, cultivation of resistant varieties, etc. But the organisations do not consider present and future climate change while designing the interventions.

Barrier 2: Lack of livelihood diversification, limited capacity to adopt adaptation technologies

86. Communities lack the know-how and capacity to identify and implement alternative resilient technologies and practices that would otherwise mitigate climate threats. Upskilling on traditional farming and diversification of activities is key to increasing their adaptive potential. However, target communities lack knowledge and are inherently risk averse to switching to new practices (e.g., adapting to saline-tolerant crop varieties), technologies (e.g., drip irrigation, hydroponics, aqua-geoponics), and sectors (such as crab farming). The barrier is further exacerbated by a lack of technical knowledge and support owing to limited capacities among peers and local extension staff. Extremely poor households are often unable to make informed risk management strategies, given that they lack information and are continuously coping with new shocks and stresses and have limited space and ability to think about and act on choices

that will make a positive difference to their future (relative to households that are relatively more resource endowed).

Barrier 3: Lack of access to finance to invest in large capital expenses

87. Despite the substantial expansion of bank branches and an increase in the membership of MFIs and other financial institutions, a large number of the country's adult population still remains financially excluded[126]. Target communities represent the poor and ultra-poor of Bangladesh, living on subsistence agriculture and wage labour.

88. These communities suffer a lack of awareness, are of low income/assets, suffer social exclusion, and financial illiteracy, which act as barriers to accessing financial services[51]. Consequently, they are highly risk-averse to investment and fail to obtain the means to address additional threats from climate change. Moreover, they have the least access to loans from commercial banks, and while some NGOs provide loans, the loan sizes are inadequate when compared to needs, especially for relatively expensive investments in homestead climate resilient infrastructure and livelihood diversification capital expenses. For this reason, most houses of the rural poor in the coastal zone are made of mud and sticks, which are no match to the cyclones and storm surges that plague this region, leading to total loss of assets and sometimes lives.

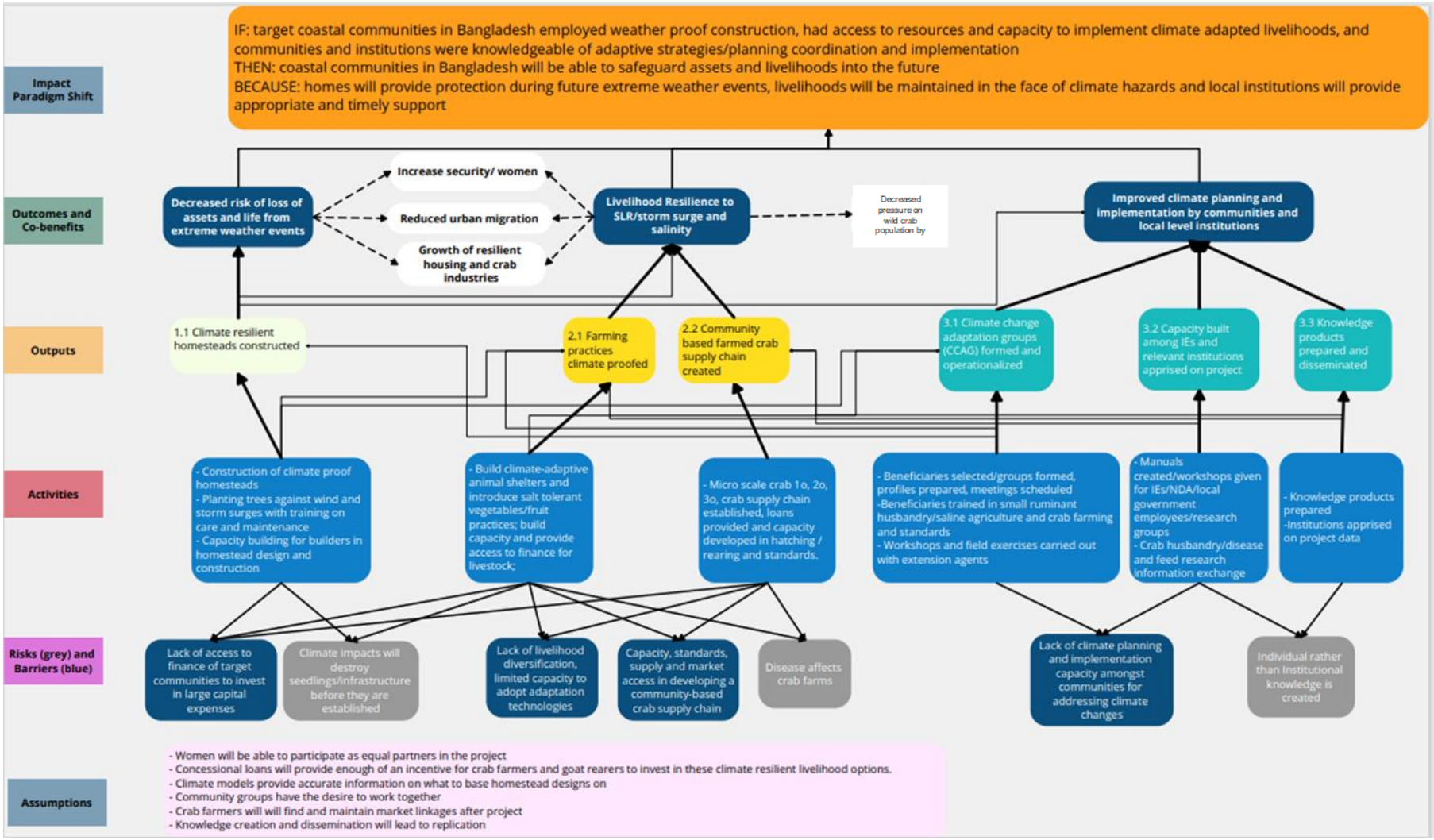
Barrier 4: Capacity, standards, supply and market access in developing a community-based crab supply chain

89. Soft- and hard-shelled crab meat has a high demand locally and internationally. As a result, crab exports from Bangladesh are increasing over time, and so is local consumption among crab producer and non-producer communities. According to World Trade Organization data, Bangladesh is the 7th largest crab exporter. Between 2010 and 2018, Bangladesh's crab exports increased three times. China is the top export market destination, followed by Thailand. The USA, Malaysia, Singapore, Japan, and Australia are other market destinations.

90. To meet this demand, poor communities have harvested wild crabs mostly from the Sundarbans. However, wild crab stocks are falling, posing a great risk to the industry and the livelihoods of the vulnerable poor. In addition, wild crab harvesting poses risks from tiger attacks and kidnapping by bandits, especially of women. The markets often disadvantage the poor and women, who find it hard to obtain a fair price. Demand for crab, however, is growing internally and externally, and the species is resilient to salinity increases, posing a livelihood and nutritional opportunity for coastal communities. To maintain a sustainable supply of crab eggs, a hatchery is needed, but technology and technology transfer have been lacking. In addition, their lack of extension capacity, investment shortfalls and poor bargaining capacity of small-scale farmers lacking direct access to markets limit the ability to establish hatcheries and robust, sustainable supply chains in the target regions[127].

91. The current crab industry lacks quality and food safety standards that hamper its growth, especially as an export commodity. There is a lack of training and guidelines on husbandry standards and activities that mitigate contamination and the spread of disease. In addition, crab feed relies on the importation of *Artemia* (a copepod used as feedstock for crabs) from Vietnam, which has a limited supply and could limit the growth of a community-based industry.

Figure 16: Theory of Change



6 POLICY AND INSTITUTIONAL FRAMEWORKS RELATED TO CLIMATE-RESILIENT DEVELOPMENT

6.1 National Policies and Climate Change

92. The country signed the United Nations Framework Convention on Climate Change (UNFCCC) in June 1992 and ratified it in April 1994. The country ratified the Kyoto Protocol in October 2001. Since then, there has been a significant change in the institutional landscape in Bangladesh centered on and around climate change. Over the years, aligning with the UNFCCC climate change negotiation, Bangladesh developed the National Adaptation Programme of Action (NAPA) in 2005, National Communications on Climate Change in 2001, 2012, and 2018, Nationally Determined Contributions in 2015, etc. Bangladesh also developed its strategic Plan called Bangladesh Climate Change Strategy and Action Plan in 2009 (updated in 2009) and established two funds e.g., Bangladesh Climate Change Trust Fund (BBCTF) and Bangladesh Climate Change Resilience Fund (BCCRF), to support the effective and timely implementation of the BCCSAP, Newer institutions within government, political system and non-government research, academic, NGOs, network and campaign have been established. To harmonize adaptation and DRR activities from Policy to the field, the government established a climate change cell (CCC) in 2004 with the financial help of DFID and housed in DoE under MoEFCC. Besides, individuals such as independent researchers and experts; and institutions, traditional development NGOs, and research organizations adopted climate change as an issue to work with. After the national election of 2008, the All-Party Parliamentary Group on climate change and a parliamentary committee of coastal Members of Parliament (MPs) were also formed.

93. Over the years, the major bilateral and multilateral donors' policies shifted to include climate change concerns in their development assistance. As a result, climate change moved from a peripheral issue to a central issue to the discussion and action of donor agencies, although the change process was not generated by the country by the changes in the international Policy of the donors.

6.2 National Plans and Climate Change

94. There are wide and complex constituencies of interest in climate change, including central Ministries, line Ministries, local government, NGOs, the private sector (including households), and development partners.

6.3 Nationally Determined Contributions (NDC)

95. Though the policy narratives in Bangladesh have evolved from not recognizing climate mitigation as an issue, given the urgency of limiting GHG emissions and in line with the decision of the Paris Climate Agreement, Bangladesh showed its voluntary interest in mitigation and already submitted its mitigation target under the 'National Determined Contributions-NDC.

96. Bangladesh's NDC sets out several mitigation actions to move to a low-carbon, climate-resilient economy and become a middle-income country by 2021 while ensuring that it will not exceed the average per capita emissions of the developing world. The NDC includes unconditional and conditional emissions reduction goals for the power, transport, and industry sectors, alongside further mitigation actions in other sectors, which Bangladesh intends to carry out. Bangladesh intends to implement its conditional emissions reduction goal subject to appropriate international support in finance, investment, technology development and transfer, and capacity building. Bangladesh's NDC also identified interventions of resilience building to the impacts of climate change and an estimated 42 billion US dollar for resilience building during the 2015-2030 period. NDC states that monitoring and evaluation of adaptation policies

and programmes is also crucial to ensure that resources are efficiently utilized in order to increase resilience overall[128].

6.4 Disaster Management Act, 2012

97. Disaster Management Act was enacted in 2012 with a vision to make activities for substantial reduction of disaster risk and resilient infrastructures for effective disaster management. To equip the GoB for robust response and action towards reducing risks of disasters and climate change at all levels, this DM Act endorses the Standing Orders on Disaster (SOD)[129].

6.5 Disaster Management Policy 2015

98. In 2015, the government of Bangladesh (GoB) approved an effective instrument - the Disaster Management (DM) Policy with strong importance on Disaster Risk Reduction (DRR). This Policy acts as operational guidelines and procedures for relevant sectors while it strengthens the capacity of the disaster management system to minimize undesirable risks. This policy emphasis on disaster management funds allocation at all levels for disaster management activities[130].

6.6 The National Plan for Disaster Management

99. The National Plan for Disaster Management (2010-2015, 2016-2020) is the first policy document of its kind, a milestone that reflects a paradigm shift from disaster relief and response to comprehensive risk reduction. The Plan emphasizes comprehensively addressing Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) in all development plans, programmes, and policies. In accordance with the global framework: the Sendai Framework for Disaster Risk Reduction, and the Hyogo Framework of Action, NPDM places importance on achieving resilience on emerging risks aligned to urbanization and climate change and disaster risk reduction for sustainable development. This Plan is flexible and adaptive in the perception of the changing nature of risks in Bangladesh and included a group of strategies: a) management of both risks and consequences of disasters, including resilience building and emergency response, and post-disaster recovery; b) involvement of the local community and local government in preparedness programs; d) integration of structural and non-structural measures, especially high priority given to community disaster preparedness through training, advocacy and public awareness[131]. The plans also include recurrent, anticipated, and climate-induced disasters and simultaneously promote risk-informed planning and implementation of continuous investment initiatives for disaster management.

6.7 Bangladesh Climate Change Strategy and Action Plan (BCCSAP, 2009)

100. The Government of Bangladesh produced the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2008, updated in 2009. The BCCSAP is focused on medium and long-term actions (it lists 44 such actions) based on the following six thematic pillars: food security, social protection and health; comprehensive disaster management; infrastructure; research and knowledge management; mitigation and low carbon development; and capacity building and institutional strengthening. Powerful ministries and departments were involved in the planning, including Finance, Planning, Agriculture, Water Resources, Foreign Affairs, Local Government, and the Prime Minister's Office. BCCSAP focuses on climate change and disaster nexus, addresses a pro-poor Climate Change Strategy, and underscores the importance of including women and children in all the activities under the Action Plan. The BCCSAP identified 44 programs (and 145 actions), that have been clustered under six thematic areas in four timelines, from immediate to long-term, focusing on medium and long-term actions (Table 7).

Table 7: Six thematic areas of BCCSAP

Theme	Description
Theme 1: Food Security, Social Protection and Health	Activities of this thematic area emphasize ensuring food and livelihood security, especially for the poorest and most vulnerable in society, including women and children. It also focuses on the needs for food security, safe housing, employment and access to basic services, including health.
Theme 2: Comprehensive Disaster Management	Activities of this thematic area recognizes to further strengthen the country's already proven disaster management systems to deal with increasingly frequent and severe natural calamities.
Theme 3: Infrastructure	This theme is to ensure that existing assets (e.g. coastal and river embankments) are well-maintained and fit-for-purpose and that urgently needed infrastructure (e.g. cyclone shelters and urban drainage) is put in place to deal with the likely impacts of climate change.
Theme 4: Research and Knowledge Management	Activities of this thematic area emphasize implementing researches to understand the impacts of climate change on different sectors of the economy and socioeconomic groups. This is also to understand the scale and timing of climate change; to underpin future investment strategies; and to ensure that Bangladesh is networked into the latest global thinking on science, and best practices of climate change management.
Theme 5: Mitigation and Low Carbon Development	This theme is to evolve low carbon development options and implement these as the country's economy grows over the coming decades and the demand for energy increases.
Theme 6: Capacity Building and Institutional Strengthening	This theme is to enhance the capacity of government ministries and agencies, civil society and the private sector to meet the challenge of climate change and mainstream them as part of development actions.

6.8 National Adaptation Programme of Action (NAPA) 2005, Updated in 2009

101. As a response to the decision of the Seventh Session of the Conference of the Parties (COP7) of the United Nations Framework the government of Bangladesh prepared NAPA in 2005. The NAPA focuses attention on three impacts associated with climate change: increasing sea-level rise, changing rainfall patterns, and increases in the frequency and intensity of extreme events and suggested 15 projects for 'immediate and urgent implementation' saying that 'delay in implementation would increase vulnerability and or would increase adaptation costs later. The preparation process was guided by a high powered Project Steering Committee headed by the Secretary, Ministry of Environment and Forests and member from other key ministries, department and agencies including the Ministry of Finance and Planning. The NAPA was further updated in 2009 and identified 45 adaptation measures with 18 immediate and medium-term adaptation measures.

6.9 Sector Development Plan (2011-25) for the water supply and sanitation sector

102. The Sector Development Plan for water and sanitation is one of the key strategic documents that emphasizes ensuring water security for all. The Plan set a cost recovery principle and emphasizes providing quality and rights-based services. The key principles of the Plan include (a) operation and maintenance of the water supply and sanitation systems based on sound technical and financial management practices, (b) adoption of cost-recovery

measures for WSS services in a manner that will ensure recovery of at least the operation and maintenance costs in the shortest possible time and then gradually recover capital costs and also generate funds for rehabilitation of degraded systems and expansion of facilities to meet future demands, (c) ensuring fairness and social justice among the customers and service providers while establishing service standards and tariff, and (d) providing safety nets for the poor and address the needs of women, children and people with disability.

6.10 Climate Change and Gender Action Plan (ccGAP)

103. Bangladesh Climate Change and Gender Action Plan 2013 (ccGAP Bangladesh) aimed to mainstream gender issues in climate actions e.g. adaptation and mitigation, and to overall development initiatives. The Action Plan identified the specific role of women in the design and implementation of activities included in 4 key thematic areas BCCSAP,2009, namely a) Food Security, Social Protection and Health; b) Comprehensive Disaster Management; c) Infrastructure; and d) Mitigation and Low Carbon Development. The other two pillars of the BCCSAP are also reflected throughout this Plan as cross-cutting issues[132]. This Plan guides policy issues and initiatives that need to be considered by government and development practitioners in collaboration with different institutions to address climate change in a gender-sensitive manner.

104. Bangladesh's ccGAP underscores the importance of developing a gender-responsive disaster management policy, ensuring increased participation of women in central and local disaster management councils, and allocating financial resources to address gender and DRR issues,

105. Aside from the issue-specific Plan (e.g. ccGAP), the government of Bangladesh also developed several national policies and plans aligned to the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW) (1979), and the Beijing Platform of Action (1995). The major ones are;

- The Women's Development Policy (WDP), 2011 within the framework of CEDAW;
- The National Action Plan to implement the WDP;

6.11 Crab related policy gaps

106. The industry is taking preliminary steps in the right direction, with an annual historic increase in demand and supply. However, while still at its nascent stage, the sector relies heavily on collecting crabs from the wild for business. With the increasing annual demand, this dependency on nature must be diverted to hatchery-based production to maintain ecological stability and supply-end sustainability. The government of Bangladesh acknowledges the potentiality of the crab sector, but it also means that proper policies need to be developed in order to nurture the industry from its nascent stage into a mature one. Presently, the Government of Bangladesh controls Crab and crab-based production and export under the Crab, and crab-based production management rules 2019 (under the Wildlife Conservation Act 2012). Under these rules, the government controls crab collection from nature (wild), crab farming, and export. But there are still some gaps in this rule. Primarily, policies need to be reformed regarding the ban on wild collection. Secondly, a policy should also be formulated on the types of crabs that can be collected from the wild in order to protect the population from getting depleted. Lastly, there needs to be a formulation of export policy mandates for the exporters in order to ensure the quality and brand are not compromised in the international market.

107. ***Breeding Policy****:* It is important that the Government of Bangladesh finalize a particular window regarding the ban on wild crab collection. While the current ban is in effect in January

and February of every year, researchers claim this ban period is inaccurate, resulting in business losses during the peak export season.

