Planning and costing agriculture's adaptation to climate change in the salinity-prone cropping system of Bangladesh

Khandaker Mainuddin, Aminur Rahman, Nazria Islam and Saad Quasem, Bangladesh Centre for Advanced Studies

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Contacts:

Khandaker Mainuddin (Senior Fellow), Aminur Rahman, Nazria Islam and Saad Quasem, Bangladesh Centre for Advanced Studies (BACS), House #10, Road #16A, Gulshan 01, Dhaka 1212 • Tel: (88-02) 8852904, 8852217, 8851986, 8851237 • Fax: (88-02) 8851417 • Website: www.bcas.net • Email khandaker.mainuddin@bcas.net

International Institute for Environment and Development, IIED, 80-86 Gray's Inn Road, London WC1X 8NH, UK • Tel: +44 (0)20 3463 7399 • Fax: +44 (0)20 3514 9055 • Email: muyeye.chambwera@iied.org

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Table of contents

Acronyms and abbreviations

AR4	The IPCC *Fourth Assessment Report: Climate Change 2007*
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BCAS	The Bangladesh Centre for Advanced Studies
BCCSAP	*Bangladesh Climate Change Strategy and Action Plan* (2009)
BDT	Bangladesh Taka (currency)
BINA	Bangladesh Institute of Nuclear Agriculture
BJRI	Bangladesh Jute Research Institute
BMDA	Barind Multi-purpose Development Authority
BRRI	Bangladesh Rice Research Institute
CCCM	Canadian Climate Change Model
DAE	Department of Agricultural Extension
DAM	Department of Agricultural Marketing
DCRMA	Disaster and Climate Risk Management in Agriculture project
DFID	Department for International Development, UK
GCA	Gross cropped area
GCAP	Global Climate Adaptation Partnership
GDP	Gross domestic product
GFDL	Geophysical Fluid Dynamics Laboratory
GIS	Geographic information system
GoB	Government of the People's Republic of Bangladesh
IIED	International Institute for Environment and Development, UK
IPCC	The UN Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management programme
LLPs	Low lift pumps
MDGs	The UN Millennium Development Goals
MoA	Ministry of Agriculture
MoEF	Ministry of Environment and Forest
MoF	Ministry of Finance
NAP	*National Agriculture Policy* (2009)
NAPA	*National Adaptation Programme of Action* (2009)
NARS	National Agricultural Research System
O&M	Operations and maintenance
ppt	Parts per thousand
SEI	Stockholm Environment Institute
SRDI	Soil Resources Development Institute
SSR	Self-sufficiency ratio
STWs	Shallow tube wells
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

Background

The agricultural sector plays a vital role in the economy of Bangladesh in terms of its contribution to GDP, employment generation, livelihoods and poverty alleviation. The sector, however, has been under increasing stress due to various natural hazards, including that of climate change. Climate change-induced extreme events such as floods, droughts, cyclones, storm surges, sea level rise and salinity intrusion are likely to occur more frequently and to become intensified in the future. This will sharply affect food production, especially in vulnerable areas such as the country's low-lying coastal belts. As agriculture is highly vulnerable to climate change, food security, food prices and nutrition will be adversely affected. Therefore there is a strong need for decision makers to take climate change into account in their development planning, and further explore the synergies between climate change adaptation and agricultural development.

Objectives

This study aims to investigate adaptation requirements and their cost implications in the context of coastal agriculture in Bangladesh. The particular objectives of the study are as follows:

1. To investigate the operation of the agricultural production system in salinity-prone areas of Bangladesh and how this may be affected by climate change.
2. To devise the necessary adaptation options and investigate the roles different stakeholders at different levels have to play in implementing these.
3. To consider how these adaptation measures can be mainstreamed into national development plans.
4. To assess the costs of such adaptation measures to the different stakeholders involved.

Methodology

The study methodology was based on different steps and methods for collecting the relevant data/information from different categories of stakeholders. The methodology, in essence, comprised the following:

- The study team reviewed all available literature and documents including, *inter alia*, the *National Adaptation Programme of Action* (NAPA), the *Bangladesh Climate Change Strategy and Action Plan* (BCCSAP), the *National Agriculture Policy* (NAP), the *Coastal Zone Policy and* the IPCC *Fourth Assessment Report*, etc. In addition, relevant secondary data from the Bangladesh Bureau of Statistics (BBS) and the Soil Resources Development Institute (SRDI) as well as other sources were also used and analysed.
- The study team consulted various institutional stakeholders including DAE, DAM, BRRI, BARI, BADC, BINA etc. The consultation with institutional stakeholders was particularly useful in accessing the information on adaptation measures and associated cost estimates for the institution/organisation concerned.

- The study area comprised three districts, Khulna, Bagerhat and Satkhira, in the south-west coastal zone of Bangladesh, where farm households were surveyed to generate primary data. Altogether 300 households, 100 from each of the three districts, were surveyed using a semi-structured questionnaire developed for this purpose. The questionnaire included relevant socioeconomic, demographic and climatic variables, along with cost of cultivation, value of farm produce, farmers' knowledge of climate change, and households' coping and adaptation strategies etc.

The generated primary data from the household surveys was processed and transformed into statistical outputs that were used for the analysis, including univariate and bivariate tables and descriptive statistics. In order to facilitate a better understanding of the findings, charts and diagrams have also been integrated into the report.

Stakeholder workshop

The results and findings of the study were shared in a stakeholder workshop attended by various organisational and institutional representatives from the agricultural sector (e.g., from research and development, and extension and marketing). The workshop participants voiced their opinions regarding the study findings and further refined the costing data.

Cropping patterns

Although different varieties of crops are grown in Bangladesh, rice is the overwhelmingly dominant crop in terms of acreage and importance as the staple food. Rice alone accounts for about 75 per cent of the cropping area in the country. In terms of acreage, other important crops grown in the country are wheat (4.4 per cent), jute (3.9 per cent), potato (1.1 per cent), pulses (2.79 per cent), sugarcane (1.12 per cent), chilli (1.05 per cent), and oil seeds (3.08 per cent). In addition, onion, gram, garlic and groundnut, etc. are cultivated on a relatively small scale.

The annual crop-growing period in Bangladesh is divided into two main seasons, known locally as *kharif* and *rabi*. *Kharif* season covers the months from mid-March to mid-October and is characterised by high temperatures, rainfall and humidity. During this period, the moisture supply from rainfall plus soil storage is enough to support rainfed crops. Aus rice and Aman rice are the most important crops grown during the *kharif* season.

The *rabi* season ranges from mid-October to mid-March and starts with dry, sunny weather that gradually becomes colder in the months of December through to February. The crops grown in the *rabi* season are largely dependent on surface as well as groundwater irrigation. Boro rice is the most important crop planted in the *rabi* season.

Climate change impacts on agriculture

Agriculture in Bangladesh is influenced by seasonal characteristics and climatic variables such as temperature, rainfall, humidity, day length etc. Production of crops, particularly rice, is often constrained by different climatic hazards such as floods, droughts, soil and water salinity, cyclones and water surges. Different models predict various levels of impacts for yield reduction under various climate change scenarios. It is predicted that a 4°C rise in temperature will reduce rice production by 17 per cent and wheat production by 61 per cent in Bangladesh. In terms of other adverse climate impacts, sea level rise and salinity intrusion are key concerns for agriculture in the country's coastal regions.

Available data show that more than 80 per cent of the total area of the three study districts is already affected by different magnitudes of soil salinity. About 35 per cent of the total area is in the grip of strong salinity. Recent assessments demonstrate that an approximately 13 per additional area will be inundated due to a 62cm rise in sea level. Thus the salinity situation in Bangladesh's coastal areas is going to worsen under the predicted climate scenarios.

Adaptation practices and cost implications

Households in the study area are already practising adaptation strategies to various extents, in order to cope with climate change-induced hazards and disasters. These include: excavating canals to conserve fresh water for irrigation, as well as planting saline-resistant rice varieties. Furthermore, the use of groundwater for irrigation and green manure are also common coping strategies to counter increasing salinity as a result of sea level rise and climate change.

The study demonstrates that an adaptation technology such as saline-resistant rice varieties can have a net benefit (in this instance, higher yield potentials than the traditional rice varieties). Many farmers, however, are not fully aware of the advantages of these adaptation technologies due to their lack of relevant knowledge and inadequate extension services. However, farmers are generally willing to adopt saline-resistant varieties and they also expressed demand for them in the study area. Although conservation of freshwater for irrigation through excavating canals can be an effective adaptation strategy, this is often expensive and beyond the affordable capacity of marginalised smallholders.