108. ***Wild Crab Collection:*** While there are policies on the type of Crab that can be collected from the wild, however, these policies have yet to be properly implemented. It needs to prepare a separate wild collection policy/manual to control the population depletion, particularly of the young crabs that are being collected from nature for the soft-shell farms before these crabs can reproduce.

6.12 Institutional arrangements

109. The climate change-related activities in Bangladesh are governed by a National Environment Committee (NEC), headed by the prime minister, and a National Steering Committee on climate change, chaired by the Minister of MoEFCC. The NEC has been set up to ensure effective top-level management of the environment and to integrate development and the environment at the national level.

110. GoB recognizes insufficient coordination as one of the major limitations of the current institutional setup to address climate change issues. Recognizing so, the MOEFCC established Climate Change Units (CCU) to facilitate the implementation of the BCCSAP. The BCCSAP also highlighted the need for cooperation across sectors by identifying the need for climate change focal points in all relevant ministries[133]. The GoB also established financial entities to provide financial support to implement climate change-related activities, plans, and projects.

111. Recognizing the uncertainties and inadequacies of international adaptation finance from both multilateral and bilateral sources, the Government of Bangladesh decided to establish the Bangladesh Climate Change Trust Fund (BCCTF) based on revenue from the national budget, within a legal mandate by the Climate Change Trust Act passed in Parliament in 2010. At the same time, an alternate Bangladesh Climate Change Resilient Fund (BCCRF - formerly known as the Multi-Donor Trust Fund or MDTF) was created to pool funds from the country's development partners.

112. BCCTF was established under the Climate Change Trust Fund Act (CCTFA), adopted by the GoB in 2010, to fund activities related to climate change. It is financed by the national revenue budget of Bangladesh as well as donor funds and is used for implementing short, medium, and long-term goals and actions relating to climate change. The Climate Change Act stipulated that 66 percent of this amount will be spent on the implementation of projects/programmes prioritized in the BCCSAP, and 34 per cent will be maintained as a 'fixed deposit' for emergencies. The interest accrued on the 34 percent fixed deposit will also be spent on project implementation. Funds from the BCCTF can be used to finance public sector and non-government projects, and it is not mandatory to spend the total grant within a given financial year[134].

113. The Bangladesh Climate Change Resilience Fund (BCCRF) BCCRF has a similar mandate to the BCCTF as it was established to facilitate the implementation of the six pillars identified in the BCCSAP. It was originally called the Multi-Donor Trust Fund in 2009, and became operational in 2010. However, there is no direct provision for BCCRF to provide compensation for actual loss and damage as it funds activities, such as climate change projects, primarily on adaptation but also on mitigation, being implemented by government agencies and NGOs. In total, 90 percent of the allocated funds will be utilised for government projects and the remaining 10 percent for implementing NGO-led projects.

114. The BCCSAP also serves as a strategy document to integrate climate change challenges and opportunities into the overall development plan and programs involving all sectors and

processes for economic and social development. This process has been supported by the Poverty, Environment and Climate and Mainstreaming (PECM) Project of the General Economics Division of the Planning Commission. Climate change is furthermore incorporated into the critical planning documents: The Development Project Proforma, the Annual Development Plan (ADP), the sixth, seventh, and eight Five Year Plan, and the Perspective Plan 2010-2021.

6.12.1 Ministry of Disaster Management and Relief

115. The MoDMR is primarily responsible for driving national risk reduction reform programs for the people, especially poor and disadvantaged people, to reduce disaster risks and ensure an efficient emergency response management system in disaster-prone areas so that the effects could be manageable and acceptable humanitarian level. The mission of MoDMR is to achieve a more comprehensive risk reduction culture through a paradigm shift in disaster management and promote food security to ensure community resilience to hazards[135].

116. DDM, a vibrant department for disaster risk reduction under MoDMR to, undertake risk reduction activities; efficiently responds to disaster events as well as strengthens and coordinating programs carried out by different stakeholders related to DRR and DRM[136] .

117. Several national instruments or drivers guide Disaster Management in Bangladesh, i) Disaster Management Act 2012; ii) Standing Orders on Disasters (SOD), first introduced in 1997 and then revised in 2010; iii) National Plan for Disaster Management 2010-2015; and iv) Disaster Management Act 2015.

118. The National Disaster Management Council reviews the national disaster management system, Policy, and planning documents on disaster management and provides strategic advice for DRR and ERM. The Council promotes dialogue across sectors to integrate disaster risk reduction into sectoral development plans and programs and promote awareness about DRR among the top policymakers. NDMC provides strategic direction towards improving the existing systems and procedures and facilitates coordination of multi-hazard and multi-sectoral measures in relation to DRR and ERM. IMDMCC is responsible for carrying out the decisions of the Council meetings[137].

119. With the support of donor agencies, Bangladesh has developed the Comprehensive Disaster Management Programme (CDMP) that emphasizes capacity building for MoEFCC and DoE to coordinate and mainstream climate change into their existing activities. The project also emphasizes strengthening existing knowledge and information accessibility on CC impact prediction and adaptation; and awareness-raising, advocacy, and coordination to promote CCA in development activities. CDMP established a Local Disaster Risk Reduction Facility (LDRRF) that supported the establishment of a Climate Change Cell at DoE that aimed to improve coordination on disaster management and climate adaptation activities at the local level

6.12.2 Ministry of Finance

120. In September 2014, GoB nominated the Economic Relations Division (ERD) of the Ministry of Finance as the National Designated Authority (NDA) of Bangladesh to the Green Climate Fund. ERD, one of the four divisions of the Ministry of Finance in Bangladesh, is responsible for mobilising external resources, including climate finance, for the country's socioeconomic development.

6.13 Priority Areas for Climate Change Adaptation

121. Considering the vulnerabilities, the Government of Bangladesh has identified the following areas of intervention to address the adverse impacts of climate change.

Key areas of intervention to address adverse impacts of climate change	
1	Food security, livelihood and health protection (including water security)
2	Comprehensive disaster management
3	Coastal zone management, including salinity intrusion control
4	Flood control and erosion protection
5	Building climate-resilient infrastructure
6	Increased rural electrification
7	Enhanced urban resilience
8	Increasing resilience of vulnerable groups
9	Development of climate-resilient cropping systems
10	Development of surveillance systems for existing and new disease risks
11	Ecosystem-based adaptation (including forestry co-management)
12	Community-based conservation of wetlands and coastal areas
13	Implementing drinking water and sanitation programmes in areas (e.g., coastal areas, flood- and drought-prone areas) move at risk from climate change
14	Policy and institutional capacity building

122. Based on the above-mentioned areas, the following adaptation actions are prioritized for Bangladesh.

Adaptation priorities for Bangladesh	
1	Improved Early warning system for a tropical cyclone, flood, flash flood and drought
2	Disaster preparedness and construction of flood and cyclone shelters
3	Protection against tropical cyclones and storm surge
4	Inland monsoon flood-proofing and protection
5	Climate-resilient infrastructure and communication
6	Climate-resilient housing
7	Repair and rehabilitate existing infrastructure (including coastal embankments, river embankments and drainage systems, urban drainage systems)
8	Plan, design and construction of urgently needed new infrastructure (various types of shelters, low cost disaster resilient housing, protection schemes, water management structures, etc.)
9	Improvement of urban resilience through the improvement of the drainage system to address urban flooding
10	River training and dredging (including excavation of water bodies, canals and drains)
11	Development and dissemination of stress-tolerant (salinity, drought and flood) varieties of rice; improved varieties of livestock and fisheries
12	Research and knowledge management
13	Adaptation based on local-level perspectives
14	Adaptation to climate change impacts on health
15	Biodiversity and ecosystem conservation
16	Capacity building at an individual and institutional level to plan and implement adaptation programmes and projects in Bangladesh

7 PAST AND ONGOING EFFORTS TO IMPROVE THE RESILIENCE OF LIVELIHOODS AND CLIMATE-RESILIENT HOMESTEAD

123. This section provides an overview of climate change-related projects governed by the GOB and national and international organizations working in the country. There are many projects and development activities that have been conducted for several decades that might be directly or indirectly linked with climate change. For example,-older construction, embankment construction, Fourth Fisheries project, SUNDARI, RECALL, RVCC project, etc. The Climate Change Trust Fund has been funding more than 850 projects throughout the country. Bangladesh has spent 10 billion dollars over the last fifty years to tackle natural disasters mostly related to climate change. It is unrealistic to review the positive and negative impacts of those investments. However, GCF has recently financed five projects in the country. Besides, the Foreign, Commonwealth & Development Office (FCDO) and EU are financing the Pathways to Prosperity for the Extremely Poor People (PPEPP) project focusing on climate hotspot areas of the country. This section summarizes mainly these ongoing projects along with some recently completed projects.

7.1 GCF financed ongoing projects

7.1.1 Climate Resilient Infrastructure Mainstreaming (CRIM) project

124. This is the first GCF-financed project in Bangladesh. KfW is the accredited entity, and the Local Government Engineering Department (LGED) is the project's Executing Entity (EE). The estimated budget is USD 80 million, of which GCF contributes USD 40 million as a grant. The project has been implemented in Satkhira, Barguna, and Bhola districts. The project has three intervention areas, i.e., a) Institutional Development, b) Pilot Climate Resilient Rural Infrastructure, and c) Pilot Climate Resilient Urban Infrastructure. The project will enhance the capacity of LGED for addressing climate change in the infrastructure sector of the country by establishing the "Climate Resilient Local Infrastructure Centre ("CReLIC")" in the organization under the first intervention area a. Under intervention b, it will build 45 new multipurpose community cyclone shelters with innovative designs in climate change aspects and rehabilitate 20 existing shelters to a climate-proof standard in the three project districts (Districts Bhola, Barguna and Satkhira). Under intervention area c, the project will improve drainage, flood protection, sanitation, water supply, and transport infrastructure, with priority given to the most vulnerable such as the inhabitants of the city slums of Satkhira Pouroshova (municipality). The CRIM and RHL geographically overlap in three districts, but there is no overlap in project activities. Instead, these two projects will complement each other. For example, the CRIM project will increase the capacity of government organisations, whereas the RHL project will increase the capacity of non-government organisations.

125. Similarly, the CRIM project will focus mainly on urban infrastructure, except for some community-based cyclone shelters, whereas the RHL project will focus on rural livelihood and homestead development activities. Most importantly, the CRIM project will develop resilient community infrastructure, whereas the RHL project will increase the resilience of individuals. To avoid duplication of resources, the RHL will additionally conduct formal and informal consultations with the CRIM to select the project sites and beneficiaries. In addition, the project will review the training manuals of the CRIM project while preparing the guidelines and training manual for this project.

7.1.2 Enhancing adaptive capacities of coastal communities, especially women, to cope with Climate change-induced salinity.

126. The GCF has financed the UNDP Bangladesh to enhance the capacity of coastal communities, especially women, to cope with Climate change-induced salinity. The total project

budget is USD 33 million, of which the GCF grant is USD 25 million, and the Ministry of Women and Children Affairs contributes USD 8 million. The project will assist 39,000 women and girls in Satkhira and Khulna to adopt resilient livelihoods while ensuring reliable, safe drinking water for 130,000 people through community-managed rainwater harvesting solutions. It will also seek to strengthen the participation of women in last-mile dissemination of gender-responsive early warnings and continued monitoring and adaptation of livelihoods to evolving climate risks. The UNDPs project implements salinity-resilient livelihoods for vulnerable people in both off-farm and on-farm sectors. In contrast, the RHL will intervene only in the on-farm sector, specifically crab farming and goat/sheep rearing. In addition, the RHL will develop climate-resilient homesteads for vulnerable people living in low-lying areas. Moreover, the UNDP project will promote crab fattening, which is mainly nature-based. The RHL project will support the crab fattening activity by supplying hatchery-produced crab-lets. On the contrary, the UNDP project will promote hydroponic fodder. The RHL project will use this fodder for goats/sheep to be raised under this project. Thus, these two projects will complement each other. The two districts are expected to overlap, but measures will be taken to avoid activity overlap and for complementarity of the two projects.

7.1.3 Extended Community Climate Change Project- Flood (ECCCP-Flood)

127. The GCF-financed project is to support the increased resilience of flood-vulnerable communities in the country's northern region. It is a four-year project having a total budget of USD 13.68 million, of which GCF grant contribution is 9.32 million US dollar. The project covers the riverine char areas of Jamalpur, Gaibandha, Kurigram, Lalmonirhat, and Nilphamari districts. Major project activities include raising homestead plinths, provision of safe water and sanitation, flood-adaptive crop production, and goat/sheep rearing in slatted houses. While some activities are similar, the ECCCP will cover the Brahmaputra-Teesta basin in the North, and RHL will support coastal areas in the South.

7.1.4 Bangladesh Climate Change Trust Fund

128. The government has established the **Bangladesh Climate Change Trust Fund (BCCTF)** and allocated 400 million US dollar to implement various adaptation projects that include the construction of embankments and river bank protective work, building resilient cyclone shelters, excavation/re-excavation of canals, construction of water control infrastructures including regulators/sluice gates, waste management and drainage infrastructure, introduction and dissemination of stress-tolerant crop varieties and seeds, afforestation, installation of solar panels. In particular, the project has allocated BDT 40.0 million in Khulna and BDT 170.7 million in Satkhira for housing and rehabilitation of cyclone-affected people; BDT 4.0 million in Satkhira for rainwater harvesting infrastructure, another BDT10 million for housing and Pond Sand Filter construction support in Satkhira Upazila. Although these activities are closely related to this proposed project, the shelters constructed under this project are mainly community-based cyclone shelters, whereas the proposed project will implement resilient housing for individual households with raised homesteads.

7.1.5 Bangladesh Climate Change Resilience Fund

129. The government has also established and implemented Bangladesh Climate Change Resilience Fund (BCCRF). Most of the projects under BCCRF are related to improving climate-resilient livelihoods through agricultural interventions, i.e., promoting stress-tolerant crop varieties, cyclone shelter reconstruction, reconstruction of dams, etc. In addition to these funds, the government has been implementing the Pilot Program for Climate Resilience (PPCR), the Strategic Programme for Climate Resilience (SPCR) fund, the Coastal Embankment Improvement Project, the Coastal Climate-resilient Infrastructure Project, the Coastal Towns Environmental Infrastructure Project, the Climate-resilient Agriculture and Food Security, Feasibility Study on Climate-resilient Housing for Low-Income Communities and Climate

Change Capacity Building and Knowledge Management projects and Least Development Countries Fund (LDCF) for implementing adaptation activities including resilient livelihoods, construction and reconstruction of embankments, safe drinking water, and afforestation, etc.

7.1.6 The Global Environment Facility (GEF)

130. The GEF supported 'Building climate resilient livelihoods in vulnerable landscapes in Bangladesh (BCRL)' to improve the resilience of people, communities, and ecosystems to climate change and improve livelihoods through increased value addition in agricultural food systems. The BCRL is a landscape-based and action research type project. The BCRL project will develop climate-resilient high-value crop advisories in collaboration with DAE's Bangladesh Agro-meteorological Information System Development (AMISDP) Project and disseminate the advisories using the same system adopted by AMISDP. It will also help improve the overall effectiveness of the advisories through process evaluation surveys of end-users, which will seek feedback on the understandability, timeliness, relevance, etc., of information provided (activity supported by project budget, Climate Smart Agriculture Expert along with DAE Deputy Project Director and Project Implementation Coordinator). The project has been implemented in three landscape areas: coastal zone, hill tracts, and Barind tracts. Regarding geographical coverage, the BCRL and the RHL are coherent, i.e., two districts such as Khulna and Satkhira districts, are common. The complementarity of these two projects is that the BCRL project focused on the crop sector, whereas the RHL project focused on the fisheries and livestock sector. In addition, the RHL project will introduce climate-resilient homesteads for poor and vulnerable communities. In the future, a project like BCRL will have opportunities to incorporate the resilient house for the farmers. So, the RHL project will complement this BCRL project regarding climate-resilient homesteads for the farmers and promote climate-adaptive aquaculture, i.e., crab farming, which is one of the important sub-sectors of agriculture to avoid duplication. In addition, a coordination mechanism has already existed at the central level, which is the Technical Advisory Committee (TAC) of the NDA (Economic Relations Division under the Ministry of Finance) to the GCF. The proposed project has already been presented to the TAC, and they received No Objection to incorporating its comments and suggestions. Again, the project will coordinate with the Department of Environment (DoE), which is the Executing Entity of the BCRL project, so that these projects complement each other rather than overlap.

7.1.7 The Adaptation Fund (AF)

131. The AF approved the 'Adaptation Initiative for Climate Vulnerable Offshore Small Islands and Riverine Charland in Bangladesh in 2019'. The United Nations Development Programme (UNDP) is the implementing entity, and the Department of Environment (DOE) of the Ministry of Environment, Forests and Climate Change (MOEFCC) is the executing entity. The AF grant amount is US$9,995,369. The project is being implemented in Rangpur and Bhola districts. Of these, only one upazila within the Bhola district is where the AF's project and RHL will have potential activity overlap - homestead. To avoid it, the RHL will collaborate with representatives of the AF project, DOE, and UNDP in the site selection process and promote the knowledge and lessons sharing with the AF project for higher effectiveness and efficiency.

7.2 Other Projects of PKSF

7.2.1 Crab hatchery-PKSF

132. After successful experimentation with crab hatcheries, PKSF established four small-scale hatcheries. Three of them are at the entrepreneur level. All these hatcheries are in operation. A total of 0.66 million US dollar was invested in hatchery development. In addition, PKSF has been promoting crab farming and has invested about 2.15 million US dollar so far to transfer this now-proven adaptive technology. The RHL project will scale PKSF's existing efforts to promote pro-saline livelihood options for vulnerable coastal people.

7.2.2 World Bank Project for the national housing market

133. PKSF has been implementing the World Bank-funded LICHSP to improve the living conditions of the low-income community in selected municipalities and city corporations since 20 October 2016. As of September 2022, PKSF, through its seven Partner Organizations (POs), has disbursed a total of about 24.40 million US dollar as a loan to 11,641 borrowers for the construction of new houses and extension or repair of existing ones in 13 towns under 'Shelter Lending & Support' component of this project. This project focused on urban and semi-urban areas, whereas the RHL project will focus on rural housing, arguably more vulnerable and communities less able to afford them. The Beneficiaries under the LICHSP are medium to low-income category and not necessarily climate-vulnerable people. However, the LICHSP has developed a guideline for implementing housing activities for the medium to the low-income group, which will help the RHL project to prepare a guideline for building climate-resilient homesteads. PKSF's experience building or repairing houses will also be useful for implementing the RHL project.