The different institutional stakeholders and actors engaged in agricultural research, extension, development and marketing, require substantial capacity building to address the challenges imposed by climate change effectively. This, however, involves significant cost implications for the institutions and agencies concerned. For instance, the Department of Agricultural Extension (DAE) would currently require an annual budget of about BDT62.0 million (US$0.82 million) to strengthen its extension activities in the salinity-affected study areas. The Department of Agricultural Marketing (DAM) would need an annual budget of BDT41.55 million (US$556,970) for its activities, including crop insurance and market promotion, and additional BDT40.84 million (US$547,453) for infrastructure – including grain storage facilities. The estimated required budget for the Bangladesh Institute of Nuclear Agriculture (BINA) to develop new saline-resistant varieties is BDT2.08 million per annum. The regional BINA at Satkhira (in the study area) would require BDT4.42 million per annum, in addition to BDT3.3 million for equipment costs. The estimated current costing for the BRRI (Bangladesh Rice Research Institute) is BDT500 million (US$6,578,947) including BDT230 million (US$3,026,315) for infrastructure and laboratory facilities.

The financial input currently required for the Bangladesh Agricultural Development Corporation (BADC) is BDT199 million (US$2.6 million) for installing power pumps and excavating canals in the coastal area. In addition, BDT70 million (US$0.9 million) will be needed for technological equipment to monitor salinity and groundwater management.

Conclusions

This research study shows that the various stakeholders in Bangladesh are aware of climate change and its adverse impacts on agricultural production, and are therefore currently trying to embed adaptation into policy and long-term planning documents. The study also indicates that extension workers are active in promoting technological advances for adaptive practices. Research agencies in Bangladesh are also up to date and in the process of developing methods and varieties for climate change adaptation. Many of the existing adaptive varieties and farming techniques were developed by local research agencies.

The claims of institutional stakeholders have been supported by local farmers, who already practise adaptation measures through using saline-resistant crops, better farming techniques, and different forms of irrigation. Farmers and stakeholders unanimously agree on the urgent need to excavate canals to resist salinity. The cost of using adaptive varieties is similar to that of traditional rice varieties, which makes the use of adaptive varieties an imperative for the future.

Another point emphasised by the stakeholders and farmers is the need for training. In order to achieve benchmarks for adaptation in the coastal zone, capacity building for agricultural staff and farmers has to be simultaneously improved. Furthermore, additional funding needs to be allocated to the relevant stakeholder institutions so that adaptation measures can be effectively implemented and scaled up further.

1. Introduction to agriculture in Bangladesh

Global expanding populations and limited space are key hurdles to the attainment of food security and poverty reduction. Climate change – increasing temperatures and causing weather extremes – adds to the challenge. The developing world must bear a disproportionate burden of adverse impacts from this debacle.

Though the discussions on climate change have been distinct from the agricultural policy debate, the two have begun to converge. There is now a clear consensus within climate change circles that due importance must be given to agricultural needs, and within agricultural circles that climate change must be incorporated in to future climate change negotiations. Discussions regarding agreements after 2012 on climate change include agricultural dimensions. This study feeds into these debates by considering the ways in which climate change affects agriculture in a case study from Bangladesh, how we must respond to this, and how much these responses will cost. To do this requires an in-depth understanding of the role agriculture plays in Bangladesh, how the farming system operates, and how it is intricately linked to the climate.

1.1 The significance of agriculture in Bangladesh

1.1.1 Agriculture and the Bangladesh economy

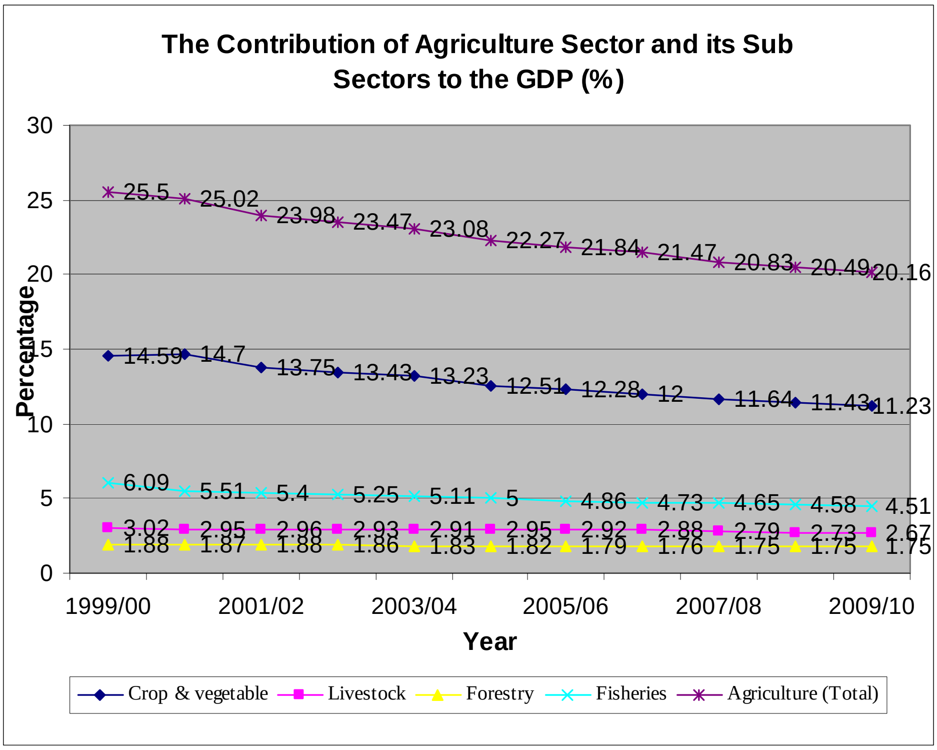
The economy of Bangladesh is primarily agrarian. Agriculture and agro-based commodities account for about a quarter of total exports. As of 2008, agriculture accounted for 20.87 per cent of the gross domestic product (GDP) of Bangladesh. Crop is the major sub-sector in the agriculture sector and accounted for 11.23 per cent of GDP in 2009/10.

Agriculture remains the dominant sector for economic growth in Bangladesh, growing annually at 3.1 per cent at constant 1995 - 96 prices. This is despite the fact that its share in GDP in the 1990s declined by about 50 per cent compared to the 1970s (the early Independence period). The share of the agriculture sector (including crops and vegetables, livestock, forestry and fishery) declined from 25.50 per cent in 1999/00 to 20.16 per cent in 2009/10 (see Figure 1, below). On average, the rate of agricultural growth is/has been higher than the rate of population growth (MoA 2004).

The gross national product (GNP) at current prices shows that the total value added from agriculture is BDT886,015 million (US$12,305 million). Of the labour force, 48.07 per cent is dedicated to the agriculture sector. The total export of commodities equals BDT985,931 million (US$13,886.35 million); the agricultural goods that are exported derive a value of BDT76,400 million (US$1,046.57 million).

A large number of the population live below the poverty line in rural Bangladesh due to an increase in the population, fragmentation and loss of land to other sectors (approximately one per cent annually), and limited job opportunities. As about 52 per cent of the total labour force is engaged in agriculture (BBS 2009), the sector has an important role to play in supporting the rural population of Bangladesh. As such the vulnerability of the agriculture sector to climate change exacerbates poverty levels and undermines efforts in poverty reduction.

Figure 1: The contribution of the agriculture sector and its sub-sectors to GDP (per cent) (Source: MoF 2010).



1.1.2 Food security in Bangladesh

A. Food availability

At the national scale, Bangladesh meets its food requirements through domestic production, imports and food aid. While imports and domestic production have increased, the flow of food aid has decreased. The role of agriculture and domestic food production in food security cannot be overemphasised given the country's low income, recurrent natural calamities, and the increasing international prices of food commodities. The agriculture sector, which according to government figures produced 27.35 million tonnes of cereal (including maize) in 2004/5, is therefore responsible for maintaining the food security of the entire country by meeting the demands for food.

Although production of rice, the main staple crop, is largely sufficient, self-sufficiency in other food items is yet to be achieved. For example, among non-cereal food, 70 per cent of the country's pulse requirements are imported and Bangladesh produces only 34 per cent of the edible oil it consumes. Estimations of requirements, and demand and supply (availability) of other food items – vegetables, pulses, fruit etc. – need to be systematically carried out.

Self-sufficiency ratio (SSR)
The self-sufficiency ratio shows the different dimensions of production in relation to domestic utilisation. It is one method of expressing food deficiency in the country. The self-sufficiency ratio is defined as:
*SSR = Production/(production + imports - exports) * 100.*

Considering the estimates of the food grain gap and self-sufficiency ratio, it can be deduced that Bangladesh has a food grain gap of 1 to 2 million tonnes, and an average SSR of about 90 to 91 per cent. According to estimates of BARC (the Bangladesh Agricultural Research Council), a surplus of 1.213 million tonnes of food grains will be reached by 2015, but an overall deficit of all others food items will be present. However, according to another estimate, at the present population and agricultural growth rates, the food gap could grow to 5 million tonnes. This discrepancy in estimations of current and future food gaps highlights the need for a better, more precise, and regular tracking of the food security situation. However, there is evidence, based on the official and private food grain production and import figures, to suggest the food grain SSR for Bangladesh is gradually declining, meaning the country is becoming more dependent on imports.

The lowest self-sufficiency rate is found in 2005, which could be attributed to crop damage during the severe flood in 2004.

B. Food accessibility

Whilst establishing the precise derivation of the food gap is a challenge, the lack of access to food produce is largely responsible for the food insecurity of over 60 million people. This happens because of the absence of purchasing power (poverty), as well as other factors such as the seasonal and spatial dimensions of market access, market functionality, and issues to do with gender and levels of human assets. The *Millennium Development Goals Bangladesh Progress Report* (GoB and UN Country Team 2005) provides a critical insight into the correlation between levels of poverty and that of child malnutrition, concluding that child nutrition is far higher in Bangladesh than would be expected at its levels of per capita GDP. Access to food is the hurdle to attaining food security in Bangladesh.

1.2 The policy environment

1.2.1 Institutions

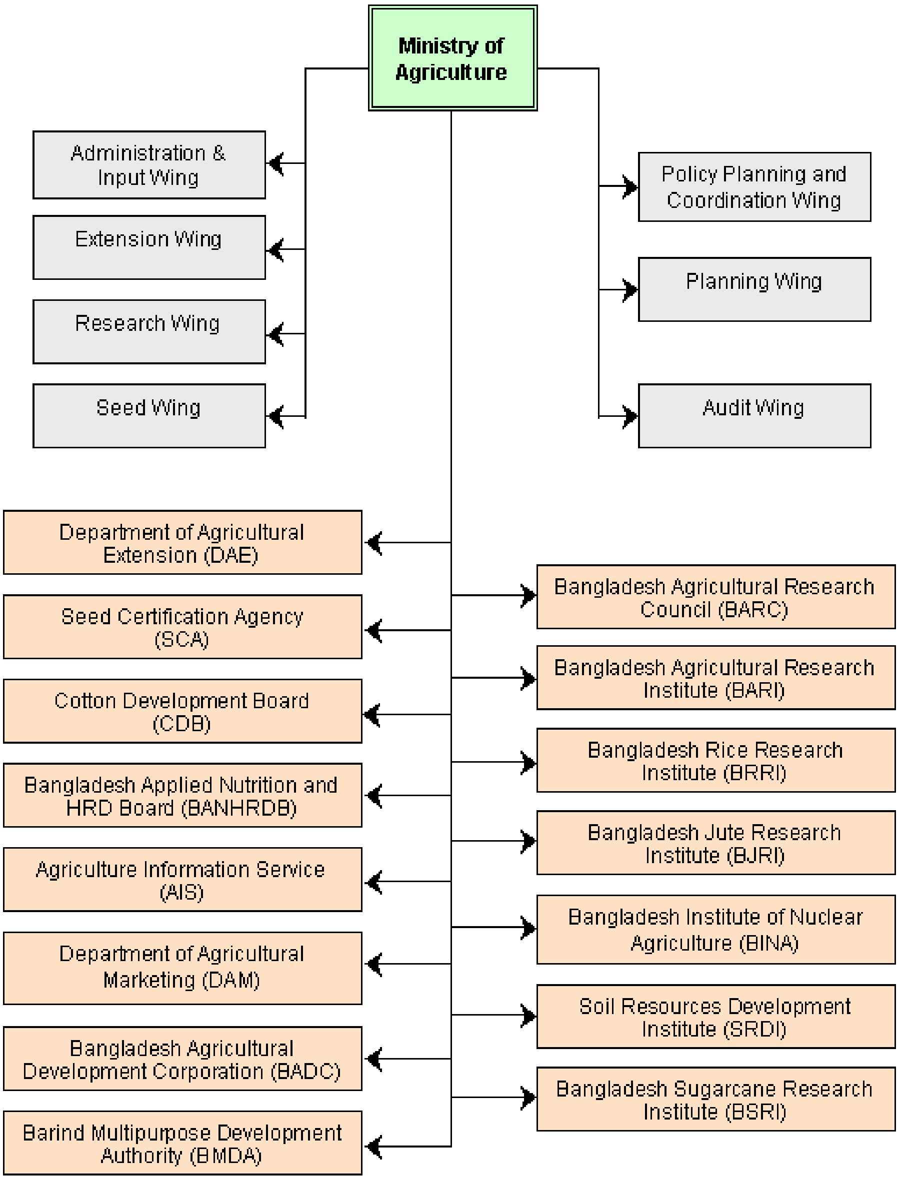
Several institutions of the government of Bangladesh (GoB) influence agriculture and the food security of the country. The primary responsibilities of the Ministry of Agriculture (MoA) are to implement policies, plans, legislation and regulations in reference to agriculture and to monitor the thirteen cells that function under the banner of this ministry. The National Agricultural Research System (NARS) is led by its apex body, the Bangladesh Agricultural Research Council (BARC).

The **Ministry of Agriculture (MoA)** carries the responsibility of implementing the policies, plans, legislation and regulations of the government of Bangladesh in reference to agriculture. The ministry is also entitled to monitor the thirteen cells that function under the banner of this ministry (see Figure 2).

The **Department of Agricultural Extension (DAE)** is the service provider of the MoA. The goal of the department is increasing the agricultural productivity of farmers. The DAE provides different kinds of extension services to farmers. DAE is also accountable for technology transfer to the farmers. It is the largest public sector extension service provider in Bangladesh. There are approximately 16,000 extension officers posted in the 64 districts of Bangladesh. Extension officers train clusters of farmers on new technologies, modern farming methods, methods of irrigation, pesticide usage, cultivation of short durational crop products, etc. The DAE headquarters is located in Dhaka, but there are regional offices in Khulna, Satkhira and Bagerhat.

Since rice is an integral part of Bangladesh agriculture, the **Bangladesh Rice Research Institute (BRRI)** has been set up to conduct substantive rice research in the country. It is also part of the NARS network. BRRI carries out research on rice productivity enhancement in Bangladesh and maintains the organisation's countrywide research facilities. BRRI headquarters is equipped with scientists and laboratory personnel who develop rice varieties in accordance with the country's needs.

Figure 2: Organogram of the institutions functioning under the Ministry of Agriculture (Source: http://www.moa.gov.bd/organisation_structure/organisation_structure.htm).



Jute is of vital importance to Bangladesh. The **Bangladesh Jute Research Institute (BJRI)** is another research centre that is part of the NARS system. Its objective is to enhance jute production in the country. BJRI conducts agricultural research on jute and allied fibres. Furthermore, the technologies needed to augment research capability on jute and allied fibres are also part of its remit, as are the economics and marketing of jute and allied products.

The **Bangladesh Agriculture Research Institute (BARI)** conducts research on a variety of crops, cropping and farming systems, plant protection, soil fertility management and water management, post-harvest handling and processing, farm implements, and socioeconomics related to production, processing, marketing and consumption. The role of BARI includes conducting high-level research in relation to its objective of increasing productivity of non-rice crops. It provides logistical support in research management, personnel management, and maintaining infrastructural development of the institute. Training scientists, extension workers, NGO officials and farmers is another responsibility of the institute, which is the largest multi-crop research institute in Bangladesh.

The **Department of Agricultural Marketing (DAM)** is a marketing entity under the MoA, which provides improved marketing services in order to ensure fair returns to the growers for their produce and maintain adequate supply to the consumers at reasonable prices. It also collects market information from farmers and traders regarding wholesale and retail prices, market arrivals, and movement and stock of farm products. DAM also disseminates pricing information through the press to farmers in order to ensure fairness and transparency and to monitor prices, identify reasons for price fluctuations, and suggest corrective measures. It is also the duty of DAM to carry out the organisation of transportation of farm products. Enforcement of the *Agricultural Produce Markets Regulation Act of 1964* is another task of this department, as is advising the GoB on production targets of different crops and procurement programmes. The headquarters of the Department of Agricultural Marketing is located in Dhaka, where the primary activity is to monitor the work of the different branches of DAM.

The **Bangladesh Agricultural Development Corporation (BADC**) focuses on research and development of agricultural systems under the MoA. Developing methods to bring about breakthroughs in agriculture in Bangladesh, and subsequently realise food self-sufficiency, is an objective of BADC, to be fulfilled by facilitating the multiplication, production and supply of high yield variety crops, providing logistical support to fruit and vegetable farmers, and supplying and operating irrigation techniques and methods.

Since a number of drought-prone areas are under the threat of climate change, a **Barind Multi-purpose Development Authority (BMDA)** has been created to provide rural and agricultural development services in Bangladesh. A principal responsibility is the augmentation of surface water and the optimisation of its use in the Barind.[1] The development of effective water distribution to ponds for fish culture is another task within its remit, as are the re-excavation of ponds for fish culture, forestation programmes, and diversified crop production.

The **Soil Resources Development Institute (SRDI)** is a research and development institute under the MoA. The main tasks of this institute are to develop the production of a series of Soil Resources Input Guides, create maps, data and other geographic information system (GIS) services, and also promote soil tests for individual farmers.