7.3 Past Projects

7.3.1 Community Climate Change Project (CCCP)

134. To enhance the resilience of the climate-vulnerable community, PKSF has applied CCCP with financial support from Bangladesh Climate Change Resilience Fund (BCCRF). The size of total funding from BCCRF was 13 million US dollar, and the duration was four years (2012 to 2016). The project targeted the zones where three notable hazards are prominent, i.e., flood, drought, and salinity. The project transferred technical availability in households, livelihood, and water & sanitation sectors. The proposed project is designed based on the experience of the project. The best practices of the CCCP are chosen for the proposed project. For example, crab farming, homestead plinth raise, sheep rearing in slatted houses, rainwater harvesting, etc. These activities have visible positive impacts in the project areas. Still, many of the interventions are being continued by the community.

7.3.2 Pilot Programme for Climate Resilience (PPCR)

135. During October 2010, “piloting” adaptation activities in climate-vulnerable areas through the Pilot Programme for Climate Resilience (PPCR) were carried out in Bangladesh with 110 million US dollar in financial support from multilateral development banks, where 50 million US dollar was a grant and 60 million US dollar was provided as a concessional loan. A substantial portion of this fund is made available to the existing major investment projects, which have also been supported by the loan components. Asian Development Bank (ADB) is the leading agency that, along with the World Bank and IFC, is handling the responsibility of different components. Implementation of PPRC aimed to a) Strengthened resilience of coastal infrastructures, e.g. housing, road transportation, improved water supply, drainage provision, sanitation, better drainage facility within the polder etc. in order to resist the Climate change-induced effects like the occurrence of natural hazards; b) Improvement in the fisheries and farming activities through the reduction of water and soil salinity; and c) Enhanced capacity of MoEFCC to operate and coordinate investments in and knowledge on climate-resilient initiatives.

136. PPCR assumed that the embankments and strong rural roads could reduce the ingress of seawater. However, there is no indication of salinity reduction due to the impact lag period required, as the scenario predicts that sea level will continue to rise and salinity will increase.

137. A significant number of preparatory meetings and a stakeholder consultation workshop have been taken place on Climate Investment Funds (CIF). The discussions have led to the identification of four thematic areas, which overall "support one of the country's top priorities: protecting people and land in low-lying coastal regions." The four thematic areas are: a) Encouraging climate-resilient agriculture and food security; b) Improvement of Coastal embankments and afforestation; c) Making the Coastal water supply and sanitation and

infrastructures as climate-resilient; d) Technical support, capacity development on climate change and knowledge management.

7.3.3 Strategic Programme for Climate Resilience (SPCR)

138. Among three climate funds (BCCTF, BCCRF, and SPCR), SPCR is one of the largest climate funds in Bangladesh, having a financial budget of USD 681.4 m. SPCR covers the twelve most vulnerable coastal areas, and it directly lends to GoB. For climate-resilient development, it founded a mechanism so that the private sector can be involved. The main structural components of SPCR comprise climate-smart agriculture technology, coastal protection through climate-proofing of coastal embankments and polders, rural infrastructure and greenbelt, water supply & sanitation, and improving livelihood.

Table 8: Key Strategic Programme for Climate Resilience (SPCR) Projects

Project	Total Amount of Funding	Duration	Key Focus
Coastal Embankment Improvement Project (Phase 1)	400.2 million US dollar	2013-2020	The areas that might experience frequent tidal flooding and storm surges due to climate change will be protected more by polders under this project. It also expects to facilitate agricultural production by lessening the saline water intrusion within polders. Funding would be gathered from a PPCR grant 25 million US dollar and 375 million US dollar IDA and credit with 0.2 million US dollar grant from GFDRR. The project's expected outcome includes dwindled impacts of cyclonic storm surges and wind damage through the upgradation of embankments and afforestation, besides improved farming activities through the reduction of salinity intrusion.
Coastal Climate-resilient Infrastructure Project (formerly Climate-resilient Infrastructure Improvement in Coastal Zone Project)	150 million US dollar	2013-2018	The livelihoods of the people in climate-vulnerable rural coastal districts (including Khulna, Satkhira) will be improved by this project. Funding would be obtained as 30 million US dollar from PPCR (10 million US dollar grant and 20 million US dollar concessional loan), 20 million US dollar from ADB, 8.8 million US dollar from KfW, U60 million US dollar from IFAD, and 31.2 million US dollar from GoB. The project expects improved climate-resilient coastal infrastructure in 12 rural coastal districts that avail the poor and women, including enhanced climate change adaptation capacity.
Coastal Towns Environmental Infrastructure Project	117.1 million US dollar	2014-2020	The project intends to ensure climate-viable water supply, sanitation, drainage, and other municipal facilities to those climate-vulnerable coastal towns that are either deprived of or have limited access to basic urban services. Funding sources: PPCR is 40.4 million US dollar (30 million US dollar concessional loan and 10.4 million US dollar grant), ADB is 52 million US dollar, GoB is 23.1 million US dollar and BMGF is 1.6 million US dollar. Expected benefits of this project include but are not limited to making the municipal infrastructure climate-resilient and improving disaster readiness in eight vulnerable coastal Pourshavas; Strengthening institutional capacity, governance & public awareness, and key infrastructure investments include water supply. The investment will be lucrative for women and the poor in coastal municipalities (e.g., Amtoli, Golachipa, Pirojpur, Motbaria, Patuakhali, etc.).

Project	Total Amount of Funding	Duration	Key Focus
Climate-resilient Agriculture and Food Security	13.1 million US dollar		Funding would be gathered as 100,000 US dollar project preparation grant, 3 million US dollar advisory services, and 10 million US dollar concessional loan. Expected outcomes of the project include (i) an increase in the revenues of farmers & agribusiness firms by adopting sustainable climate-smart agriculture technologies & practices; (ii) Presenting a business model for climate-smart agriculture technologies, products, and services that can ameliorate productivity of cultivators and offer incentives for the private sector to invest in climate-smart agriculture-related products and services to ensure sustainable sourcing.
Feasibility Study on Climate-resilient Housing for Low-Income Communities	0.4 million US dollar		This project expects to have the following outcome: (i) Formulate a pilot program to build climate-resilient and personal household units in order to adjunct the existing cyclone shelters; (ii) Establish a sustainable business model to incite private sector involvement in the lower-income housing market; and (iii) pressure and dependency on the traditional cyclone shelters can be reduced through introducing safe and affordable shelter. Besides, the project also covers a study and training for chosen financial institutions and real estate developers.
Climate Change Capacity Building and Knowledge Management	0.6 million US dollar	2012-2014	The size funding is 0.6 million US dollar, where the PPCR grant is 0.5 million US dollar, and GoB provided 0.1 million US dollar. Tasks under this project include but are not limited to (i) a web-based network on climate change Information and Knowledge Management (CCIKM), (ii) production and dissemination of climate change adaptation information and knowledge products, (iii) increasing organizational strength concerning climate change adaptation and IKM.

7.3.4 Least Developed Countries Fund (LDCF)

139. With the assistance of LDCF, UNDP, and FAO, the Government of Bangladesh has been implementing priority NAPA projects. Through mobilizing the activities like horticulture, livestock, and forestry at the community level in the coastal zone, the UNDP projects have attained great success in promoting agricultural adaptation. These community-focused projects have let them work right away with the vulnerable people who are living in the coastal localities and offshore islands. An Adaptive Social Protection (ASP) approach assembles the elements of Climate Change Adaptation (CCA), Disaster Risk Reduction (DRR), and Social Protection (SP). The contribution of this project was realized when it received a UNFCCC Best Practices Award on Adaptation. See Table 9.

Table 9: LDCF projects in Bangladesh ongoing

LDCF Project title	Total project cost (USD million)	Year	GEF agency	Executing agencies

Integrating community-based adaptation in afforestation and reforestation program	47.834	2012	UNDP	Department of Forest, MoEFCC
Community-based climate-resilient fisheries and aquaculture development	21.240	NA	FAO	Department of Fisheries, MoFLS
Community-based adaptation to climate change through coastal afforestation	10.890	2008	UNDP	Department of Forest, MoEFCC

7.3.5 The Local Disaster Risk Reduction Fund (LDRRF)

140. Community Risk Assessments (CRA) are used by the Comprehensive Disaster Management Programme (CDMP) to successfully recognize Climate change-induced risks of vulnerable people; these are local-level climate change-sensitive (risk-informed) assessments. These assessments are then translated into Risk Reduction Action Plan (RRAP). However, the CRA and RRAP are not included by the LDPs in the comprehensive long-term development planning process. The Local Government Institutes focus on small schemes and projects emphasizing community-level Infrastructure development. Previous interventions and lessons learned also suggest that local government financing does not directly address the climate change adaptation needs of the most vulnerable households. So, to assist vulnerable women, a dedicated financial mechanism is needed to assist climate-resilient livelihoods.

7.3.6 Chars Livelihoods Programme (CLP)

141. Poor women in the river Islands are given Livelihood resilience support by the DFID[138]. In 2013 an impact review was done[139]. The review showed a positive impact on the status of women of the household, and while several women realized that they were consulted more during money expenditure-related decisions, virtually the degree of women's participation in decision-making on expenditure and loans were not changed. But the evidence was provided in terms of involvement in decision-making in qualitative terms in the same study. Some studies suggest a more positive picture, e.g., Oxfam suggests that livelihood grants exclusively targeted at women do not affect gender relationships at the household level.

142. It has been assessed that the males and females from core beneficiary households were satisfied, and intra-households were not affected negatively as the female member was selected. CLP has assessed this, and it also suggests that the harmony of the community did not provoke as the women have been the targeting criteria and processes. Women were insured with improved social mobility among the core beneficiary households, and within the community, improved interaction was insured.

7.3.7 The Rural Employment Opportunities for Public Assets (REOPA)

143. In order to benefit rural communities and improve public assets, and strengthen local government institutions' capacities for better management of social safety nets and pro-poor initiatives, employment opportunities were created for destitute women and landless poor by the project. REOPA has created a well-designed graduation policy. It is also known for its transparent fund management, balancing correct targeting, and for effective engagement of disadvantaged women. The project policy comprises of skills development training, and livelihoods, investment capital gathering for microenterprises, access to service delivery sectors, mobilization of social capital, and customized backing for practical livelihood actions.

8 SELECTION OF ADAPTATION OPTIONS

144. As per the assessments of vulnerabilities to and impacts of climate change in coastal areas of Bangladesh in section 3, agriculture-based livelihoods (including crops, fisheries, livestock, etc.), drinking water, and housing/shelter are the most vulnerable sector to climate change. Hence, the proposed project prioritizes these sectors while selecting the adaptation options. The study also found that safe drinking water and sanitation are highly vulnerable to climate change in this area. Water supply and sanitation are incorporated into the concept of housing under the project. The feasibility study has conducted consultation meetings at national and local levels to understand the adaptation needs and priorities in the southwest coastal region of the country. The consultation meetings focused on sector-specific vulnerabilities and adaptation responses. In addition to consultation meetings, the study reviewed past and ongoing projects related to climate change, particularly that of the southwest coastal area. Through these exercises, the study has identified the following adaptation interventions:

8.1 Adaptation interventions related to resilient livelihoods

145. The coastal community, particularly poor and vulnerable people, depend on fragile agricultural activities and natural resource collection from the Sundarban and Bay of Bengal. They saline tolerant crop varieties (applicable for low salinity affected areas typically less than 10 ppm), shrimp farming, honey collection, crab collection, timber collection, and fish collection activities. In addition to these, there are some emerging livelihood practices that may be effective adaptation activities for the coastal zone. Homestead gardening, hydroponics, aqua-geoponics, sesame cultivation, plant nursery, crab farm/fattening, crab nursery, crab feed processing, crab hatchery etc. The following table presents the climate resiliency of existing and potential livelihood interventions in the coastal areas of the country, including the southwest coastal zone:

Table 10: Assessment of climate-resilient livelihood options

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
Paddy cultivation (Aman)	Moderate level of salinity tolerant rice variety; can withstand at a salinity level up to 8 ds.m-1 (equivalent to 5.12 ppm)	Intrusion of saline water caused by the cyclone and tidal surge may hamper productivity in the context of the high level of salinity	estimated annual yield loss of traditional rice up to 35 percent in the context of saline water intrusion[140] . Changes in crop cultivation suitability and associated agriculture biodiversity, decrease in input use efficiency, and prevalence of pests and diseases are some of the major impacts of climate change on agriculture[141].	Though salinity level reduces during Aman season, tidal surge and coastal flooding pose a high risk to this crop, particularly with 10 km of coastline. So, this project discourages this livelihood option.
Maize cultivation	Maize is sensitive to salinity. Its economic losses	Maize is vulnerable to cyclone-induced	Estimated impacts of both observed and projected	Cannot be considered as a climate change

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
	start above 2.7 ds.m-1and yield decreases by about 10% at EC 3.7 ds.m-1, 25% at 7 ds.m-1[142].	tidal surge of salt and freshwater. Further, direct wind impacts on maize can be severe	climate change impacts on cereal crop yields in different regions indicate that yield losses can be up to 60% for maize, depending on the location.	resilient livelihood option due to dependency on freshwater irrigation and low profitability.
Sesame seed oil	Some sesame cultivars are tolerant to salinity stress up to EC 6 ds.m-1[143].	Vulnerable to cyclone and extreme storm winds	Like maize, sesame is relatively salinity tolerant. But the areas where salinity is more than 6 ds.m-1, cannot be grown	Cannot be considered because this project will be implemented in highly salinity affected areas.
Homestead tree plantation	Sensitivity to the saltwater of trees depends on the species. Species such as *Acacia auriculiformis*, *Acacia hybrid*, *Achras sapota*, *Casuarina equisetifolia*, *Leucaena leucocephala* and *Tamarindus indica* etc. are moderately salt tolerant. According to farmers' experience, coconut, velvety apple and date palm are high salt-tolerant species (12-16 6 ds.m-1)[144].	Low risk of flooding, resilient to cyclonic storm	The irrigation needs of fruit trees differ between species, but only those species with low irrigation needs will be considered for the livelihood interventions.	Can be considered as climate change resilient livelihood option as well as protecting houses from storm.
Vermi composting	The process of vermicomposting is dependent on input materials. No evidence could be identified to show whether increased soil salinity will affect plants that are used for the process of vermicomposting. Secondary salinity	Depending on location of vermicomposting, flood risk and vulnerability towards extreme winds can be considered low	The key input of vermicomposting is earthworms which require specific soil conditions. Saline soil can negatively impact the effectiveness of the earthworm and reduce the quality and usability of produced fertilizers. The	Cannot be considered as a climate change resilient livelihood option.

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
	induced by the application of organic fertilizers is not considered particularly worrying. However, that the increase or decrease in the concentration of determined ion in the soil depended on its concentration in the compost, the application rate, the removal of the crops and to leaching.		nitrogen transfer by the earthworms in the compost fertilizers is hindered due to saline soil.	
Aqua-geoponics (Haque et al. (2015)[145]	The technology itself will function with some levels of saline water. The salt resilience of cultivated plants varies by species. Some moderately saline tolerant vegetables which can be used include BARI tomato (4.1-86 $ds.m^{-}1$)[146], spinach (<6 $ds.m^{-}1$)[147]. These vegetables can be paired with brackish water fish species to utilize the aquaponics approach.	Low risk of cyclone induced flooding. Extreme winds could be a threat to the system.	The climate change resilience of aqua-geoponics can be assumed to be high, as it is a technology solution that can adjust its production to varying salinity levels and available through the selection of plants and fish species and structure of technology.	Cannot be considered due to extreme storm wind
Hydroponics cultivation	The technology itself can be set up on land or as a floating garden. Both options can deal with some levels of salinity, whereas the resilience depends on the selected plant species.	Low risk of cyclone induced flooding. The extreme wind could be a threat	The climate change resilience of aqua-geoponics can be assumed to be high, as it is a technology solution that can adjust its production to varying salinity levels and available through the selection of plants and fish species and	Cannot be considered due to extreme storm wind

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
			structure of technology.	
Homestead gardening	Resilience depends on the species grown. Tomato, for example, is moderately sensitive to salinity. Its economic losses start above 25 $ds.m^{-1}$. Its economic losses start above 25 ds.m-1 and yields decrease about 10 percent at 3.5 $ds.m^{-1}$, 25 percent at 5 $ds.m^{-1}$ and 50percentat 7 $ds.m^{-1}$	Low risk of flooding by tide and cyclone if the proper drainage system is installed	Unseasonal rainfall may have serious negative impacts on vegetables. Irrigation requirements depend on the plants, which should be selected according to water quality and availability	Can be considered as climate-resilient livelihood
Shrimp farming in own, rented or community pond	Salt water shrimp aquaculture is resilient against increasing salinity. However, shrimp farming exacerbates the rate of salinization due to leaks in tanks, spills and seasonal release of highly saline water into surrounding agricultural lands[148].	Cyclone-induced surge overtop shrimp farms leading to losses of stock. Ponds are quite resilient against extreme winds.	This is an adaptive livelihood option. However, it presents risks associated with its propensity to increase salt deposits. The surrounding soil where shrimp enclosures are set up collect salt deposits and agricultural cultivation is hampered.	Cannot be considered as a potential option due to maladaptive consequences of exacerbating the rate of salinization.
Crab farming	Saline tolerant up to 40 ppt. depending on the species[149].	May be affected by cyclone-induced inundations and/or seasonal water-logging i.e. the ponds flood and crabs escape[150]. Relatively resilient against extreme winds. *Mitigation measure: In order to reduce losses from inundation, embankments can be built and*	This activity must be carefully managed to ensure that crab seedlings are not obtained from the wild, affecting wild stocks. No additional freshwater will be needed to pursue this livelihood, as crabs can be raised in brackish to highly saline ponds. Crab farming should	Can be considered as a climate change resilient livelihood option due to relative high salt resilience.