The **Bangladesh Institute of Nuclear Agriculture (BINA)** uses nuclear technology for the development of new varieties. Research on bio-technology, crop physiology, soil science, entomology, plant pathology and agricultural engineering is conducted. With the use of funds from the Bill and Melinda Gates Foundation, BINA has excelled in providing matured seed varieties.

As agriculture and climate change agendas have converged over the past couple of years, the **Ministry of Environment and Forest (MoEF)** has also begun to play a role in influencing agriculture. Although its policies for climate change adaptation are cross-sectoral, since agriculture is one of the sectors likely to be most affected by climate change, it features prominently in such climate change policies.

1.2.2 Policies

Agriculture in Bangladesh is influenced by stakeholders under the Ministry of Agriculture (MoA), which include the Department of Agricultural Extension, Department of Agricultural Marketing, Bangladesh Rice Research Institute, Bangladesh Agricultural Development Corporation, Bangladesh Institute of Nuclear Agriculture and Bangladesh Agricultural Research Council, etc, as discussed previously. These organisations implement their actions using the policies that are relevant to each department.

[1] The Barind is a geographic region covering parts of north-western Bangladesh and north-central West Bengal state, India.

The MoA has initiated implementation of the 2004 ***Actionable Policy Brief*** to address the problems of improving land, water and labour productivity by promoting a balanced use of fertilizer, small-scale mechanisation, quality seed production and supply, irrigation interventions in drought-prone areas, crop diversification, interventions for improving water use efficiency, and supply of other agricultural inputs including credit. Strengthening the agricultural technology system through appropriate institutional reforms is one of the major interventions undertaken by the MoA for improving institutional efficiency.

The ***National Agriculture Policy*** (NAP) of 2009 has been drafted on the basis of the current socioeconomic and geo-physical situations. The main focus of the policy is to improve the yield of agriculture and to maintain the livelihoods of those involved with agriculture. NAP 2009 explicitly acknowledges climate change along with the threat of declining natural resources. The urgency of addressing these problems has been demonstrated in the policy. The objective is to align policies towards combating climate change. The policy in principle supports agricultural research for the enhancement of agricultural output. However, the policy remains a draft and the implementing mechanisms for the activities have not yet been finalised.

(The previous *National Agriculture Policy* of 1999 highlighted the topics of food security, profitable and sustainable production, land productivity, and income gains. The policy also dealt with issues of input supplies, fair output prices, and improving credit facilities, as well as creating marketing mechanisms and agro-based industries while protecting small-scale farmers' interests. The policy included room for the creation of a reliable database for agriculture; agricultural credit systems were to be enhanced to address newer goals. Frameworks for training and education in the agricultural sectors and the establishment of agricultural products processing activities were outlined in the policy. Implementation of a power delivery system was specified as a necessity, along with a credit system for access to mechanical products. The need for infrastructure to be built for water harvesting, and consequently for consumption, was also stressed. The draft NAP document of 2009 was created with close reference to the 1999 policy and its shortcomings.)

In 1996, the ***New Agricultural Extension Policy*** was formulated. Demand-led extension services to all types of farmers, training extension workers, strengthening research-extension linkages and promulgating environmental protection were some key issues in the policy.

The Department of Agricultural Extension's *First Strategic Plan* (for 1999-2002) draws out strategies to reach out to the farmers at small-scale and local levels, including assessing and addressing the information needs of farmers, usage of low- or no-cost extension services, marketing methods for crops, and mainstreaming gender and socioeconomic development issues with existing extension policies. (This version was revised from the 1994 version of the same extension development approach.) The policy also outlines the steps necessary to reduce environmental degradation and raise awareness on current problems of environmental degradation, to be conducted concurrently after environmental policies and legislation are reviewed. The plan also calls for the development of eco-villages. Literature published and printed for extension development is recognized as part of the media campaign to raise awareness on extension needs for sustainable development. Technological advancements to enhance communication are also mentioned.

The objective of the DAE ***Agricultural Extension Manual,*** published in the year 1999, is to promote sustainable agriculture with the best possible results. The manual is used by extension staff as reference material. Vital information on annual crop planning, seasonal extension monitoring, participatory technology development, and rural approval partnerships, technical audits, attitudes, and practice surveys are the points to be referred to.

Mass media and awareness campaigns to promote extension services are to be carried out through radio, newspapers, audio and visual aids. Farmers' rallies, folk media, motivational tours of other farms, and participatory technology development are also needed to bolster farmer morale. Assessing farmers' information needs, and collating planning information, district extension planning meetings and agricultural technical committee meetings have to take place so that the farmers receive all kinds of information in all kinds of ways. Extension officers need to visit individual farms in order to acquire useful information.

The 2009 ***National Adaptation Programme of Action*** (NAPA) for Bangladesh has been prepared by the Ministry of Environment and Forest (MoEF). NAPA identifies that agriculture will be one of the most drastically harmed sectors as a result of climate change. Adaptation options stated in NAPA include the development of a climate-resilient cropping system, which is to be developed by promoting agricultural research and through the discovery of crops that are resilient to floods, droughts and salinity. Indigenous knowledge and scientific research must be carried out simultaneously in order to produce the best results. Adaptation recommendations also include the introduction and scaling up of existing innovative crop technologies to deal with flood, drought and salinity. For example, projects such as no-tillage potato cultivation, vegetable cultivation, the *sorjan* system of cropping, etc. must be scaled up in order to gain fully from adaptation.[2] Adequate measures must be taken to lessen climate-induced stresses on poultry and ruminants. Livelihood protection in ecologically vulnerable areas must be enacted into policies and regulations for the smooth operations of adaptation measures. Forty-five identified adaptation measures have been mentioned in NAPA at a cost of US$4 billion for implementation during the next five years. However, only one project on the basis of NAPA has started and is only currently at its preliminary stage.

Amongst the 45 adaptation measures in NAPA, 12 of the programmes are relevant to agriculture, food security and nutrition. Development of climate change-resilient cropping systems includes programmes on research to diversify cropping patterns and develop crops that are resilient to floods, droughts, cyclones and salinity. Similar practices will need to be developed for livestock and fisheries. Introducing and scaling up existing innovative crop technologies to deal with natural disasters and other extreme events happening due to the changing climate will need to be undertaken, as will agricultural research for greater climate resilience in all relevant sub-sectors (including crops, horticulture, fisheries, livestock and poultry, and village forestry). Other aspects include improvement in the supply of feed and forage for livestock and poultry through community-based production and conservation in floods; strengthened risk management against property loss and income erosion for the vulnerable (small-scale farmers and small enterprises); and building the capacity of key government ministries and agencies to take forward climate change actions, (including the MoA and the National Agricultural System). More research should take place on links between climate change and nutrition and developing adaptive participatory water resources management in all water bodies, including fisheries. The adaptive part would be through community management.

The recently adopted *Bangladesh Climate Change Strategy and Action Plan* (BCCSAP) (MoEF 2009a) is built on six pillars, of which five are related to impact management and one is related to mitigation through low carbon development. These six pillars are a) food security, social protection and health; b) comprehensive disaster management; c) infrastructure; d) research and knowledge management; e) mitigation and low carbon development; and f) capacity building and institutional strengthening. This strategy has identified 44 programmes and 145 projects under the thematic areas.

[2] Sorjan is an indigenous technology to cultivate crops, especially vegetables, on raised beds and ridges, and fish in ditches, in saline-prone areas.

The pillar of 'food security, social protection and health' of BCCSAP appreciates that climate change is likely to impact the most vulnerable Bangladeshis, who happen to be the most destitute. Capacity building for these vulnerable people – who are mostly women and children – will be carried out in order to cut down on the harmful impacts that climate change has the potential to create. Better access to services such as insurance and safety nets are a must. The development of climate change-resilient cropping systems is another necessity highlighted by BCCSAP, in order to realise the adaptation needs of the country. Facilitating access to clean water and water security is another strategy to combat climate change.

There are nine programmes highlighted under BCCSAP for combating climate change. The first programme focuses on building the institutional capacity of institutions to deal with 'climate resilient cultivars and their dissemination.' Therefore stakeholders have prescribed further state-of-the-art research. The recommended actions are: introducing climate-resilient cropping patterns; organising seed circulation; and developing production technologies and early warning systems for the use of farmers.

Adaptations in the fisheries and livestock sectors are other areas of focus as well; one of the programmes calls for GIS mapping and developing systems that encourage growth in saline-prone and drought-prone areas. The practice of integrated water management is also part of the issue. Adaptation of fisheries consists of assessing the potential threats to fish spawning and the growth of fish, shrimp and other marine organisms. Other adaptation measures include evaluating the migration patterns of hilsa and other socio-economically important fish. Adaptation in the livestock and poultry sector includes actions that assess the potential threats and distribute information on them to farmers. Strengthening of veterinary services is also part of the programme.

2. Background to the study

2.1 Climate change and agriculture in Bangladesh

Rises in temperatures across Bangladesh are likely to cause the production of staple crops to dwindle. While farmers in some areas will start growing different crops that have been shown to be more resilient, other areas will not be able to produce traditional crops any more. Rainfall patterns have already begun to vary from area to area. The frequency and intensity of floods, droughts, cyclones, and storm surges will increase and the prevalence of sea level rise and salinity will also increase. Food production will be sharply affected in vulnerable areas, such as the coastal belts. As temperatures rise, some areas that are prone to high levels of rainfall will demand more water due to the higher rates of evapotranspiration. Food security, food prices and malnutrition are all likely to be affected by climate change.

There is a clear need for decision makers to take climate change into account in their planning. In particular, there are synergies between climate change adaptation and agricultural development that should be capitalised upon. This study aims to investigate these.

2.2 Aims and objectives of the study

This project is one component of a broader research programme on climate change, agriculture and food security. The aims of this programme are to collate existing research with new research methods in order to accumulate knowledge, to provide guidance and demonstrate how agriculture can be part of post-2012 climate change agreements, and to investigate how best to mainstream and integrate agricultural adaptation measures into national plans so that climate risks are better incorporated into development.

At the local level, a bottom-up approach to planning the costs of adaptation is crucial. A case study analysis determines the costs and ground realities of climate change and thus stresses local-level needs in respect of adaptation. The computed costs are then more realistic and focused, which is key to successful adaptation. Importantly, the approach gives an indication of where the costs are likely to fall, and on what, which is crucial when planning agricultural adaptation. As such the objectives of this project are:

1. To investigate the operation of the agricultural production system in salinity-prone areas of Bangladesh, and how this may be affected by climate change.

2. To devise the necessary adaptation options and investigate the roles that different stakeholders at different levels have to play in implementing these.

3. To consider how these adaptation measures can be mainstreamed into national development plans.

4. To assess the costs of such adaptation measures to the different stakeholders involved.

2.3 Methodology

The methodology undertaken was in accordance with the study objectives listed above. In Bangladesh, the one specific goal is to draw the adaptation pathway in rice-based, salinity-prone landless, marginal, small- and medium-scale production. The methodology for this study consisted of several steps and components to collect required data/information for the target area. The steps and methods comprising the study methodology were as follows:

A. Inception meeting with the IIED team

As an initial step of the Bangladesh economics of climate change adaptation study, discussions were held between the IIED and the Bangladesh Centre for Advanced Studies (BCAS) research teams to gain a comprehensive understanding of the specifics of this project.

B. Review of related secondary literature and documents

The BCAS team reviewed the available relevant policy documents including: the *National Adaptation Programme of Action* (NAPA), the *Bangladesh Climate Change Strategy and Action Plan* (BCCSAP), the *National Agriculture Policy*, the *Coastal Zone Policy*, the IPCC (UN Intergovernmental Panel on Climate Change) *Fourth Assessment Report* (AR4) 'Summary for Policymakers', and the United Nations Framework Convention on Climate Change (UNFCCC 2010) methodology guidelines, etc. to identify the important policies of adaptation in agriculture. Detailed maps were also reviewed to research the situation at the study areas. A database of households from the demographic and socioeconomic survey was generated to identify the best areas for the case study.

C. Institutional consultations

The BCAS team consulted the various stakeholders who influence the state of agriculture nationally, as well as in the study areas of Bagerhat, Khulna and Satkhira. Since this project was aimed at finding the cost of adaptations related to rice cultivation in saline-prone areas, departments under the MoA and relevant government research institutes were consulted. The different organisations and institutions included: DAE, DAM, BRRI, BARI and BADC. The context, objectives and expected outcomes of the project were explained to each of the stakeholders. After familiarising them with the project, stakeholders were asked to list adaptive trends and practices they consider to be important. After an evaluation of the adaptation options, an estimation of costs was provided by the stakeholders – which included both capital and operating costs. The costs provided comprised institutional costs that have to be borne to assure the practice of adaptation options as a response to the climate change scenario.

The estimations of future costs were derived from stakeholders' past and current experiences in project planning and implementation. The future costs were broadly computed taking inflation into account (ten per cent each year) by the year 2030.

The adaptation measures were based on current trends and practices. The only difference between the present and the future adaptation measures is in the scale of operations, which – keeping climate change predictions in mind – will have to be more widespread and on a larger scale than at present.

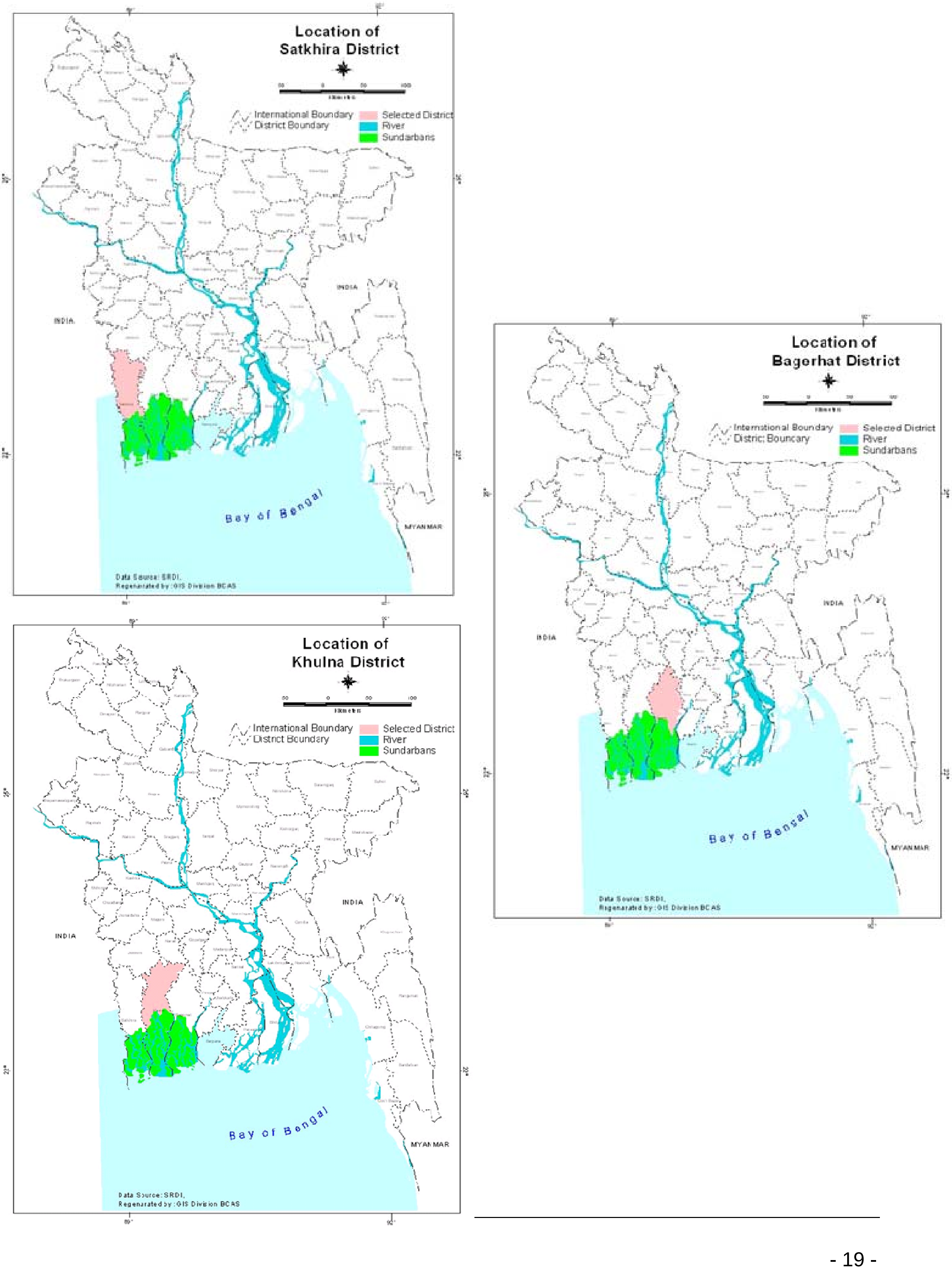
D. Selection of the study population

The agreed methodology was to study only farm households. The list of households per village from the demographic survey was used as a sampling frame, verified while in the field.

E. Site selection

High rates of salinity are threatening coastal agriculture in Bangladesh. With a view to highlighting the problems that are being (and will be) faced due to more and more salinity intrusion in the agricultural fields – which in turn affects the livelihoods of poor people living in coastal Bangladesh, as well as national food security – the focus of the research was salinity-prone agriculture, and in particular rice cultivation. The BCAS team consulted with the *upazila* (sub-district) agriculture office and the block supervisor regarding areas that were highly affected by salinity. Projections from the Soil Resources Department Institute identified the *upazilas* and within those the villages that were gravely affected by salinity. The areas were chosen through recommendations from the *upazila* agriculture office. Households that sourced their income from agriculture were surveyed and were identified on the basis of agricultural income and losses from higher levels of salinity.