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
		avoiding one production cycle can reduce the seasonal cyclone risk.	avoid the pitfalls of shrimp farming in terms of seasonal release of highly saline water into surrounding agriculture land by only being practised in tidal zones that are inundated with brackish water.	
Crablet catching from river and Sundarban	Saline tolerant up to 40 ppt., optimal salinity depends on the species . Due to saline habitat and the largest mangrove Sundarbans close to the region, collection of young crabs and nurturing in separate ponds is an increasingly preferred option for income generation.	Cyclone can damage fishing equipment or prevent people from being able to safely pursue this livelihood.	Extracting large amounts of crab-lets from natural waters has severe negative impacts on aquatic ecosystems and their biodiversity. Thus, it is considered a maladaptive livelihood option.	Cannot be considered as a climate change resilient livelihood option
Crab and fish feed processing	The processing of crab and fish feed and trading will not be directly impacted by increasing salinity or tidal surge	Depending on the building structure of the processing facility or work place, the livelihood can be cyclone and flood resilient.	Crab and fish feed processing will face few climate-induced constraints if inputs are available. However, if crab and fish feed inputs depend on fish fingerlings and by –catch from fishing in natural waters, then producing feed can have serious impacts on the aquatic ecosystem.	Cannot be considered as climate-resilient livelihood
Crablet production in micro crab hatcheries	Saline tolerant up to 40 ppt. It is a pro-salinity livelihood option	Cyclone and storm surge may affect the building of hatcheries. Mitigation measure: Cyclone and tidal surge height will be	It will protect the natural stock of crab and crablets and improve the ecosystem	Can be considered as climate-resilient livelihood

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
		considered during the hatchery establishment.		
Crab nursery	Saline tolerant up to 40 ppt. It is a pro-salinity livelihood option	Cyclone and storm surge may affect the building of hatcheries. Coastal flooding may inundate nursery ponds. Mitigation measure: Cyclone and tidal surge height will be considered during hatchery establishment. Nursery pond dykes will be raised above flood level.	It will protect the natural stock of crab and crablets and improve the ecosystem	Can be considered as climate-resilient livelihood
Brackish water fish farming and trading	Salinity resiliency depends on the species ranging from 7 ppt to 12 ppt.	Cyclone and intensive rainfall-induced coastal flooding is the main threat to fish farming.	Brackish water fish seedlings can be obtained from existing local markets. A semi-intensive or extensive system would have greater climate change resilience in the form of technology and management. No additional fresh water will be needed to pursue this livelihood since brackish water fish can be raised in brackish to highly saline ponds.	Though this activity seems climate-resilient, the local people themselves do this practice. So, this project will not consider this activity.
Fishing in natural water (sea, rivers, channels) for trade	Increased salinity and change in water quality can instigate a change in species composition and distribution, especially in coastal areas. There will be a clear change in the	Cyclone can damage boats and fishing equipment. Frequent early warnings cause losses of investment of the fish catchers	This is primarily a maladaptive approach. Fishing from natural sources would result in overfishing and reduction of natural fish stock. Overfishing, though profitable in	Cannot be considered as a climate-resilient livelihood option

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
	seasonal abundance of individual fish species. There is an observed trend of decreasing fish stocks due to increasing salinity in southwest Bangladesh.		the short run, would worsen the ecosystem by reducing natural sources and thus would be an unsustainable livelihood option. Further, fishing is a high-risk livelihood activity due to the fugitive nature of the resource, the hostile environment of the seas, and perishability of the product[151].	
Poultry and duck rearing	Poultry and duck are not resilient to salinity and could be affected by increasing salinity	Cyclone-induced storm and inundation can reduce the availability of duck and poultry shelter.	Scarcity of scavenging feed and inadequate knowledge are the main constraints that reduce potential poultry and duck rearing	Cannot be considered as a climate-resilient livelihood option
Goat/Sheep rearing in slatted house	Goat/Sheep can tolerate higher salt concentrations than other livestock (13000 in milligrams per litre) but sudden changes to more saline water may cause lowered production because goat/sheep may not drink more saline water immediately. Salt resilient Samna grass can be used as feed.	Cyclone-induced inundations can reduce the availability of dry spaces from rearing goat/sheep. Vulnerable to extreme winds. *Mitigation: Strom resilient slatted houses will be built.*	High tolerance to salinity and resilience to lower intake of feed and water makes goat/sheep more resilient than any other livestock. An adult goat/sheep can survive with 2-6 litres of water per day.	Can be considered as climate-resilient livelihood option
Mat making	The input products for mat making, a plant called Mele, is not overly resilient to salinity. It has been found that it can germinate up to 217 mM of Na^{+}(ca, 5% Nacl). A	Cyclone induced inundation can destroy Mele- the input for mat making	Reduced availability of input materials, due to climate change impacts, can reduce the sustainability of mat making as a livelihood option.	Cannot be considered as a potential climate change resilient livelihood option due to the unavailability of

Livelihood options	Salinity tolerance	Cyclone risks	Climate change resilience	Comments
	significant weight decrease was found in seedlings at salinities between 25 to 50 mM NaCl (ca. 3%) but no leaf wilting or death[152].			input materials.
Handicrafts	The activity of handicraft production will not directly be impacted from increasing salinity levels. However, the reduced availability due to salinity will reduce the feasibility of the activity.	Depending on the building structure of the workplace and input storage space, the production can be cyclone and flood resilient.	Heavily dependent on natural resource base, for example, agricultural products like straw or coconut shells. Coconut has reportedly been affected by more frequent cyclones. If the natural resource base is threatened, the existence of the handicrafts also remains under threat.	Cannot be recommended as climate change resilient livelihood option
Wood and *gol pata* collection from Sundarban	High salinity tolerant	Frequently affected by cyclone	Risk of overexploitation, destroy ecosystem, risk of the collector to be affected by wild animal	Cannot be considered as climate change resilient livelihood option
Honey collection from Sundarban	Do not have a direct impact of salinity	Cyclone and extreme storm may affect bee comb	Risk of overexploitation, destroy ecosystem, risk of collector to be affected by wild animal	Cannot be considered as climate change resilient livelihood option

8.2 Selected livelihood options

146. Based on the analysis, the project selected the following livelihood interventions:

- Development of crab hatcheries
- Technical and financial support for crab nursers
- Training and technical support to crab farmers
- Construction of slatted houses for goat/sheep rearing
- Introduce the cultivation of saline-tolerant vegetables within homestead areas
- Homestead tree planting

8.2.1 Development of crab hatcheries

147. The feasibility study by CECD. pointed out three types of hatcheries considering size and capacity. These are a) Micro household or small-scale crab hatchery farm model, b) Medium-scale crab hatchery farm, and c) Large scale Crab hatchery model. The first hatchery in Satkhira in category b is currently being used as a resource center for crab hatchery and farming. PKSF has also established three enterprise hatcheries, a category a. This project will promote category a, i.e., small-scale crab hatchery model. The details of the hatchery are presented below:

148. **Machinery and equipment**: The micro hatchery will require a centrifugal pump with 5 cm diameter of the suction pipe for pumping water from the sea, a pump for transferring water from the tank to the tank inside the hatchery, blower roots for oxygen circulation, 2 pieces (suction and deliver) pipes of 5 cm diameter, stand by a generator of 10 KVA and 5 KWT capacity, national grid electricity etc. 10 pieces of fiber tank having 300 liter water-bearing capacity, 20 plastic buckles for preserving mother crab, cartridge filter of 2.54 cm diameter for in and out, 50 cm long PVC materials for sea water pump, air supply line PVC of 5 cm diameter, 10 cm diameter of PVC pipe for internal drainage, water supply PVC pipe, control valve, air switch, air horse, air stone, lead weight, shed with concrete and tin, staff room and freeze for medicine etc. The micro hatchery will require 400-500 meter^2 of land.

149. **Construction:** The place for the hatchery establishment needs to have water availability of at least 28 ppt, or it should be riverside by which desired sea water can be collected from the sea. It should be situated by the roadside, and the land should be high so that the water drainage from the hatchery is easy. Also, it will be safe from floods or heavy rainfall. It should be constructed in a sunny area, it should not be in a crowded place, and not be by the side of agricultural land. It has to be in the area where the electricity supply is available.

150. An entrepreneur-level crab hatchery that has an estimated production capacity of 1,00,000 crablet per cycle should have had 6-8 larvae rearing tanks (5.68 ft x 5.68 ft x 4.87 ft), 2-4 treatment tanks (5.68 ft x 5.68 ft x 4.87 ft), 2 number of filter tank (4.6 ft x 4.6 ft x4.6 ft), 2 number of seawater treatment tank (16 ft x 13 ft x 4 ft), one overhead tank (5ft x 5 ft x 5 ft). The filter tank should be set up in a way that its bottom is at least one ft higher than the larvae-rearing tank. It will ensure a smooth flow of water from the filter tank to the larvae-rearing tank and treatment tanks. It is to be mentioned that larvae are rearing. The filtered water will be transferred to the larvae rearing tank for the Zoea rearing (day one larva) tank, treatment tank, and mother rearing space will be in one section of the brick house to maintain the optimum temperature. Water collected from the deep sea should be stored in the reserve tank. After that, seawater is treated with chlorine, then after dechlorination, water will be filtered by a filter tank.

151. An entrepreneur-level crab hatchery that has an estimated production capacity of 1,00,000 crablet per cycle should have had 6-8 larvae rearing tanks (5.68 ft x 5.68 ft x 4.87 ft), 2-4 treatment tanks (5.68 ft x 5.68 ft x 4.87 ft), 2 number of filter tank (4.6 ft x 4.6 ft x4.6 ft), 2 number of seawater treatment tank (16 ft x 13 ft x 4 ft), one overhead tank (5ft x 5 ft x 5 ft). The filter tank should be set up in a way that its bottom is at least 1 ft higher than the larvae-rearing tank. It will ensure a smooth flow of water from the filter tank to the larvae-rearing tank and treatment tanks. It is to be mentioned that the larvae rearing tank, treatment tank, and mother rearing space will be in one section of the brick house to maintain the optimum temperature. Water collected from the deep sea should be stored in the reserve tank. After that, seawater is treated with chlorine, then after dechlorination, water will be filtered by a filter tank. The filtered water will be transferred to the larvae rearing tank for Zoea rearing (day one larva).

152. Every larvae-rearing tank and treatment tank will be connected to a filter tank by a plastic pipe for a smooth supply of filtered water. All tanks in the section should have a connection with a blower for the continuous oxygen supply through a plastic pipe. For continuous oxygen

supply, the reserve tank needs to be connected to a blower machine. Every tank needs an electric light hanging from the ceiling in the middle of the tank for continuous light supply. A generator will be installed in the hatchery area for the uninterrupted power supply. For the observation of the zoea, there needs to have a microscope in the hatchery to diagnose the problems of the zoea. For waste water drainage and for the cleaning purpose, a systematic drainage will be constructed in and outside the hatchery.

153. For installing the Generator, storing different equipment, and other purposes, there will be a space outside of the hatchery section but not far away from the hatchery. There needs to have a living room if the hatchery is far away from the residence of the entrepreneur.The design of the proposed hatchery is presented below:

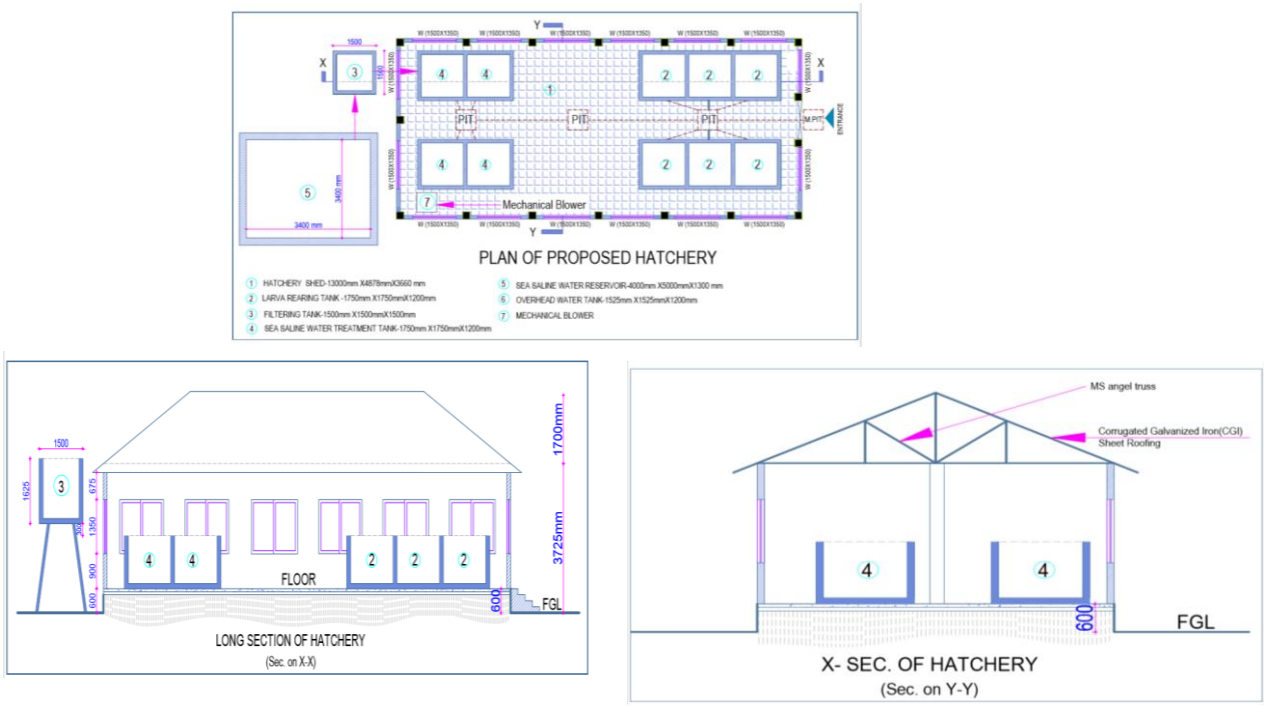


Figure 17: Design of Proposed Hatchery

154. The project will not consider large and medium scale hatchery because these hatcheries require big investment. As it is a comparatively new technology in the country, people may not feel reluctant to invest a big amount. With the success of the small-scale hatcheries at the enterprise level, the investors will be interested in the expansion of medium and large crab hatcheries.

8.2.2 Technical and financial support for crab nursers

155. Crab farming has emerged as a salinity-resistant livelihood and economic activity for the coastal people. Because crab farming requires salinity-environment. It is less affected by the disease. Its management cost is also low. So, crab farming should be an effective adaptation to climate change in the coastal zone. Currently, the coastal community is already fattening the crab. The sustainability of crab fattening as an alternative livelihood for poor farmers faces challenges due to the over-exploitation of the species from nature. The technological intervention will reduce the dependency of the crab farmers on nature. Hence, the project will implement available technologies that would make livelihoods sustainable in the long run.

8.2.3 Training and technical support to crab farmers

156. The project will engage an intermediary group between the hatchery owners and crab fatteners. The project termed this group as crab nursers. Some of them may also be involved in

crab fattening. The crab nursers will be provided necessary training along with financial support on transporting and nursing crab-lets. They will buy crablet from the hatchery and rear it for two months. At this stage, the crablets will be adolescents with 90 gm. weight and readable in the pond. The nurses will sell the adolescent crab to the fatteners.

8.3 Market Analysis of crab sub-sector

157. Crab fattening poses two coin-side opportunities for Bangladesh. It increases resilience by promoting pro-salinity means of livelihood, such as crab fattening in coastal regions where brackish water reduces normal crop productivity. On the other hand, it has a greater opportunity to earn foreign currency by grabbing more share of the crab export market.

158. In general, the economy in coastal regions is mostly coastal ecology-based and differs from that of any other ecological system. Globally in salinity-prone coastal regions, the means of livelihoods of local coastal communities are pro-salinity based. In those regions, salinity tolerant crop varieties and other sea-based plants are cultivated; brackish water-based crab, shrimp, lobster, and other seafood are fattened and captured.

159. Bangladesh has significantly large coastal areas in the southern part of the country. Salinity intrusion in that region is a common phenomenon, and it will exacerbate gradually when climate change-induced sea level will further rise. Such salinity intrusion has changed the coastal ecology, and further, the process of change will increase. In this changing context, the local community must adapt to the new ecological system. The reluctance to accept and/or failure to adapt to the newly evolved ecological system will cause reduced productivity of crops and other agro-based means of livelihood, hence lower income and low level of climate change resiliency.

160. Globally, crabs are traded in multiple forms; live, frozen, dried, cooked or steamed, etc. And it has a few varieties. One variety of crab is fattened or captured in some specific ecological zones. Bangladesh has an ecological advantage to fattening highly valued but low-supplied mud crabs.

8.3.1 World Trade of Crabs

Crab Import

161. The crab import market is concentrated as the two largest crab importers- the U.S.A. and China imported $1.2 billion and $0.76 billion, respectively, in 2017. The largest two importers have imported 55% of global crab imports. In 2017, 20 markets imported crab either live, frozen, dried, and cooked, or steamed. Table-11 ranks the top ten crab importer markets with respective values in the U.S. dollar and their global market share.

Table 11: Crab Import in 2017

Rank	*Destinations*	*Value ($)*	*Share (%)*
1	USA	1,214,416,012	34
2	China	761,263,099	21
3	Japan	531,205,001	15
4	Korea	431,704,946	12
5	Hong Kong, China	146,378,975	4
6	Canada	111,339,458	3
7	EU	89,864,023	2
8	Taiwan Province of China	71,898,000	2

9	Thailand	62,072,018	2
10	Singapore	60,930,520	2
Top Five Sum		3,084,968,033	86
Top Ten Sum		3,481,072,052	97
World		3,601,556,573	100

Trends of Crab Import

162. Top importing markets except Japan are increasing their import volume over time. Hence global crab import value is also increasing. Diagram-1 shows the trends of global and top ten importers of crab import over the time.

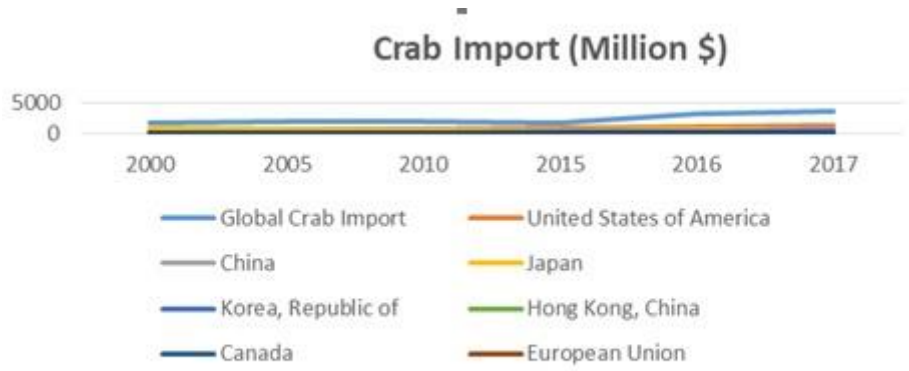


Figure 18: Global Crab Import

163. Globally crab import market is in a growing position. The largest importing markets, except Japan, have increased their crab import, and other (Table 11) importers' export values are in stable or in slightly changing positions.