Figure 3: Locations of the study areas (Source: SRDI, regenerated by GIS Division, BCAS).



F. Development of the survey questionnaire
BCAS and IIED developed a questionnaire focusing on demographic and socioeconomic variables, the cost of farming and value of farm produce, the respondents' knowledge of climate change, their ability to cope with natural disasters, and issues of adaptation. Most of the questions were structured but some open-ended questions had been deemed necessary too. The structured questions were pre-coded to expedite the process of data entry.

The questionnaires were carefully reviewed while training the field staff and further amendments made after training and pre-testing in the village of Santashpur in Chitalmari *upazila* (sub-district) in the district of Bagerhat and in Kamarkhola village, Dacope *upazila*, in the district of Khulna.[3]

G. Training of field staff
Prior to conducting the survey, the project coordinator held a two-day long training programme for the field investigators at the BCAS office. The training focused on field work, ethics, and expected norms and behaviour of the field staff, including introductions, rapport building and a mock interview. Part of the training had also involved capacity building in the qualitative and quantitative methods that were utilised as part of the research methodology.

H. Organisation of field work
BCAS deployed a field team of 15 field staff, who were split into three teams. Once the full team was on the site, communication was built with the private and governmental institutions in the area in order to gain further information regarding the target area. The three teams conducted the household survey of the proposed 300 sample households, each team covering 100 households each in a period of one month. Every two days, random samples of the completed questionnaires were picked and checked for possible errors. If errors occurred, the household in question was revisited.

I. Editing and coding of questionnaire
The completed questionnaires were reviewed and edited for errors, and omissions and inconsistencies were corrected with advice from the field staff, supervisors and the project coordinator. In a few rare cases the sites were revisited to obtain correct data from the households in question. The questionnaire was mostly pre-coded, yet a code plan was developed covering the additional information and the open-ended questions.

J. Data entry
Editing and coding of the questionnaire was followed by data entry using the SPSS (Statistical Programme for Social Science). This maintained consistency with the database of the demographic survey. The entered data were checked to remove any errors. Logical and range tests on each variable and cross tabulations were conducted to identify the mistakes and to make amendments. A frequency run of each variable was also obtained and examined to segregate any irrelevant data.

K. Data processing and analysis
Statistical data processing including frequency runs, and descriptive statistics such as mean, median, range, standard deviation, etc. were employed. Furthermore, univariate and bivariate tables were obtained for the analysis. The findings from the survey were disaggregated at *upazila* and district levels.

[3] A union *parishad*, comprising several villages, is the lowest administrative unit governed by elected representatives. The *upazila* is the next higher administrative unit, consisting in several unions.

L. Stakeholder workshop

A stakeholder workshop took place on the 16th of May, 2011. Representatives from the institutions that participated in the initial interviews were present at the workshop (DAE, DAM, BADC, BRRI, BARI and BINA). The collated institutional costs and the results from the household survey were presented by the BCAS team. The costs compiled by the BCAS team were assessed by the stakeholders, who analysed the gaps in both the top-down and bottom-up costs and subsequently refined the data to reach the final costings. The participants of the workshop also gave their comments on the findings of the household survey, which were also duly addressed by the study team.

3. The production system in salinity-prone areas of Bangladesh

3.1 The farming systems of Bangladesh

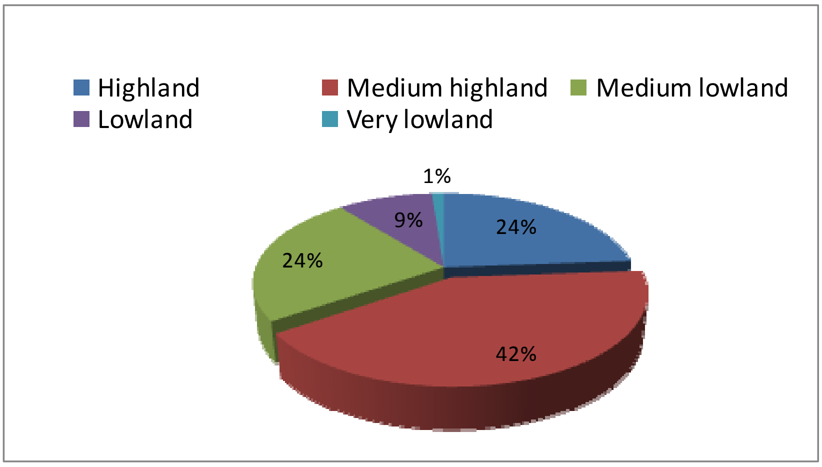
Bangladesh is an agricultural country, where the vast majority of people depend directly upon their own farm production for survival. The country's agriculture is multi-faceted, labour-intensive, and has a low technological and resource base. Agro-ecological conditions are complex in most parts of Bangladesh – there are several distinct land types in the country. In any village, at least three major land types exist and this situation makes land use a complicated undertaking.

Most of the large farms (> 3 hectares) have more than one enterprise; these may be complementary or supplementary depending upon the situation. In a mixed farming situation, cropping, raising livestock and poultry, fisheries activities and possibly other enterprises are present within the farming system. For example, some possible production systems are: crop - cattle - goat - poultry - fish; crop - cattle - buffalo - poultry; cattle - goat - poultry; and crop - fish. Climatic, physical, and socioeconomic differences result in many cropping systems with different crop varieties, technologies, sowing dates, etc. Most farmers follow cropping patterns that involve sequential cropping, mixed-cropping, and relay cropping.

3.2 Agricultural land and soil salinity

The total land area of Bangladesh is about 14.4 million ha, of which about 66.6 per cent is available for cultivation. Depending on flooding depth, the land is categorised as highland, medium highland, medium lowland, lowland and very lowland (Figure 4). Additionally, and based on aspects of the physical environment that are relevant to land use, the land is divided into 30 agro-ecological zones and 88 sub-regions by the Soil Resources Development Institute (SRDI) of Bangladesh.

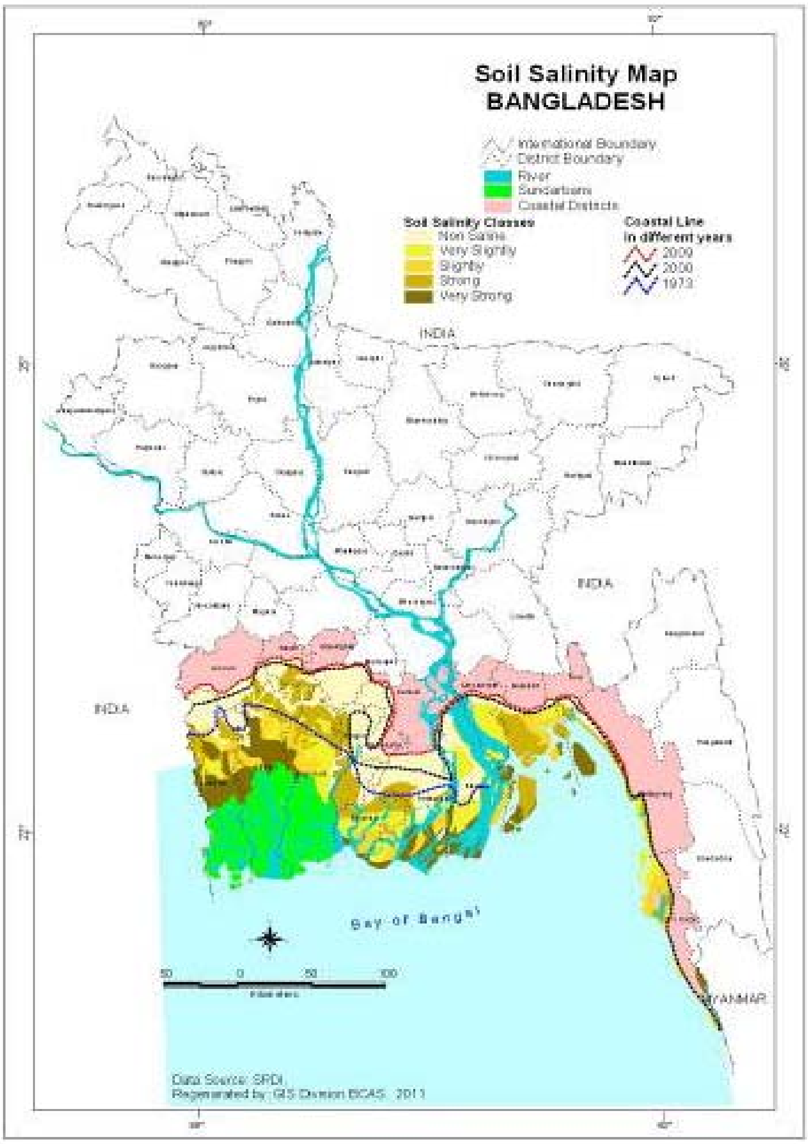
Figure 4: Land classification based on flood level.



Inundation plays a crucial role in determining the type of agriculture practices across the country. This study considers the lowland and very lowland areas of the coastal belt, which are subjected to flooding at least once a year, focusing on Khulna, Satkhira and Bagerhat as case study districts. Coastal regions cover approximately 17 per cent of the total area of Bangladesh and support one third of the population. Of crucial importance to agriculture, the frequent flooding in the coastal areas means the region is subject to high levels of soil salinity, although this varies over the year.

A draft 2009 World Bank report, *Implications of Climate Change Risks on Food Security in Bangladesh*, indicates that during June to September, the five parts per thousand (ppt) iso-line (line of equal salinity level) intrudes more than 70km landward in the western part of Sundarbans, whereas comparatively higher freshwater flows through the primary Ganges channels push the five ppt saline front towards the estuary mouth.

Figure 5: Increasing trend of salinity coverage area in different years, and present salinity level in those areas (Source: SRDI, regenerated by GIS Division, BCAS).



In contrast, during the dry season (December to March), saltwater intrusion occurs through various inlets in the western part of the coastal zone and through the Meghna River estuary. The five ppt iso-line intrudes more than 90km landward at the western part of the coastal area in the Sundarbans. Moreover, with decreases in freshwater flow in the Lower Meghna River, the saline front can move by as much as 30 - 40km from the coast. During the monsoon, about 12 per cent of the total area is under high salinity levels, which increases to 29 per cent during the dry season. With sea level rise, drainage gradients may reduce the decreasing flow to the Bay of Bengal and allow riverine salinity to move inland. This results in seasonal fluctuations in salinity levels in the coastal belts, with the peak salinity occurring during February to April, and the least saline conditions occurring during July - September. Figure 5 above shows the soil salinity across Bangladesh, highlighting that high salinity levels are highly concentrated in coastal regions such as Khulna, Satkhira and Bagerhat.

3.2.1 Soil salinity classifications

The Soil Resources Development Institute (SRDI) of Bangladesh has classified soil salinity into six classes.

1. *Non Intrude* represents no soil salinity, but the trends show that salinity might take place in the future.

2. *Non Saline* ranges up to 2 dS/m. This level of salinity is negligible.

3. *Very Slightly Saline* corresponds to the types of soil where soil salinity ranges from 2 to 4 dS/m.

4. *Slightly Saline* represents the soil salinity range of 4 to 8 dS/m. Many crops find it difficult to survive in these conditions.

5. An area is considered *Strongly Saline* when salinity ranges from 8 to 16 dS/m and crop cultivation is more or less nil.

6. The highest bracket of salinity happens when it is *Very Strongly Saline,* which characterises soil salinity above 16 dS/m.

Due to the proximity of Khulna, Satkhira and Bagerhat to the Bay of Bengal, these districts have been subject to high levels of salinity. Different degrees of soil salinity affect the area variably.

Table 1: Salinity level with implications for agriculture (Source: SRDI 1998).
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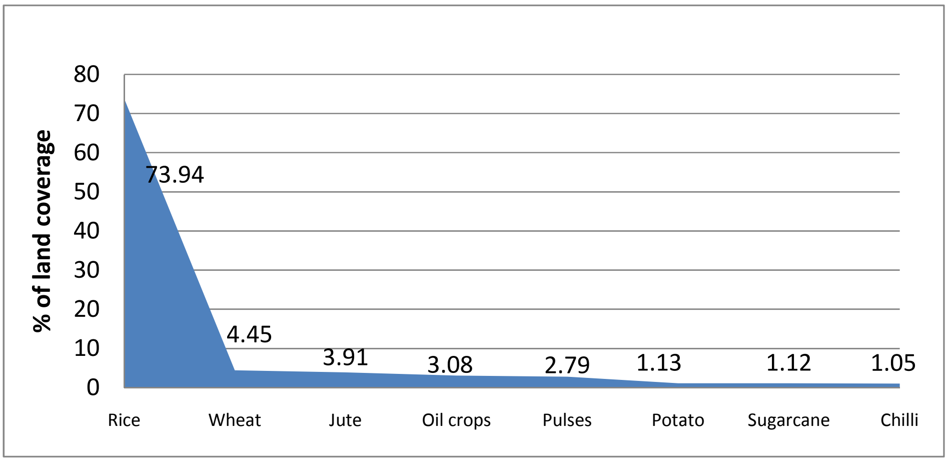
Classification	Level of salinity (dS/m)	Implications for agriculture
Non Intrude	No soil salinity	Favourable for agriculture
Non Saline	0-2	Favourable for agriculture
Very Slightly Salinity	>2-4	Favourable for agriculture
Slightly Saline	>4-8	Favourable for agriculture
Strongly Saline	>8-16	Partially favourable for crop and livestock agriculture but favourable for brackish water fish culture
Very Strongly Saline	>16	Not favourable for crop and livestock agriculture but strongly favourable for brackish water fish culture

3.3 Crops in Bangladesh

3.3.1 Major crops

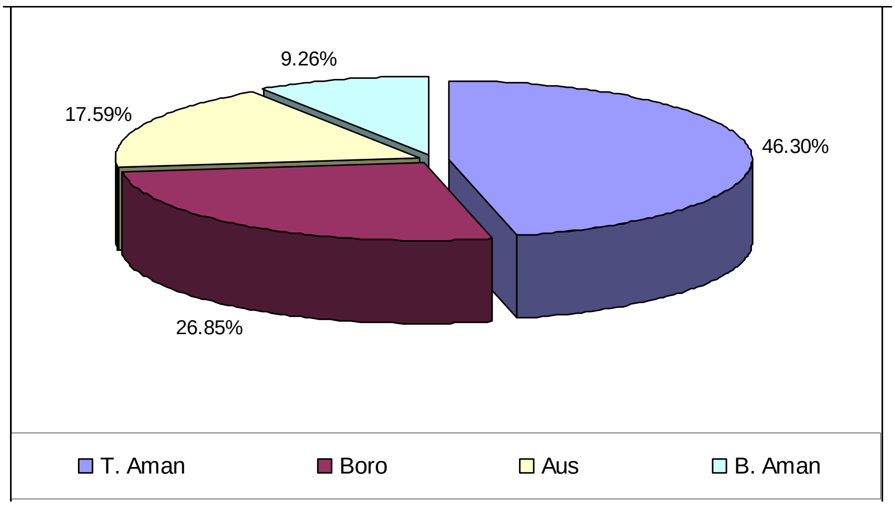
In Bangladesh, only nine crops (rice, wheat, jute, rape and mustard, lentil, cowpea, potato, sugarcane, and chilli) are grown on 90 per cent percent or more of the crop acreage (14.61 million ha) and may be considered as major crops. As can be seen from Figure 6 below, rice dominates the cropping pattern throughout Bangladesh.

Figure 6: Land coverage status of major crops in Bangladesh (Source: BBS 2008).



The rice crop has been broadly divided into three types: Aman (transplanted and broadcast varieties), Boro (dry season variety), and Aus (rainfed variety), according to the seasons in which they are harvested (November - January, March - May and July - August respectively).

Figure 7: Acreage of different types of rice cultivated in Bangladesh (Source: BBS 2008).