Crab Export

164. Crabs are highly valued products in the global market, and it has a significantly large export market. In 2017, more than $3.6 billion crabs have been exported globally.

Table 12: Crab Export in 2017

Rank	*Destinations*	*Value ($)*	*Share (%)*
1	Russia	1,141,209,916	31.69
2	Canada	1,088,225,934	30.22
3	USA	259,755,993	7.21
4	China	232,101,691	6.44
5	Norway	104,186,394	2.89
6	Chile	69,476,169	1.93
7	Bangladesh	63,880,363	1.77
8	Indonesia	56,983,112	1.58
9	Korea	53,770,355	1.49
10	Philippines	46,850,080	1.30
Top Five Sum		2,825,479,928	78.45
Top Ten Sum		3,116,440,007	86.53

World	3,601,556,573	100

165. A total 42 markets have exported crab (one million US dollar and above valued) in 2017, Russia and Canada are the two largest crab exporters, and they exported 1.1 billion US dollar and one billion US dollar respectively. More than 60 percent of global crab export are exported from these two largest exporters. Hence, the global crab export market is highly concentrated. Annex-1 shows the top ten destinations of the top ten exporters. Excluding China from the top ten exporters, five of them have China as their number one export destination market.

8.3.2 Bangladesh's Crab Market

166. Bangladesh has a greater possibility to broaden crab fattening in coastal regions. Bangladesh has the potential to expand both the national and global markets.

Bangladesh's Crab Export Destinations

167. Bangladesh is the seventh-largest crab exporters. In 2017, Bangladesh exported around 64 million US dollar valued crab, either live or frozen, which is almost 1.77 percent of global crab export.

Table 13: Bangladesh Crab Export Destinations in 2017

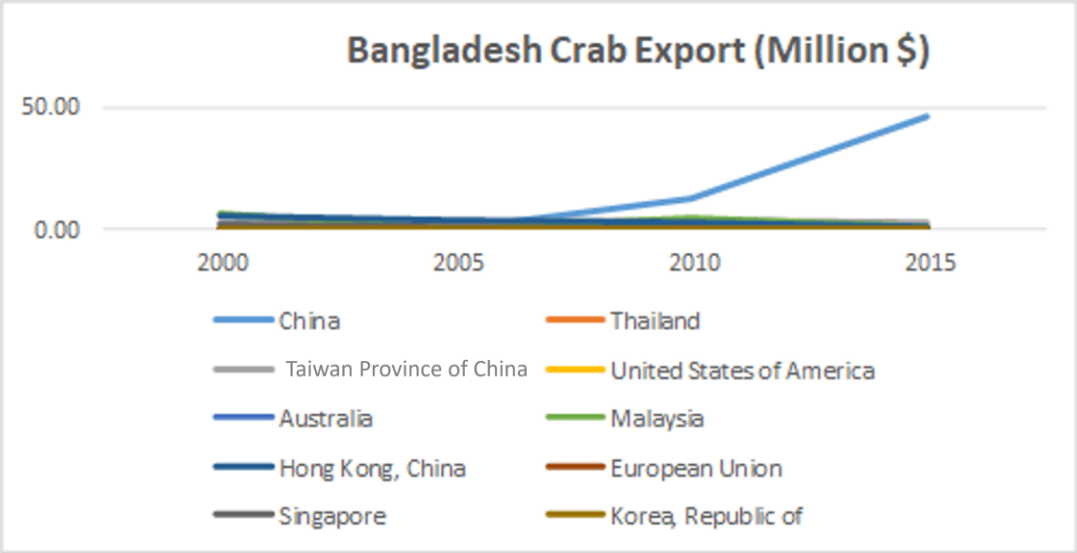
Rank	*Destination*	*Value ($)*	*Share (%)*
1	China	47,379,677	74.17
2	Thailand	10,620,553	16.63
3	Taiwan Province of China	1,524,700	2.39
4	United States of America	964,645	1.51
5	Australia	919,756	1.44
6	Malaysia	906,580	1.42
7	Hong Kong, China	700,466	1.10
8	European Union	587,196	0.92
9	Singapore	141,523	0.22
10	Korea, Republic of	85,008	0.13
Top 10 Sum		63,830,104	99.92
Top 5 Sum		61,409,331	96.13
BGD Total Crab Export		63,880,363	100

168. Table-13 ranks the top ten destination markets of Bangladesh's crab export. Three-fourths of crab export from Bangladesh are destined for China. The second-largest crab export destination of Bangladesh is Thailand. In 2017, Bangladesh's export of crab to China and Thailand was about $47.38 million and $10.62 million respectively.

Bangladesh Crab Export Trends

169. Over the year, crab export to the largest export partner, China, is increasing. Figure 18 reflects the trends of Bangladesh crab export to its' ten largest crab export destinations.

Figure 19: Bangladesh Crab Export



Market Share of Bangladesh in Its Top Ten Destinations

170. Bangladesh is doing well in four out of its top ten crab export destination economies. In Thailand, the second top destination, Bangladesh has the highest market share (17.11%) of Thailand's total crab import. China's fourth crab source economy is Bangladesh, which supplies around 6.22% of total crab import in the crab market in China. Bangladesh has secured the sixth position as the crab source economy in Australia and Malaysia. The market shares for these two economies are 6.24% and 4.65%, respectively.

Table 14: Crab Market Share of Bangladesh in Top Ten Crab Export Destinations in 2017

Rank	*Destination*	*Crab Import ($ Million)*	*From BGD ($ Million)*	*BGD Share (%)*	*BGD Position as Source economy*
1	China	761.26	47.38	6.22	4th
2	Thailand	62.07	10.62	17.11	1st
3	Taiwan Province of China	71.90	1.52	2.12	9th
4	United States of America	1214.42	0.96	0.08	17th
5	Australia	14.73	0.92	6.24	6th
6	Malaysia	19.48	0.91	4.65	6th
7	Hong Kong, China	146.38	0.70	0.48	17th
8	European Union	89.86	0.59	0.65	17th
9	Singapore	60.93	0.14	0.23	24th
10	Korea, Republic of	431.70	0.09	0.02	21st
Top 10 Sum			63.83		
Top 5 Sum			61.41		
BGD Total Crab Export			63.88		

Market Share of Bangladesh in Top Ten Crab Importers

171. Bangladesh lagged to grab a significant market share of the crab market in the top ten importers except for Thailand. It has further scope to grab more share by increasing export to those economies.

Table 15: Crab Market Share of Bangladesh in Top Ten Crab Importers in 2017					
Rank	*Destinations*	*Crab Import ($ Million)*	*From BGD ($ Million)*	*BGD Share (%)*	*BGD Position as Source economy*
1	USA	1,214.42	0.96	0.08	17th
2	China	761.26	47.38	6.22	4th
3	Japan	531.21	0	0	
4	Korea	431.70	0.09	0.02	21st
5	Hong Kong, China	146.38	0.70	0.48	17th
6	Canada	111.39	0	0	
7	EU	89.86	0.59	0.65	17th
8	Taiwan Province of China	71.90	1.52	2.12	9th
9	Thailand	62.07	10.62	17.11	1st
10	Singapore	60.93	0.14	0.23	24th
Top Five Sum		3,084.97			
Top Ten Sum		3,481.07			
World		3,601.56			

8.3.3 Crab Export Potentiality

172. Bangladesh has a greater potential to increase crab export. Many of the top ten crab importers are yet to explore significantly by Bangladeshi crab exporters. Bangladesh supplies almost none in the U.S. crab market, the largest crab importer, which imported around1.21 billion US dollar in 2017. Japan and Canada (it imports some types of crab such as mud crab) are untouched by Bangladeshi crab exporters.

173. Regular air, freight forwarding, and other forms of communication between any economy listed in the top ten crab importer categories, especially the South East Asian and European economies, and Bangladesh, pose a geographical advantage for Bangladesh to expand its crab export. Within a 10-hour air trip, Bangladeshi exporter can send their crabs either live, frozen, dried, or any other form in South East Asian and European economies. Frozen, dried, or any other forms except live crab can be transported at cheap transportation cost by overseas freight forwarding in all the economies.

8.3.4 Local Crab Market

174. In addition to export in the global market, demand for crab is flourishing in the local market also. Many of the urban restaurants regularly offer crab dishes to their customers. In coastal regions, crab dishes are popular with local farmers, consumers, and travelers. In 2017 about 360 metric tons of crab are consumed in the domestic market. There are many restaurants in the big cities like Dhaka, Chottogram, etc. serve crab and crab-made food which are not measured. The project will have a special activity for increasing crab demand nationwide so that the local market is also expanded.

8.3.5 Crab Production baseline

175. Over the year, crab production area and volume are increasing in Bangladesh. Before the 2015-16 fiscal year, crab production was calculated with the shrimp sub-sector, so solely crab production data before 2015 is not readily available. The yearbook of Agricultural Statistics, released by BBS, shows that 13160 metric tons , 14421 metric tons , and 11787 metric tons of crab were produced in the 2015-16, 2016-17, and 2017-18 fiscal years, respectively.

8.3.6 Crab market supply chain

176. Despite the high market price in Bangladesh's crab export destinations, the price of crab farmers got is still low. In Bangladesh, several intermediaries play a role in the process of crab collection from farmers to exporters. So, actual farmers get a small fraction of the crab price in a wholesale market in destinations. Besides, due to the absence of large-scale production and export, large-scale crab processing infrastructures are yet to be established. So, the cost of processing, including export and crab collection, is high. In June, crab price in Beijing wholesale market was US dollar 42 per kg, but farmers in Bangladesh get BDT 500 to 1000 (equivalent to around 6 to 12 US dollar).

177. Two types of crab are exported from Bangladesh. One is a live crab (hard shell), and the other is a soft shell crab. For live crab, the crab collectors collect different sizes of crab from nature and take it to the depot or sell it to the local middleman called *Faria*. There is an agent at the depot. The agent scrutinizes the crabs before buying from the collectors or *Farias*. The exportable size of crabs are packaged and sent to Dhaka (the capital city), and the non-exportable crabs are sold again to the farmers and the consumers. Here the central-level buyers re-grade and repackage before sending it to their international buyers. Crabs that are not exportable size are sold in the local market. For soft sell, the chain is a little different (Figure 20).

178. For soft shell crabs, local agents buy small crabs from collectors or hatcheries (minimum scale). These agents sell it to the large-scale farm holders, and the small farm holders buy crab from the collector directly. There is a processing plant in every farm who are involved with direct exporting of the soft shell as a frozen item. The farmers sell it to the processors after rearing. On the other hand, the collectors themselves rear crabs to produce soft shell crabs, and they also sell them to the processing plant. The processors do packaging and grading for export (Figure 21).

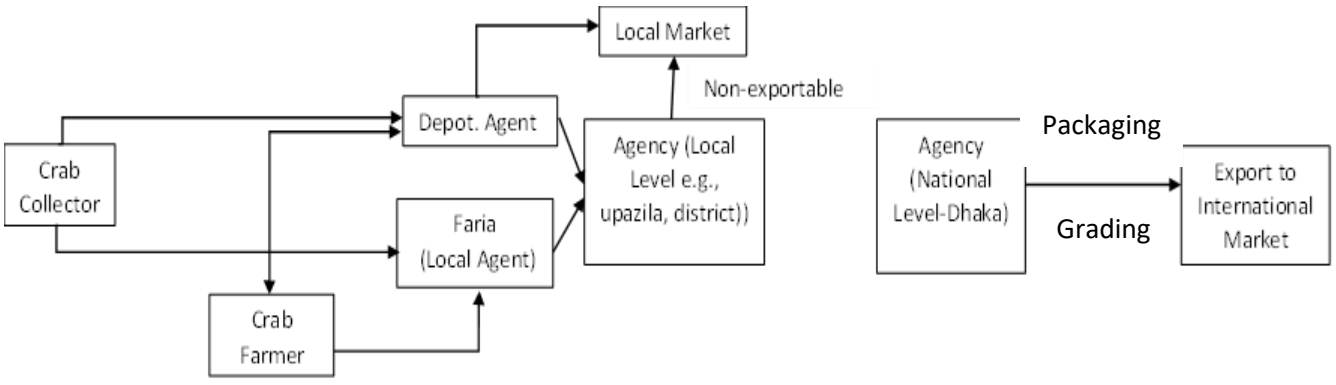


Figure 20: Value chain of live crab (hard shell crab)

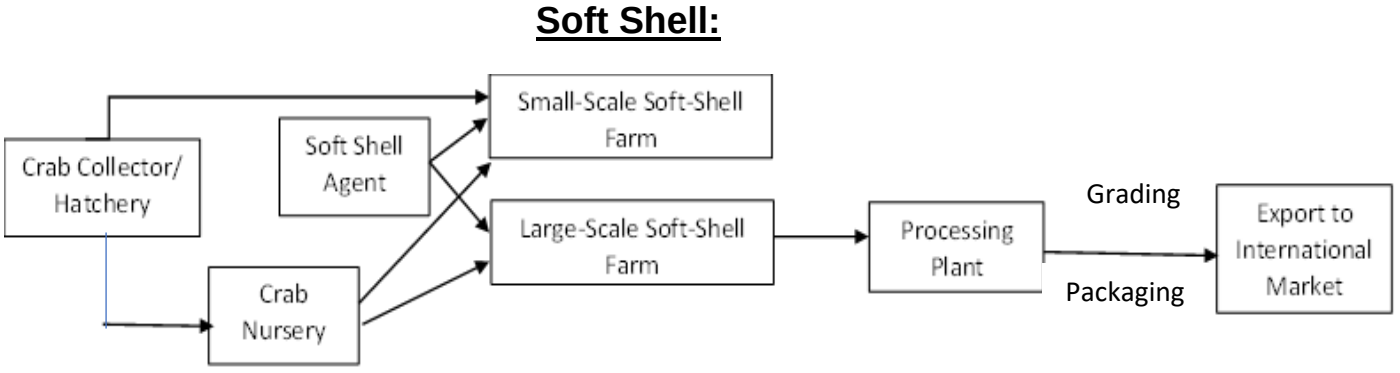


Figure 21: Value chain of soft-shell crab.

8.3.7 Challenge in Crab Sub-Sector Development

179. Despite huge market potential Bangladesh is lagging to widen its crab production. Yet, crab production depends on the capture of crablets from nature. But over-extraction of wild crablets disrupts ecological systems. Hence, crablets have been being scarce day by day.

180. The production of crabs is dependent on nature, so crab production volume is extremely uncertain in Bangladesh. That's why buyers lack faith in continuous supply, which reluctance buyers to place an order in Bangladesh. We have through the proposed project activity, nature-based crab production will be substantially reduced.

8.4 Construction of slatted houses for goat/sheep rearing

180. Sheep rearing is a proven pro-poor adaptation livelihood in rural areas of Bangladesh. The project will add improved technology and management system i.e., slatted housing system, to the conventional goat and sheep rearing process to make it climate-resilient. The experience of PKSF found that sheep are highly resilient to increased salinity. It is less affected by diseases and requires minimum feed for survival. On the other hand, its productivity is very high. Women can easily get involved. The proposed project will provide financial and technological support for improved management of goat rearing as a supplementary livelihood to the poor and vulnerable crab farmers because many of the crab farmers cannot produce crab around the year. This activity will be carried out mainly by the female member of the selected household. This will empower them by contributing to family income and reducing vulnerabilities to climate change. Slatted house and capacity building and technology part of the activity will be grant finance, and buying goats or sheep will be from the loan part of the project.

8.5 Introduce the cultivation of saline-tolerant vegetables within homestead areas

181. Homestead-based vegetable cultivation is one of the important options for the livelihood of the poor community. It meets their nutrition demand and enhances income earning. At present, the coastal people cannot cultivate vegetables at their homesteads due to the high level of salinity in the soil. There are some saline-tolerant species that can resist less than 10 ppt salinity, whereas, in many areas, salinity exists more than 10 ppt, particularly during the dry season. If the homestead plinth is raised above the high tide level, the soil salinity would be limited through rain. Thus vegetable cultivation would be an effective adaptation in the coastal zone.

8.6 Homestead tree planting

182. Tree plantation around the selected house is an approach to making the house resilient to storm and tidal surges. Trees slower the wind speed of storms, leading least damage to houses. It will also improve the ecosystem and biodiversity of the selected areas. The project will motivate the selected households to plant trees around their homesteads. Trees can reduce the impacts of storms and tidal surges. The tree species will be selected in consultation with the local community. The project will emphasize local species which are resilient to strong winds. The cost of the activity will be contributed by the participating household.

8.7 Assessment of climate-resilient houses

8.7.1 Existing status of housing in the southwest coastal zone of Bangladesh

183. The CTCN has commissioned a study on housing and water technologies in the coastal zone of Bangladesh to the KICT based on the proposal submitted by PKSF to CTCN. The study found that the average family size was 4.19, with an average yearly household income of BDT 82,556. The average size of a house was around 95m^2, with 1.4 rooms and 1.5 windows. Table 16 below presents housing information on the southern coast of Bangladesh.

Table 16: Housing information in southern coast Bangladesh

	Average	Maximum	Minimum
Family Size	4.19	10	1
Male child	1.35	7	1
Female child	1.45	5	1
Yearly Income	977 USD	2,130 USD	43 USD
Number of rooms	1.4	5	1
Number of windows	1.5	15	0
Housing area	95.75m^2		
Floor-to-ceiling height	2.11 m		
Ground to the floor (plinth of the house)	0.64 m		

184. Around 50 percent of the dwellings have one or two cracks in their roofs and walls, and the rest of the houses have three to fifty cracks. For roofs, 41.30 percent indicated that decay is the reason for the cracks, 38.70 percent said salinity, 30.30 percent said cyclones and 23.20 percent said the low quality of building materials, etc. On the other hand, 43.40 percent of the respondents reported that salinity is the major reason for the wall cracks, while 35.5 percent said decay, 26.8 percent said low-quality building materials, 25.4 percent said cyclones, 1.3 percent said tidal surges, and 3.5 percent said other reasons.

Figure 22: A meter height of plinth with cracks

Figure 23: Temporary ceiling finishing with fabric to avoid the hot temperature

Figure 24: Bamboo wall structure

Figure 25: Indoor floor with mud

185. In the survey areas of Satkhira and Bagerhat, the basic structure of a dwelling consists of a cluster of small shelters or huts around a central courtyard, locally known as an “Uthan.” The huts usually consist of a single room, are detached, and are loosely situated around the central courtyard. Usually, kitchens are not attached to houses. From table 17, we can see that the areas’ residents use various types of materials to build the basic structures of their houses, such as *gol pata* leaves, brick, bamboo, wood, mud, asbestos, and concrete. Furthermore, the areas' residents use various types of materials to build the roofs of their houses, such as Kolkata leaves/straw, brick, bamboo, wood, mud, asbestos, concrete, and corrugated iron sheets. Out of surveyed 600 houses, 122 (20.3%) had roofs made of corrugated iron sheets, 118 (18.7%) were made of asbestos, and 107 (17.8%) were made of *gold pata* leaves/straw.

Table 17: Current building materials

Material	Description	cost
Ferro cement Pre-cast	Ferro cement is ideally suited for thin wall structures as the uniform distribution and dispersion of reinforcement provide better crack resistance, higher tensile strength-to-weight ratio, ductility, and impact resistance Ferro cement precast elements can be constructed at convenient places (e.g., factories, workshops) and transported to the sites.	135TK/ ft^2
3D panel	A 3D panel is a prefabricated panel, which consists of a super-insulated core of rigid expanded polystyrene sandwiched between two sheets of steel welded wire fabric mesh.	182TK /ft^2
Sandwich Panel	The sandwich panels consist of two thin Ferro cement layers, reinforced with one layer of iron wire mesh, with the core(middle part)made of Expanded Polystyrene Sheet	135TK/ ft^2
Organic/Bamboo mat	Typically in kutcha houses, *semi-pucca* houses also often have bamboo mat walls. Organic materials (e.g., jute stick, catkin grass) have a lifespan of 2-3 years, and bamboo matt 4-5 years.	20TK/ ft^2
CGI sheet	CGI or Corrugated Galvanized Iron is a building material composed of sheets of hot-deep galvanized mild steel, cold-rolled to produce a linear corrugated pattern in them	127TK/ ft^2
Aerated concrete block	Autoclaved cellular concrete (ACC) is made with fine aggregate, cement, and an expansion agent that causes the fresh mixture to rise like bread dough	25TK/ ft^2

186. The structures can be classified by structural type and materials used. The structural types of houses in the southern coastal region of Bangladesh can be classified into bamboo, masonry, and reinforced concrete buildings. The main constituent materials of the walls are brick, bamboo, soil, wood, stone, and *gol pata*, while the roofs are mainly composed of S.G.I. sheet, *gol pata*, slate, and straw.

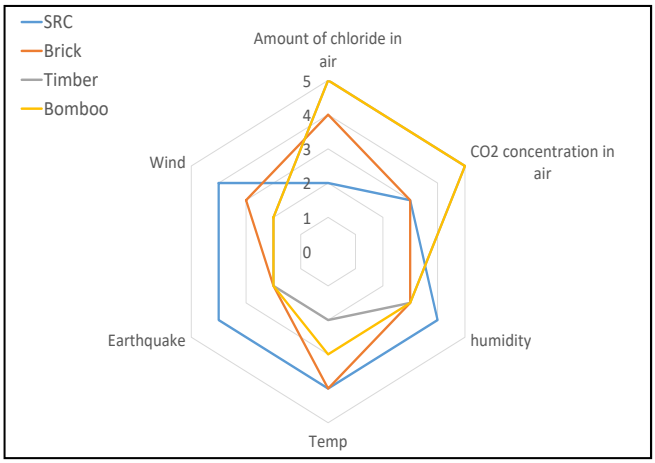


Figure 26: Factors affecting the durability of housing in the southern coastal zone of Bangladesh

187. Factors that affect the durability of houses are water, wind, and vibration. If there is salinity in the water or wind, in the case of reinforced concrete structures, durability can be compromised quickly, and the corrosion of metal roofs, such as tiles, can progress rapidly. The main components used in the region are SRC, brick, timber, and bamboo.

188. Factors that affect durability include salinity in the air or Water, CO_2 concentration in the air, high humidity, high temperature, wind, and the physical factor of earthquakes. The influence of each factor can be classified according to a five-level scale. Reinforced concrete structures have a strong resistance to wind, earthquake, temperature, and humidity but are vulnerable to high concentrations of salinity or CO_2 in the air. In particular, the deterioration and peeling of old building surfaces can be vulnerable to the weakening of its concrete structure due to neutralization. Therefore, they deteriorate further, affected by expansion due to the infiltration of water.

189. Timber and bamboo, which are widely used as wall and roof materials in the region, can be obtained locally and have the advantage of having accumulated technology in accordance with their long history of usage, which leads to shortened construction periods. In particular, using bamboo or timber as roof and wall materials and having an SRC structure can be advantageous in preparing for strong winds and ensuring a pleasant climate space. Brick is also available for building construction everywhere in the country.

190. The results of the field survey and HBRI data analysis showed that there are not many inorganic materials that can be used locally. Soils with a high content of organic impurities are disadvantageous in terms of durability. Therefore, bamboo, rice straw, and *gol pata* are the most appropriate local construction materials in the southern coastal region of Bangladesh.

191. The HBRI produces classic autoclaved lightweight concrete (ALC) blocks using cement and aluminum powder. This proposal outlines the use of a small amount of cement of less than 5% and proposes instead the construction of aerated blocks using fly ash or clay. ALC is a functional building material, as it maintains a pleasant indoor environment. However, it may cause problems such as mold and contamination during prolonged periods of high humidity due to its low water resistance.

192. Rice straw is an organic material that has the disadvantage of rotting when it is exposed to moisture. However, when rice straw is used to strengthen inorganic materials, it is possible to use it to produce building materials with high durability because of its high tensile strength. In

addition, it enables the use of eco-friendly materials, as it allows humidity control. Once the rice straw is sufficiently dried, it is possible to produce plates and blocks by applying pressure molding using a binder such as cement.

193. To secure long-term durability for more than 10 years, the method of partially utilizing vacuum extrusion-molded cement panels was suggested. Moisture is the most important factor that inhibits the durability of buildings. Cement extrusion panels are products that perform vacuum extrusion molding using cement, sand, and reinforcing fiber. In theory, their absorption rate is low because they are completely free of internal voids.

Table 18: Suitable building materials in southern Bangladesh

Aerated Bricks	**Cellulose Brick & Boards**	**Vacuum extrusion panel (Exterior)**
		
- Uses a small amount of cement, uses fly ash, and clay - Manufactured in room temperature hardening form - Lightweight, processable - Local materials available	- Rice straw is used as the main material, and adhesive is applied differently depending on the application - The exterior material is cement-bonded, and the interior material is resin adhesive. - Utilization of local rich rice straw	- Need to examine the use of exterior materials to ensure durability - High price and poor processability - Optimized product with high-density product for 30 years

194. There are several sintering-fired brick factories scattered throughout the country, including the Khulna region, which can produce high-quality cement and perforated bricks. It is common to use cement and fine aggregates for cement bricks, as well as cement, sand, and crushed stone powder instead of fine aggregates.

Figure 27: Cement brick factory in the Southern Coast area

Figure 28: Cement bricks

195. Various construction material options had derivate as above throughout the literature review and the field survey trip, but these technologies have to be well accepted by the community, such as household-level local community members economically and technically. As economic factors can be analyzed according to material price, construction method, technical skills, availability of materials, duration of construction, and localization. Bamboo was evaluated as the most economical construction material, followed by wood and brick. For the technical factor, performed an experiment on the resistance to salinity, humidity, CO^2, earthquakes, wind, and temperature with steel, masonry, wood, and bamboo material; the results came out that bamboo and bricks were excellent in terms of resistance to salinity, and bamboo was excellent in terms of cyclone resistance. Considering both aspects of durability and economic efficiency, it seems to be most effective to apply various combinations of building materials, such as precast R.C. structures with bamboo or wood walls and extruded concrete panels for facades with strong wind protection.

8.7.2 Improved housing structure

196. Coastal inundation, cyclonic storm and high wind in this region are guiding factor in fixing the form and shape of the house. The magnitude of the wind loads on the structure influences the shape of the roof. Based on the local experience, most of the houses in the village constructed a hip roof (*Chouchala*) over the Ghar (room) and a lower roof over the verandah, which is separated from the hip roof. The expert opinion is that the houses with hip roofs have a better record of resistance, and the recommended pitch of the roof lies between 30 to 40 degrees[153]. In the roof structure system, the most sensitive locations are the joinery of beams and columns and the connection between the rafters and beams. To make the house safe against high wind, these connections should be strong. Local builders use iron bolts at the connection between vertical supports with beams. In terms of cyclone resistance, experts recommended using 20 gauge galvanized metal straps, nails, nuts, and bolts along with nylon rope[154].

197. The facade of the traditional houses has windows and perforation over the windows for better ventilation. This is a good practice in respect of local climatic considerations in this tropical region. At the presence of too much perforation in the facade during cyclone build high wind pressure, which eventually increases suction pressure under the roof can blow the roof away from the main structure. To get relief from this effect, the expert gave an opinion to place one door at the center of the wall and add a small window in the rear wall[155]. The type of shutter in the window plays a significant role during the cyclone. Shutters hinged along the top of window frames are preferred as these will not suddenly open and let the wind in during cyclone, which eventually increases internal pressure to cause the roof to blow off. The lowered shutter would be a better choice with this top hung window. The study proved that corner openings (door/window) are not safe for the stability of the structure during cyclone rather than the opening in the middle of the facade[156]. As per expert suggestion the housing for the coastal area will be:

Sitting

- Raising the level of homestead above the level of maximum surge height and flood water depth
- Raise the structure on a mound (*killa*).
- Building on treated bamboo or timber stilts in cyclone-prone areas

Design

- The shorter face of the house towards the windward direction
- Single (flood) or double story house (cyclone), with square or rectangular geometry
- Pitch roof – vertical rise to horizontal spread ratio – 2:3, slope within 30-45 degrees, hip roof over ghar (room), low roof over verandah, minimize roof overhangs beyond vertical claddings

- Openings – minimize door and window openings, openings at the position of external suction reduce the pressure significantly inside the house thus the risk of lifting off the roof

Structure/Construction Methods

- Wall frame – cross bracing, inverted 'V' bracing to withstand lateral
- Vertical poles – adequate anchoring of vertical poles into the ground
- Roof frames – cross bracing, adequate anchoring of roof and vertical claddings to basic frame and bracings
- Wire lashing at roof/wall/post junctions

Improved local materials

- Plinth/base - use of mud-concrete (mixture of rise husk, rise husk ash and cement - 5%) Usability of spaces – single-use
- Basic frame – bamboo posts treated with bitumen or motor oil coating, insertion of the bamboo column in concrete block with the whole
- Combination of local and non-local materials

198. The feasibility study also reviewed houses in Viet Nam coastal zone and Mozambique coastal zone. A coastal district located in the Southeast of Ho Chi Minh City (HCMC), Vietnam, is characterized by low average terrains ranging up to only 1.5m above sea level. Impacted by climate change and sea-level rise in recent years, certain neighborhoods in the Can Gio District of Vietnam have been facing the loss of their residential and arable lands and undesired relocations. Together with riverbank and coastal erosion, this phenomenon has several negative impacts on people's lives in residential areas and on their economic activities. Sea level rise adaptive housing and thereby suggests certain solutions for the Can Gio District. The solutions include saving space for water, elevating floors, constructing floating floors, and creating biological ditches and osmotic lines to help quickly drain flooded water. These solutions aim to protect people's lives and houses against the rising sea level and ensure the neighborhoods' sustainable development.

199. The World Bank initiated the Global Program for Resilient Housing in Africa, Latin America and Caribbean Island. This program focusses on complementing rebuilding efforts and improving preparedness before disasters. The program has been tested and employed in Latin America and the Caribbean, and Southeast Asian countries such as Colombia, Mexico, Peru, Saint Lucia, and Indonesia. The aim is to protect individuals and families and their most important investment, i.e. the housing asset.

200. The impacts of climate change in Mozambique led to the establishment of affordable solutions and techniques for building. Importantly this includes design elements and resilience throughout the construction process (i.e. foundation, walls and roofing) (see Table 19).

Table 19: Key design elements for resilient construction in Mozambique

Technique	Description
Low vulnerability site selection Reduces potential impact of hazards (e.g. avoiding areas with high exposure to flooding and strong winds).	Systems to properly identify risks and allocate plots for construction; improve municipal regulations; and guidance on site selection.

Raised foundation (plinth) Elevated platform above the maximum level of flooding.	Built with material that supports weight of the house and withstands storm-force rain; constructed using conventional or mixed materials such as cement bricks, or reinforced concrete beams.
Reinforced wall With galvanized wire and diagonal poles (at a 20cm separation) and finished with mortar plaster.	Constructed with durable construction material, such as coconut or bamboo wood.
Secure roof with rainwater harvesting capacity Roofing should be symmetrical (square or rectangular) and constructed with an adequate slope to withstand strong winds.	Materials include purlin, roof batters, rafters and iron rod. Roofing sheets should be properly nailed into the roof supporting beams and tied with galvanized wire. Roofing cover sheet must be sufficiently waterproof, constructed with water collection system (gutters and drop tubes) made of suitable PVC and/or aluminum materials, and of a weight that is resistant to winds and can support the rain harvesting system.

8.7.3 Past housing projects and lessons learned

201. The concept of climate-resilient housing under the project includes raising homesteads plinth, constructing and/or reconstructing houses resilient to climate change and associated shocks (i.e., cyclone, storm surge, tidal surge, salinity, coastal flooding, etc.), construction of climate-resilient sanitary latrines, rainwater harvesting system, etc. Resilient housing is very important for building the resilience of the affected community; because they have to spend much of their income on repairing their houses each year during the post-monsoon period. In some cases, the people might be unable to repair their houses and migrate from their ancestral home to the cities.

202. Following Cyclone Sidr, the Government, international community, and local agencies addressed the post-disaster shelter need in various ways. During the emergency phase, they delivered cash grants and shelter materials for rebuilding and repairing. Later on, core houses and transitional houses were built for targeted vulnerable families in the affected areas. However, this direct reconstruction assistance covered a limited need in comparison to that of the total shelter reconstruction needed. The majority of housing reconstruction was owner-driven without any external assistance from the government or agencies. Although the Cyclone Sidr early recovery strategy emphasized self-recovery with the building of model houses meant to demonstrate hazard-resilient construction practice, this strategy was not applied by the shelter-providing agencies, including the government. This was due to the absence of any good practice that can be replicated, as well as having limited knowledge of implementing 'Owner Driven Housing Reconstruction' or 'self-help' housing schemes.

203. Cyclone Sidr affected families had shelters delivered as a relief product rather than by following a developmental relief process. In order to raise funds from external donors, the agencies' shelter delivery program focused on building prototypes, which sometimes addressed hazard-resilient design considerations. This prototype was sometimes of transitional nature and sometimes of semi-permanent or permanent nature. The confusion of defining a shelter program prevailed all through the design stage because it was not well defined at the strategic planning level. Many agencies were measuring the houses built in terms of durability whilst

taking into account the donors' expectation to provide shelter for a significant number of the affected population as a transitional measure. Very few agencies carried on extensive house repair work as their focus was primarily on designing prototypes that could be replicated for all sites, despite knowing the logistics challenges ahead of them for bulk procurement, transportation to site and construction quality control for each site. Shelter reconstruction was seen as a low-cost construction project, which was often done by the contractors due to the difficulty of construction management by the implementing agencies or even by the government themselves. The house owners had limited authority in decision-making on the house type, design, and construction process. Instructions and preconditions were given to the house owners to acquire suitable land, raise their plinth for the house to be built on. In the end, most of the house owners were happy to have a roof over their heads, even if some of the delivered houses were neither complete nor durable. Those who received a strong core shelter were confident about its durability and do not feel the need to seek a safer refuge during future cyclones. This raises the issue of disaster preparedness planning and the need for the shelter providers to be clear about the extent of the cyclone and tidal wave a core house can withstand. As many houses built in the coastal area are prone to high storm surges during cyclones, building a house alone cannot address disaster risk reduction holistically. Therefore, environmental planning and clear information on the capacity of the house for ensuring safety need to be integrated with the shelter program. The following models were implemented in the project:

Figure 29: Cyclone resilient house piloted by ACF in Barguna District (Central Coastal Zone)

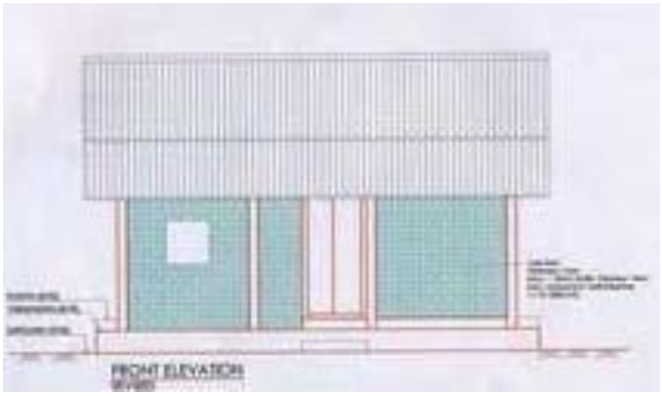


Figure 30: This house was constructed by Action Aid Bangladesh in Bagerhat and Patuakhali district in the southwest coastal zone of Bangladesh.

8.7.4 Recommended model by KICT

204. Based on the literature review, reinforced concrete (RC), brick, timber, and bamboo seemed to be the most appropriate materials for housing construction in the southern coastal areas. RC showed excellent resistance to humidity, CO_2, extreme temperatures, earthquakes, and wind. On the other hand, bamboo showed the best resistance to salt and CO_2. Considering the price of the construction materials, ease of construction methods, technical skills required, duration of construction, the supply of local materials, localization issues, and so on, it was determined that the most appropriate materials were bamboo, wood, brick, and reinforced concrete (RC).

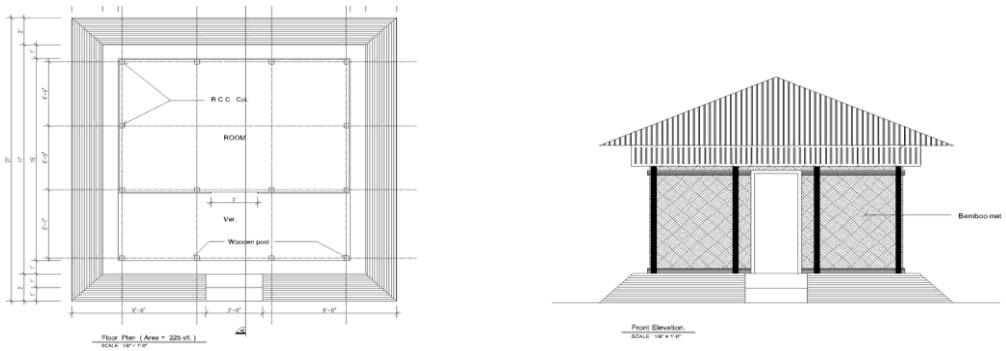


Figure 31: Recommended Model by KICT

205. There are four considerations when devising a climate-responsive design: 1) resilience against the impact of the environment, 2) introduction of low-impact building materials and construction technologies, 3) development of standardized and labor-friendly pre-fabricated modes of construction using minimum (economic) building elements, and 4) consideration of contextual issues. Technical options are the most important issue in determining durable housing designs. To achieve greater resistance to natural disasters, the structure, walls, roof, and foundation must be the most important design considerations. Three main options for sustainable materials were suggested for the southern coastal areas of Bangladesh. Table 20 is a summary of the structure, wall, roof, and foundation design targets for this project.

Table 20: Design targets for durable housing

	Design considerations	Main Materials
Structure	- Should be resistant to strong winds and flooding - Should facilitate easy replacement of wall and roof material - Should be economically efficient - Should be connected to a foundation structure	- Steel frame - Wood and bamboo structure - R.C. - Precast products using Ferro-cement with rebar
Wall (exterior/ interior)	- Use local materials - Use simple materials - Use replaceable materials - Use materials that are dirt and moisture resistant - Use materials that cost less than USD 5/m^2	- Burned products (ensuring durability) - Local straw, *gol pata* - Brick and replaceable panel
Roof	- Should have strong resistance to salt - Should be resilient against strong winds such as cyclones - Should not be corrosive - Should be able to construct a ceiling structure - Should be less than USD 5/m^2	- Use inorganic products or bone fragments for repairs - Fiber-reinforced cement slate or burned tile (CGI sheets are prohibited due to insulation problems)
Foundation	- Should be at least 60 cm above the ground - Should be a durable structure for flooding - Should be able to stabilize the structural frame	- Waterproof surface

206. In the context of the results mentioned above, housing was designed for residents of the southern coastal areas based on three income levels. The following assumptions were made about the average composition of a household: 1) a family size of four members, 2) a house height of 2.3 m, 3) the presence of at least 2 rooms and at least 1 window per room, 4) a housing area of 50m^2, and 5) a plinth height of 1 m. The three design concepts, separated by income level, are as follows:

Table 21: Summary of 3 housing proposals

	Type A	Type B	Type C

Number of floors	1 floor	1 floor	1 floor
Area	568ft²/52.7㎡	572 ft²/53㎡	758 ft²/70.1㎡
Main Material	Lightweight foam block/Local brick	Lightweight foam block/ Cement brick	Extruded concrete panel
Wall structure	Cement hollow Block	Cement brick	Concrete panel
Roof structure	G.I. steel gable roof	G.I. steel gable roof	G.I. steel gable roof
Division	Room(1,2), Living & Dining, Kitchen, Toilet, Shower	Room(1,2), Living & Dining, Kitchen, Toilet, Shower	Room(1,2), Living & Dining, Kitchen, Toilet, Shower, Verandah, Open terrace
Price / household	USD 10,990	USD 12,570	USD19,770
Price /㎡	USD 207	USD 237	USD 283
Solar system	3KW	3KW	3KW
Rainwater tank	1 ton	1 ton	1 ton

207. Type-A is designed for low-income residents in the southern coastal area of Bangladesh. This housing design represents similar to the traditional southern coastal residents living environment, separate toilet and shower area outside of the main building so that residents can feel comfortable in their own lifestyle. The main building includes two bedrooms with a living & dining room and a kitchen, and an annex building includes a toilet and shower area. This housing will utilize local materials such as *gol pata*, bamboo, and lightweight foam blocks. One ton of the rainwater tank and 3KW solar system will be installed. Table 22 shows the Type-A housing room divisions with the sizes.

Table 22: Type-A housing room divisions with the sizes

	Room 1	Room 2	Living & Dining	Kitchen	Shower	Toilet
UNITS	12'-0"X14'-0"	12'-0"X14'-0"	10'-0"X14'-0"	8'-0"X6'-0"	4'-0"X6'-0"	4'-0"X6'-0"
AREA	168 ft²/15.6m²	168 ft²/15.6 m²	140 ft²/13 m²	48 ft²/4.4 m²	24 ft²/2.2 m²	24 ft²/2.2 m²

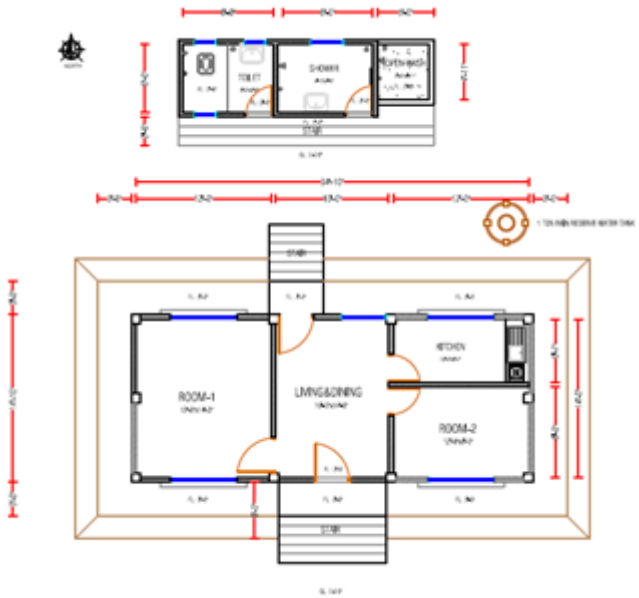


Figure 32: Type-A Plan

208. The basic concept of the proposed design for low-income residents in the southern coastal areas of Bangladesh is to develop a building's walls using local materials that improve durability with existing methods. For the A-type design, we suggest using wall materials that do not exceed a cost of $3 USD/$m^2$. Table 23 provides a description of Type-A materials.

Table 23 Type-A material description

Raw materials	Additives	Descriptions	Specifications
Straw, soil	Cement, lime, resin	- Local soil is used as the main material, and straw is used to enhance reinforcement - Exterior walls are reinforced with resin - For interior materials, use only cement or sodium silicate to improve the humidity - Produce in various brick shapes such as 300 * 300 * 150 mm, 300 * 150 * 150 mm - Intermediate hollow structure to prevent crack breakage - Variable adjustment on length of straw	- Density: 1.0~1.2 g/cm^3 - Compressive strength: 10~15MPa - Additive content: >10% - Resin content: >5%

209. Forming process: Preparation of soil (sieving after drying as certain powder) → preparation of straw (cut to a certain length after drying, within 100 mm) → preparation of additive → mixing of binders (soil: total amount of additive = 80:20) → mixing with straw [within 2% of binding material (by weight)] → mixing of water (within 30% of total weight) → casting a mold (pressurizing mold) → natural curing after de-molding

210. Type-B is designed for low-middle-income residents in the southern coastal area of Bangladesh. This design is dedicated to the residents who want to have a bathroom inside of the house. As mentioned above, in Type-A, most of the residents live in a traditional way of separating the kitchen, and toilet to be separated from the main rooms. On the other hand, some of the residents in the middle of low and middle-income wished to have a kitchen and toilet inside the house if there were any kind of flushing and ventilation problems. Type-B is designed for53m^2same size as Type-A; it is composed of two bedrooms, a living & dining room with the one-ton size of the rainwater tank, and a 3KW solar system.

Table 24: Type-B housing room divisions with the sizes

	Room 1	Room 2	Living & Dining	Kitchen	Shower	Toilet
UNITS	12'-0"X14'-0"	12'-0"X14'-0"	10'-0"X14'-0"	8'-0"X6'-0"	4'-0"X6'-0"	4'-0"X6'-0"
AREA	168ft^2/15.6m2	168 ft^2/15.6 m^2	140 ft^2/13 m^2	48 ft^2/4.4 m^2	24 ft^2/2.2 m^2	24 ft^2/2.2 m^2

211. The basic concept of the design proposal for low- to middle-income residents in the southern coastal areas of Bangladesh is to develop a building's walls using local materials that improve the durability of the existing methods and replace cement brick as a construction material. For a B-type dwelling, we suggest using wall materials that can be processed on-site

using the molding method. Wall materials should not exceed $5 USD/m^2. Table 25 provides a description of the proposed materials for a Type-B dwelling.

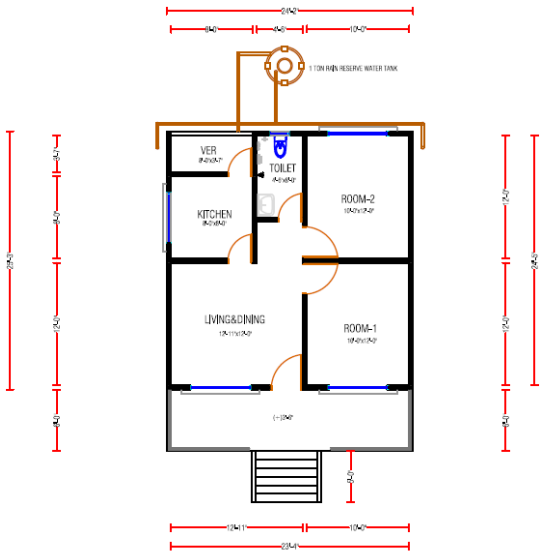


Figure 33: Type-B plan

Table 25: Type-B material description

Raw Materials	Additives	Descriptions	Specifications
Ash, clay, bamboo	Cement, sodium silicate, Al powder	- Main materials are fly ash, clay, and cement - a form of foam structure to give lightweight - Foaming uses Al powder or hydrogen peroxide - Water repellent to improve water resistance for exterior material - Molded up to 500 * 500 * 100 mm - No extra reinforcing fiber - Partially mixed with cement to improve the hardness of the product - The structure of the wall is made by stacking it into a bamboo molding frame	- Density: < 0.5 g/cm^3 - Compressive strength: < 5MPa - Water absorption: < 15%

212. Forming process: Preparation of raw materials (fly ash with high concentrations of CaO, clay, and cement) → sieving after drying as certain powder → preparation of foaming agent (Al powder or hydrogen peroxide) → preparation of a mold → mixing of binders (ash : clay : cement = 50 : 30 : 20) → mixing of foaming agent (Al powder is mixed in advance, hydrogen peroxide is mixed with less than 1% water) → insert into a mold → de-molding → insert into a bamboo mold

213. Type-C is designed for middle-income residents in the southern coastal area of Bangladesh. During the field survey, we found that there are more middle-income class residents than we thought. This Type-C design is dedicated to the middle-income class who

want to have some big spaces with a toilet inside of the house. Also, they wish to have a private area, such as an enclosed verandah. Type-C is designed for 70m^2; it is composed of two bedrooms, a living & dining room, a kitchen, and a toilet with a small private verandah space. It is also designed for a one-ton size of the rainwater tank and a 3KW solar system.

Table 26: Type-C housing room divisions with the sizes

	Room 1	Room 2	Living & Dining	Kitchen	Toilet	Verandah
UNITS	12'-0"X14'-0"	12'-0"X12'-0"	13'-5"X14'-0"	10'-0"X12'-0"	5'-0"X7'-0"	3'-0"X4'-0" 5'-0"x3"-7"
AREA	168 ft^2/15.6m^2	144 ft^2/13.3 m^2	256 ft^2/23.7 m^2	120 ft^2/11.1 m^2	35 ft^{2}3.2 m^2	35 ft^2/3.2 m^2

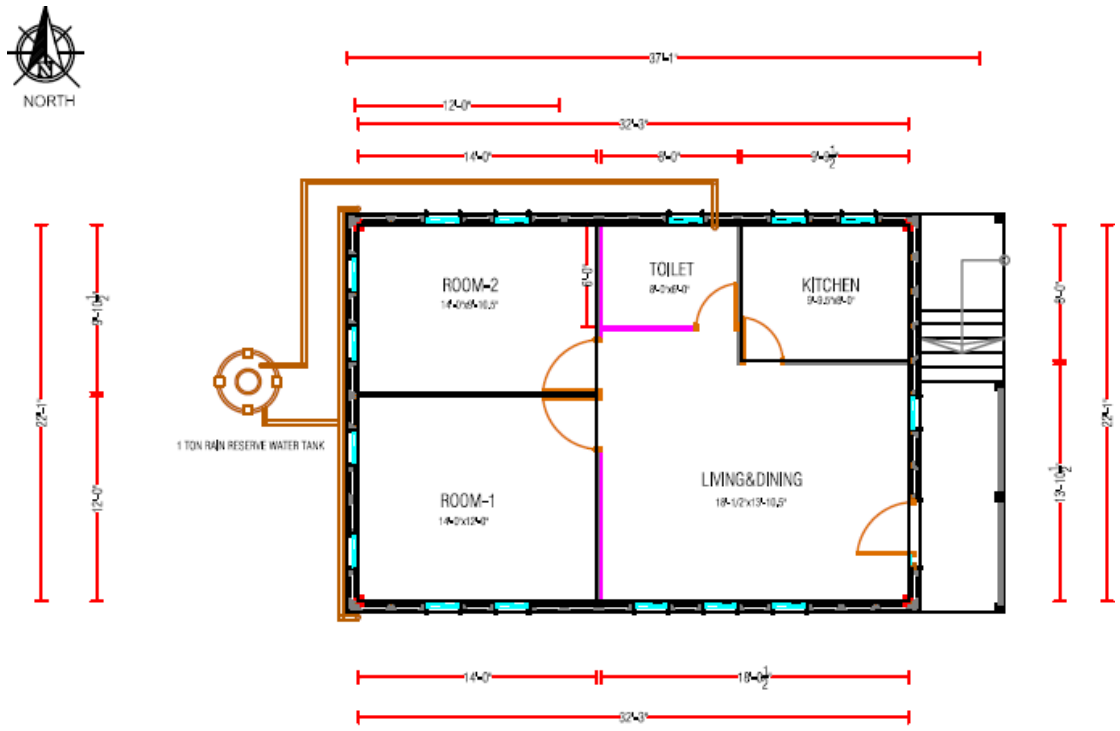


Figure 34: Type-C plan

214. The basic concept of the design proposal for middle-income residents in the southern coastal areas of Bangladesh is to focus solely on durability. This ideal material would be a durable one with high corrosion resistance to minimize the damage caused by exposure to seawater, and the wall panels should be easy to assemble and should be manufactured on-site. The cost of the wall materials should be 20~30 US dollar m^{-2}. Table 27 provides a description of the proposed materials for a Type-C residence.

Table 27: Type-C material description

Raw Materials	Additives	Descriptions	Specifications
Cement, silica powder	Cellulose fiber, methylcellulose	- Cement extrusion molding - Using large-scale facilities	- Density: > 1.5 g/cm^3 - Flexural strength: >

	powder	- Use 40–50% of cement as the main raw material (ample cement supply in Bangladesh) - High-density and water-resistant - Excellent U.V. resistance - High bending strength and compressive strength - Straw can be used as reinforcing fiber	14MPa -Water absorption: < 15%

215. Forming process: Preparation of raw materials (cement, silica powder, fiber, additives) → mixing of binders → extrusion molding → first curing (at 65 ℃ for 8 hours) → second curing (at 180 ℃ for 8 hours) → cutting → construction.

8.7.5 Coastal housing model suggested by House Building Research Institute (H.B.R.I.)

216. The House Building Research Institute (H.B.R.I.) carried out research on durable housing in disaster-prone areas of the country. This research has carried out the community's feedback on different donor projects, as mentioned above. These are:

- Houses should be near workplaces, as many previous examples were found unsuccessful.
- Houses should be in the inner areas of the dam/embankments.
- Minimum plinth height 2' (height might vary in case of low-lying areas and flood level, the base should be properly prepared)
- The plinth should be fully stabilized/pucca.
- Cross-bracing of appropriate materials needs to be used.
- In the case of precast elements, transportation is an issue.

217. This research has suggested building design for the coastal community in the country. They considered cyclones, high wind pressure, tidal surge, intensive rain, Nor Wester, salinity, and solar radiation while designing the structure. However, the suggested model is provided below:

218. Engineering Basis: A standardized 7"x 7" hollow column with an optimized center-to-center spacing which also ensures the local measuring practice (1 haat= 1'6"). Thus the longer side of the house is 22'6" =15 haat (hand measure), and the shorter side is 10'6"=7 haat (hand measure).

219. Anthropometric Basis: The model 1 house covers an area of 236.25 ft. Maintaining the minimum sphere standard of 3.5 m2 space per person and thus ensures 6 no's of person per house. The dimension of the houses can be altered according to the habitant's preferences considering the structural feasibility.

220. User Friendliness: The modular form of the house plan gives greater flexibility for future expansion, quick installation, and dismantling features as well. The engineering plan and structural design are presented below:

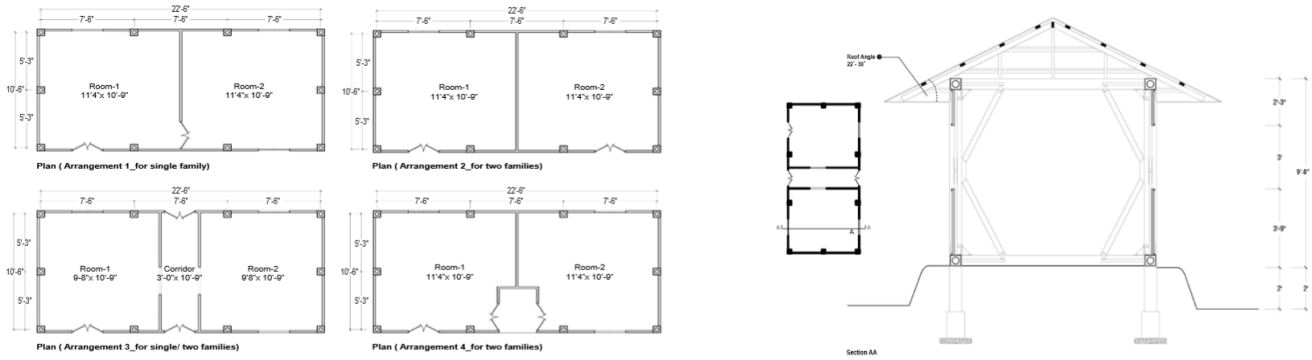


Figure 35: Coastal housing model suggested by HBRI

221. These structures are durable and resilient to coastal flooding, storm surge, cyclone, etc. The main gap in the design is that most of the designs consider raised plinth of the house only, but it requires raising the total homestead area of the household for greater sustainability and supply safe water and sanitation and accommodation of livestock and homestead gardening.

8.7.5 Construction of climate-resilient house under the proposed project

222. In Bangladesh, cyclone storms and surges are major features of the Coastal Zone. Between 1548 and 2020, the country has confronted about 88 powerful cyclones, along with many other atmospheric depressions. In the last 12 major cyclones since 1965, about 479,490 people died, and substantial damage to households took place whenever the cyclone attached the coastal belt of Bangladesh. Recent cyclones like S.I.D.R. and Aila caused massive damage to the household of many people (Hussain and Mullick, 2020)[157].

223. With the increased instances of cyclones, people in the coastal areas are becoming increasingly vulnerable to loss of lives and economic assets. The only protection in these areas is offered by the existing embankments, which were built in the 1960s and are now in serious need of rehabilitation and/or upgrading. Also, projections made at the time of their creation no longer hold true as the rate of change in climatic conditions has been greatly accelerated in recent times. On the other hand, most of the poor people build *kacha* (durable and non-permanent) houses made of wood and *gol pata*. Hence, their houses are vulnerable to cyclones, storm surges, and coastal flooding. They spend most of their income on repairing their houses each year. As women, children, and elderly members of the household stay at home maximum time, they are particularly vulnerable to these impacts. The proposed project will help them building climate-resilient houses so that they make their Development in a sustainable way.

224. The constitution of the People's Republic of Bangladesh has given rights to all citizens to have a secured residence. The government's national housing policy has a vision "To ensure accessibility of people from all strata of society to suitable housing, and to improve housing and settlements towards sustainable development, equitable living standard, improvement of working environment and access of all to basic services and amenities considering health, security and affordable price to uphold the equal right of all citizens"[158]. The project will support the most vulnerable coastal people to avail their rights as per the constitution. This will contribute to the government's different policy implementation, particularly addressing climate

change impacts, including BCCSAP, Bangladesh National Adaptation Programme of Action (NAPA), National Communications, 8th Five Years Plan, Perspective Plan, etc.

225. The project will implement the HBRI model because it will be durable as well as affordable to the poor and vulnerable people in the coastal zone. The structure of the house should be as simple as possible, with easy construction and repairing techniques, taking the rural people's preferences into consideration. Core essential elements like water, solar, etc., incorporated in-house design as a dedicated Rainwater Harvesting System, and Alternate Energy/Solar Energy is provided for every unit. Moreover, the plinth height will be raised more than 1 meter (may vary based on location) to reduce the risk of flooding and waterlogging.

226. The house will be rectangular, and the shorter edge will be facing the direction of the wind, which will reduce overall wind exposure. Secondly, the side of the roof with the greater slope will be faced towards the wind, and the roof will not extend beyond the wall, which will allow the wind to pass over the roof without affecting the core structure. Moreover, the roof will only be attached to the core structure and will not be supported by any walls, so even if the roof is affected, the walls will not be. Furthermore, there would be some gaps between the wall surface and the roof, so when the wind hits the roof, the thrust will be reduced.

227. The core structure will be made of bricks and concretes. The project will ensure that the bricks and concretes are not made with saline Water or soil. Freshwater will also be ensured during the construction of the house. In addition, there is local/indigenous knowledge of the coastal community to remove salt from water. Use of dental (tamarind, an extract of a traditional plant) and some weak acids in treating saline Water are these types of local practices. With this engineering model, the project will incorporate raising plinths of the whole homestead and planting trees of local species surrounding the houses to make it more sustainable. It is to be noted that the homestead dwellers will not move anywhere. Rather, their existing homestead will be used to promote climate-resilient homestead.

228. PKSF proposed different types of houses depending on the local context, and the site-specific model will be finalized in consultation with C.C.A.G. members. The average per square feet house construction cost is 20-30 US dollar, and the average area is 164-244 ft^2. In this way, the figure of 5,700 US dollar is surfaced.

8.8 Economic and financial viability of the project

229. It is envisioned that through proposed interventions, the project will address several crucial sustainable livelihood and resiliency-related issues pertinent to the coastal inhabitants of Bangladesh. Specifically, the project will employ interventions related to (i) inadequate quality of human settlements in low-lying areas of Bangladesh, (ii) climate sensitivity of the population in selected regions, (iii) scarcity of safe drinking water.

230. While it is expected that all proposed project interventions will provide significant benefits to intended beneficiaries and the entire economy, the benefits stemming from some of these interventions cannot be monetized due to the issues related to the lack of proper valuation mechanisms. The benefits of these interventions were evaluated economically only using non-market valuation techniques. On the other hand, interventions that consist of activities expected to positively influence the incomes of intended beneficiaries (e.g., interventions proposing the establishment of crab hatcheries and fattening crab activities, etc.) were assessed in financial and economic terms.

231. It is envisioned that the project will help establish micro crab hatcheries and crab culture/fattening facilities in the coastal areas of Bangladesh. PKSF's piloting experience setting up crab hatcheries will help facilitate the process. The project will provide micro-enterprise loans

to the beneficiaries (micro hatchery and crab growers) and technological and value chain support. PKSF will continue these project's activities through the same IEs with microenterprise loans to the crab sub-sector. The necessary technical know-how and value chain development are expected to be passed on to all intended beneficiaries.

232. The goal of proposed project interventions in the crab sector is to jump-start seafood production by providing the necessary financial support for establishing environmentally conscious and economically sustainable crab production. This sub-sector will additionally help promote innovative and climate-friendly technological solutions in other branches of seafood production. Furthermore, it is expected that the private sector will catch up in the longer run, and private entrepreneurs will start investing in the sector, helping it grow beyond the project's life. The Government of Bangladesh will help create a favorable policy and business environment to promote the sector. It is expected that when the sector develops further and shows investment potential, the availability of commercial funding will increase.

233. Furthermore, it is envisioned that similarly to crab sector interventions, the other proposed activities in the livestock sector (e.g., construction of slated houses for goat and sheep rearing or delivery of proper inputs and training for saline-tolerant vegetable production) and saline-tolerant vegetable production will also positively influence the incomes of intended beneficiaries. Once initiated by the funding stemming from this project in the long run, these activities will be financed by the local MFIs, once they become commercially operational and viable.

234. As to adaptation benefits, overall, the project is expected to deliver multiple positive adaptation impacts in the coastal communities of Bangladesh and will contribute to the national GDP. The project will help in developing a base of various entrepreneurs at different stages of the value chain of the crab, livestock, and vegetable sub-sectors. The project is also expected to create employment for vulnerable coastal people and provide livelihood support to more than 362,475 beneficiaries. The project envisions a significant impact on the women and youth population as many of the proposed activities can be pursued by females or youth. Thus, the project financing will effectively obtain the project's objectives and help diminish gender disparities in coastal communities by empowering women. By implementing project activities that are gender inclusionary, the community will automatically continue this activity in the long run.

235. Lastly, the project will organize workshops and meetings with stakeholders, including government representatives, policymakers, national and local NGOs, and financial organizations. The workshops will share project lessons with these stakeholders to create a favorable policy environment for scaling proposed interventions. The project’s-facilitated communication and knowledge pass-through is expected to help create an enabling environment for the future development of supported sectors. It is anticipated that the NGOs and financial organizations will be more willing to provide financial support to the entrepreneurs to extend the business co-financed by this project.

Economic and Financial Analysis

236. The RHL project proposes implementing several activities to increase livelihood resilience to climate change in the coastal region of Bangladesh. As the coastal areas of Bangladesh are the most vulnerable to climatic shocks, e.g., cyclones, and the frequency and intensity of these shocks are expected to increase over time, the proposed project’s activities will help address population vulnerabilities to these shocks.

237. The appraised project’s interventions are geared toward the most vulnerable communities in the coastal areas of Bangladesh with highest poverty rates and significant levels of social and economic disadvantage. The intended beneficiaries are characterized by limited scope to

increase their incomes and livelihoods. It is certain that without any external support, these communities will be unable to internalize on their own the costs of improved adaptation technology due to low incomes and lack of access to commercial financing (e.g., lack of collateral or credit worthiness to obtain a commercial loan).

238. Financial Analysis was pursued on interventions that are expected to provide income increase for intended beneficiaries. The analysis was conducted separately for all five (05) activities (goat rearing, traditional vegetable farming, crab hatchery, crab nursing and crab fattening), under two different scenarios; one with RCP 4.5 (medium case scenario) and another with RCP 8.5 (worst case scenario), with and without adaptation measures, and compared with the BaU case. The results of models assessed in the financial analysis are presented in Table 28.

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Table 28: Results of Financial Analysis – Individual Level

1. Goat rearing

Aggregate Results of Financial Analysis									
Activities	NPV			IRR			Payback Period		
	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5
	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme
Without GCF (No grant/100% PKSF loan)	-$51,951	-$1,162,565	-$1,361,291	9%	6%	5%	More than 14 years	More than 14 years	More than 14 years
With GCF (GCF grant+ PKSF Loan)	$2,309,726	$1,199,112	$1,000,386	17%	13%	12%	More than 9 years	More than 10 years	More than 11 years
With GCF (100%GCF grant+0%PKSF loan)	$5,472,686	$4,362,072	$4,163,346	35%	30%	29%	More than 6 years	More than 6 years	More than 6 years

2. Traditional vegetable farming

Aggregate Results of Financial Analysis									
Activities	NPV			IRR			Payback Period		
	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5
	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme
Without GCF (No grant/100% PKSF loan)	-$939,211	-$954,994	-$966,357	-	-	-	More than 9 years	More than 9 years	More than 9 years
With GCF (GCF grant+ PKSF Loan)	-$453,640	-$469,423	-$480,785	-	-	-	More than 9 years	More than 9 years	More than 9 years
With GCF (100%GCF grant+0%PKSF loan)	$31,932	$16,149	$4,786	24%	17%	11%	More than 1 years	More than 1 years	More than 1 years

3. Crab Hatchery

Aggregate Results of Financial Analysis									
Activities	NPV			IRR			Payback Period		
	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5
	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme
Without GCF (No grant/100% PKSF loan)	-$262,666	-$361,450	-$442,454	5%	5%	4%	More than 24 years	More than 24 years	More than 24 years
With GCF (GCF grant+ PKSF Loan)	$227,060	$128,276	$47,272	12%	11%	10%	More than 16 years	More than18 years	More than 19 years
With GCF (100%GCF grant+0%PKSF loan)	$618,841	$520,056	$439,052	22%	20%	18%	More than 9 years	More than 10 years	More than 10 years

4. Crab Nursing

Aggregate Results of Financial Analysis									
Activities	NPV			IRR			Payback Period		
	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5
	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme
Without GCF (No grant/100% PKSF loan)	-$27,989	-$173,262	-$272,351	8%	6%	4%	More than 24 years	More than 24 years	More than 24 years
With GCF (GCF grant+ PKSF Loan)	$172,725	$27,452	-$71,637	13%	10%	7%	More than 16 years	More than 21 years	More than 24 years
With GCF (100%GCF grant+0%PKSF loan)	$273,082	$127,808	$28,720	18%	13%	10%	More than 14 years	More than 18 years	More than 24 years

5. Crab Fattening

Aggregate Results of Financial Analysis									
Activities	NPV			IRR			Payback Period		
	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5	BaU	RCP 4.5	RCP 8.5
	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme	Present Climate	Moderate	Extreme
Without GCF (No grant/100% PKSF loan)	-$728,730	-$5,126,099	-$6,094,944	8%	4%	3%	More than 24 years	More than 24 years	More than 24 years
With GCF (GCF grant+ PKSF Loan)	$5,266,466	$869,098	-$99,748	17%	10%	9%	More than 11 years	More than 18 years	More than 24 years
With GCF (100%GCF grant+0%PKSF loan)	$8,363,984	$3,966,616	$2,997,770	29%	18%	16%	More than 7 years	More than 12 years	More than 13 years

The overall result shows that, with proposed grant support from GCF (both proportionate GCF grant and proportionate PKSF loan), respective NPV is positive for four (04) individual activities (goat rearing, crab hatchery, crab nursing and crab fattening) under RCP 4.5. But under RCP 8.5, there are both positive and negative NPVs. In case of traditional vegetable farming, NPV is positive under all three scenarios (BaU, RCP 4.5 and RCP 8.5) only with 100% grant support from GCF (No PKSF Loan). The analysis represents the necessity of GCF funding for increasing resilience under vulnerable climatic situation.

In case of IRR, its generally low under RCP 8.5 regardless with and without adaptation measures due to the intensity/scale of cyclones of this category. In general, payback period increases under both RCP 4.5 & 8.5, in comparison to BaU situation. Under RCP 8.5, payback period is more than respective project life for all activities.

239. In the EA process, Economic Analysis was also pursued on interventions that are expected to provide income increase for intended beneficiaries. The analysis was conducted separately for all five (05) activities (goat rearing, traditional vegetable farming, crab hatchery, crab nursing and crab fattening), under two different scenarios; one with RCP 4.5 (medium case scenario) and another with RCP 8.5 (worst case scenario), with and without adaptation measures, and compared with the BaU case.

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240. The results of models assessed in the economic analysis under BaU scenario are presented in . The results under RCP 4.5 and RCP 8.5 are not shown in funding proposal due to the large volume of data.

Table 29: Economic Analysis of RHL Project (Without GCF)-Aggregate

Goat/sheep rearing

	Economic Benefits in Present Value	Economic Costs in Present Value	ENPV	EIRR	Benefit to Cost ratio
Without GCF (No grant/100% PKSF loan)	$33,185,624	$31,964,842	$1,220,782	9%	1.04
With GCF (GCF grant+ PKSF Loan)	$37,301,085	$31,475,670	$5,825,415	23%	1.19
With GCF (100%GCF grant+0%PKSF loan)	$37,301,085	$27,949,811	$9,351,274	44%	1.33

Traditional Vegetable Farming

	Economic Benefits in Present Value	Economic Costs in Present Value	ENPV	EIRR	Benefit to Cost ratio
Without GCF (No grant/100% PKSF loan)	$3,222,915	$4,272,338	-$1,049,424	9%	0.75
With GCF (GCF grant+ PKSF Loan)	$13,074,602	$13,475,872	-$401,269	23%	0.97
With GCF (100%GCF grant+0%PKSF loan)	$13,074,602	$12,950,941	$123,661	44%	1.01

Crab Hatchery_Nursery_Fattening (as a value chain activity)

	Economic Benefits in Present Value	Economic Costs in Present Value	ENPV	EIRR	Benefit to Cost ratio
Without GCF (No grant/100% PKSF loan)	$112,162,819	$99,983,407	$12,179,411	13.88%	1.12
With GCF (GCF grant+ PKSF Loan)	$112,164,387	$92,812,976	$19,351,411	26.59%	1.21
With GCF (100%GCF grant+0%PKSF loan)	$112,164,387	$88,951,166	$23,213,221	48.91%	1.26

241. ENPVs are positive and benefit to cost ratios is more than 1.00 in all the proposed funding scenarios under this proposal. Crab hatchery, crab nursery and crab fattening have been considered as a chain activity in order to conduct economic analysis.

242. The obtained results in the above economic analysis include the guestimate of economic benefits like biodiversity gains due to the environmentally friendly production of crablets suggest that the RHL project will be economically viable and sustainable. Economic benefits will be increased if the disability adjusted life year, savings from avoidance of injuries, number of days in hospitals, avoidance of labour-day loses etc. factors are also considered.

Cost Effectiveness and efficiency.

243. The total budget of the RHL project is proposed at 49.99 million, with the GCF co-financing of USD 42.20 million (GCF grant)-84.42% of the total funding and USD 7.79 million-around 15.58% as co-financing. The project is expected to deliver direct benefits to an estimated 362,475 direct beneficiaries and 770,050 indirect beneficiaries.

244. The project's concessionality is rationalized through: (i). the project's provision of goods that are largely public in nature (e.g., interventions in mangroves and climate adaptive homesteads), (ii). the delivery of interventions to communities that might initially be private in nature (e.g., funding of hatcheries for crabs or crab fattening or funding improved production of saline resistant vegetables) but in the longer run due to biodiversity co-benefits might become public in nature.

9 EXIT STRATEGY AND SUSTAINABILITY

245. The project interventions will establish crab sub-sector for adaptation to salinity in the coastal areas of Bangladesh. The project will develop entrepreneurs on crab hatching, farming, processing and marketing. It will create a business environment at local, sub-national and national levels. It is expected that many private companies will be established on crab farming, processing, marketing etc. So, the project interventions will sustain in the long run as it will create a profitable business environment. Besides, the project will establish a community mechanism to extend the business in all around the coastal zone.

246. The crab hatchery is technically a critical intervention. The project will emphasize enhancing capacity of the local entrepreneurs and community people in crab hatching and farming system. Long term hands-on training will be provided to them. Through this training, the community peoples will be experienced in crab hatching technology and modern farming system. It is expected that they would easily solve their problems with the help of a Bangladeshi expert. At the same time crab fattening farmers can rear in their fellow land. Whenever necessary, the entitled person will draw the required amount of money from the bank to meet the needs. In this way, the project will sustain for a long time. PKSF will provide financial support through the project implementing partners. The established hatchery may support to produce crab as an enterprise. Value chain and smooth marketing facilities help to continue the project long run. After the expiry of the project, the Implementing Entities (IEs, PO) will stay as it is their working area. So, the linkage with the beneficiary and the POs will be long term. The exit strategy will follow PKSF's policy on project closure. The POs will be provided necessary guidance on project closure. The project will organize workshops at national level involving policy makers and actors to share the results of the project interventions. The IEs will organize workshops at the local level involving local government representatives and local actors. Necessary publications will be carried out during the last year of the project.

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