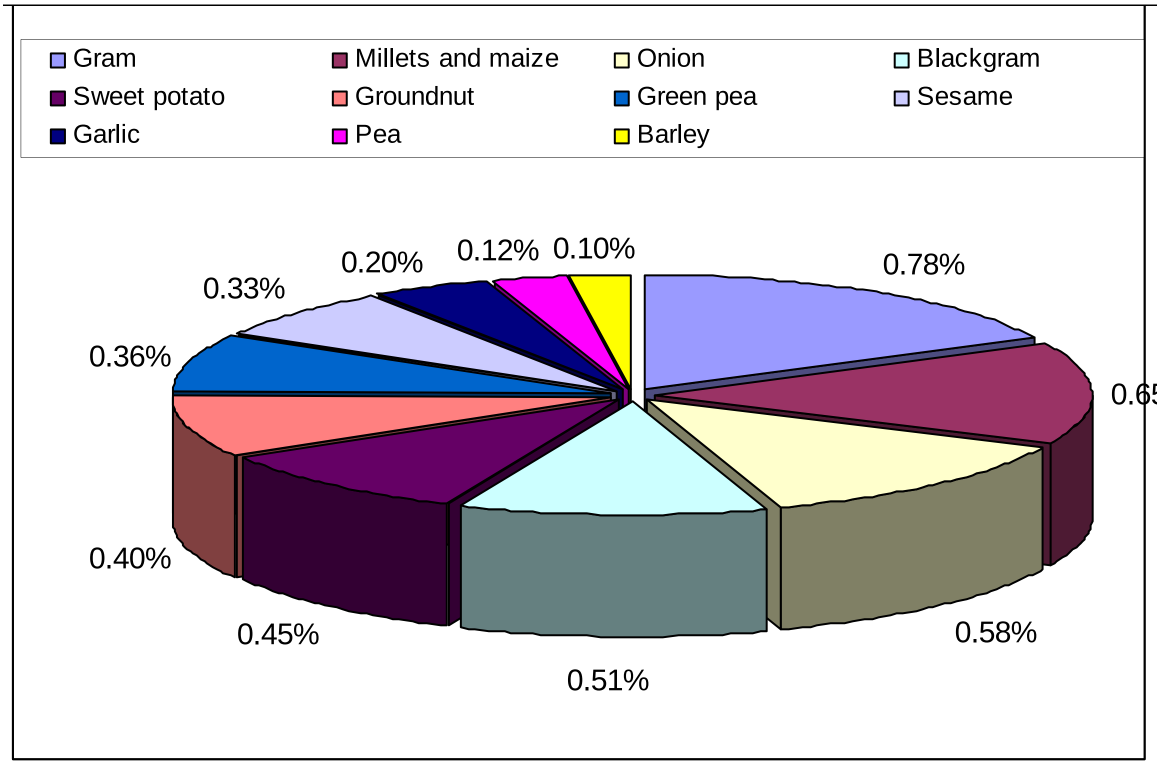


Next to rice, wheat is the most important crop in Bangladesh. It is grown mainly in the drier parts of the north and is cultivated only as a winter crop. Jute leads the country's list of export crops but is ranked third in terms of area cultivated. It is confined mainly to the low-lying areas of the Brahmaputra-Jamuna and Padma floodplains. Mustard (including rape) is the fourth most important crop. It is grown mainly in the low-lying areas of the Brahmaputra-Jamuna and Meghna floodplains. Lentil and *khesari* (cowpea) are the two important varieties of pulses produced in Bangladesh. Lentil is mainly grown in the Gangetic Delta while cowpea is a well-scattered crop in the islands and *chars* (any accretion in the riverbed, usually sandy islands). Potato is the most important of the winter vegetables and is widely grown. At present, potato is a very important crop to the districts of Munshiganj, Comilla, Rajshahi, Rangpur, Dinajpur, Bogra, Joypurhat and Nilphamari. Sugarcane is the eighth important crop in Bangladesh. Although chilli is produced to a certain extent in every district of the country, its cultivation is mainly concentrated in the northern districts including Bogra, Sirajganj and Pabna.

3.3.2 Minor crops

Crops that are grown on less than one per cent of the gross cropped area (GCA) of a country are considered minor crops. In Bangladesh gram, millets and maize, onion, black gram, sweet potato, groundnut, green pea, sesame, linseed, garlic, pea and barley, etc. are usually considered as minor crops. In addition some crops, including certain vegetables, spices, etc. occupy a very insignificant proportion of the GCA (i.e., less than 0.10 per cent to each crop), and they account for 1.57 per cent altogether.

Figure 8: Land used under minor crops in Bangladesh (Source: BBS 2008).



This study focuses on a system dominated by rice production. However within a single farm there are also supplementary crops, livestock and alternative sources of income.

Crop production in the last two years indicates some changes, with increased yield of rice, particularly Boro. There were similar increases in Aman and Aus too, although not as significant. The growth of rice yield is still far below the average yield usually obtained in experimental (research) fields, which is not less than 5 tonnes/ha. So there is still potential for improvement of rice yield, provided all factors for growth are present at the correct time in the growing cycle.

Yield of wheat also showed significant improvement, from 2.18 to 2.80 tonnes/ha. The reason behind this is the changes in the behaviour of climatic patterns. Continued wetness of soil due to erratic rainfall, and therefore the sowing time of the crops, is also affected. Winter maize has replaced wheat crop to a great extent. Yield of potato has increased. There is great potential for the potato crop in the country, but storage is the problem. In most cases, where there is bumper crop yield, the crop (potato) rots under the open sky. Sugarcane showed some decline in yields. Various reasons could be attributed to this. Again, apart from climate change, proper and timely utilisations of crop protection measures are important, although they are lacking in most places.

3.4 Cropping in Bangladesh: seasons and patterns

3.4.1 Rainfed crops

Due to the agro-ecological and socio-economic conditions, many of the farmers in Bangladesh use a sustainable, low-input, risk-aversion type of mixed farming – that uses little or no irrigated water – to attain minimum food security in the face of natural hazards. The total rainfed food grain-cropped area in 1994 - 95 was 10.6 million ha, which was about 76 per cent of the total cropped area.

The rainfed rice crop consists of Aus and Aman groups, high yielding varieties, *pajam*, local Aus, broadcast Aman, and local transplant Aman. The total irrigated and non-irrigated areas are given in the table below. The extent of the rainfed area is about 93 - 94 per cent of the total area under Aus and Aman crops.

Table 2: Rainfed and irrigated areas of Bangladesh (Source: BBS 2008).

Year	Total cropped area (million ha)	Rainfed area (per cent)	Irrigated area (per cent)	Rainfed area (million ha)	Irrigated area (million ha.)
2000-01	14.30	69.10	30.90	9.88	4.42
2001-02	14.19	67.62	32.38	9.60	4.59
2002-03	14.17	66.67	33.33	9.45	4.72
2003-04	14.04	64.85	35.15	9.10	4.94
2004-05	14.10	64.30	35.70	9.07	5.03

3.4.2 The cropping seasons

Due to its geographical location, Bangladesh has a unimodal monsoon climate bracketed by a hot-humid summer and a dry, mild winter. This determines the cropping pattern. The whole of the crop-growing period is divided into two main seasons, namely *kharif* and *rabi*, as well as a transition season called pre-*kharif.*

A. *Kharif* season (mid-March to mid-October)

The *kharif* season is characterised by high temperatures, rainfall and humidity. During this period, the moisture supply from rainfall plus soil storage is enough to support rainfed crops. *Kharif* crops are grown in the spring or summer season and harvested in late summer or in early winter. The season is divided into *kharif* I and *kharif* II. *Kharif* I, often called pre-*kharif*, actually starts from the last week of March and ends in May.

The principal crops grown in the country during this season are as follows: a) cereals: broadcast and transplant Aus, transplant Aman, millet, foxtail millet, and sorghum; b) tuber and root crops: *panikachu, mukhikachu, olkachu, mankachu*, and *pancha mukhikachu*; c) oil seeds: sesame, groundnut, and soybean; d) pulses: black gram, mungbean, cowpea and pigeon pea; e) summer vegetables: lady's finger, red amaranths, amaranths, Indian spinach, sweet gourd, ash gourd, bitter gourd, squash, *palwal*, snake gourd, teasel gourd, yardlong bean, brinjal, and summer tomato; f) spices: green chillies, ginger, and turmeric; g) fibre crops: jute, *kenaf*, *mesta*, and cotton; h) sugar crops: sugarcane; i) stimulants: tea; and j) fruit plants: banana, pineapple, papaya, and melon.

B. *Rabi* season (mid-October to mid-March)

This season is characterised by dry, sunny weather and is warm at the beginning and end, but cool in December - February. The average length of the *rabi* growing period ranges from 100 - 120 days in the extreme west to 140 - 150 days in the northeast part of Bangladesh.

Major *rabi* crops grown in the country include: a) cereals: wheat, maize, barley, and Boro rice; b) tuber and roots crops: potato and sweet potato; c) oil seeds: mustard, sesame, groundnut, niger, sunflower, linseed, and sunflower; d) pulses: chickpea, lentil, grass pea, and cowpea; e) winter vegetables: cabbage, cauliflower, brinjal, tomato, carrot, turnip, radish, spinach, lettuce, bottle gourd, country bean, and garden pea; f) spices: chilli, onion, garlic, coriander, sweet cumin, black cumin, and fenugreek; g) fibre crops: sunhemp; h) sugar crops: sugarcane; i) stimulants: tobacco; and j) fruit plants: watermelon.

3.4.3 Cropping patterns

A large number of cropping patterns are practised across Bangladesh, depending on land type, soil texture, flooding regimes, rainfall (amount and distribution) and the resource base of the farmers. Some dominant cropping patterns under variable crop production environments are as follows:

Table 3: Irrigation system with cropping pattern.

	Rabi	***Kharif-I***	***Kharif-II***
Rainfed condition	Wheat/potato/pulses/oilseeds/sugarcane	Boro (local) Aus/jute	Fallow
Irrigated condition	Wheat/Boro/potato/ tobacco/ winter vegetables	Fallow/T. Aus	T. Aman/ fallow

Generally, deep-rooted crops (such as jute) are grown after shallow-rooted crops (such as rice), which helps the uptake of soil nutrients from different depths and also helps to improve soil quality.

Figures 9 and 10, below, show how two common cropping patterns (Boro - fallow - T. Aman and wheat - B. Aus - T. Aman) vary according to inundation land type.

Figure 9: Cropping pattern: Boro - fallow - T. Aman in the study area (source: GIS Project, BGD /95/006, BARC).

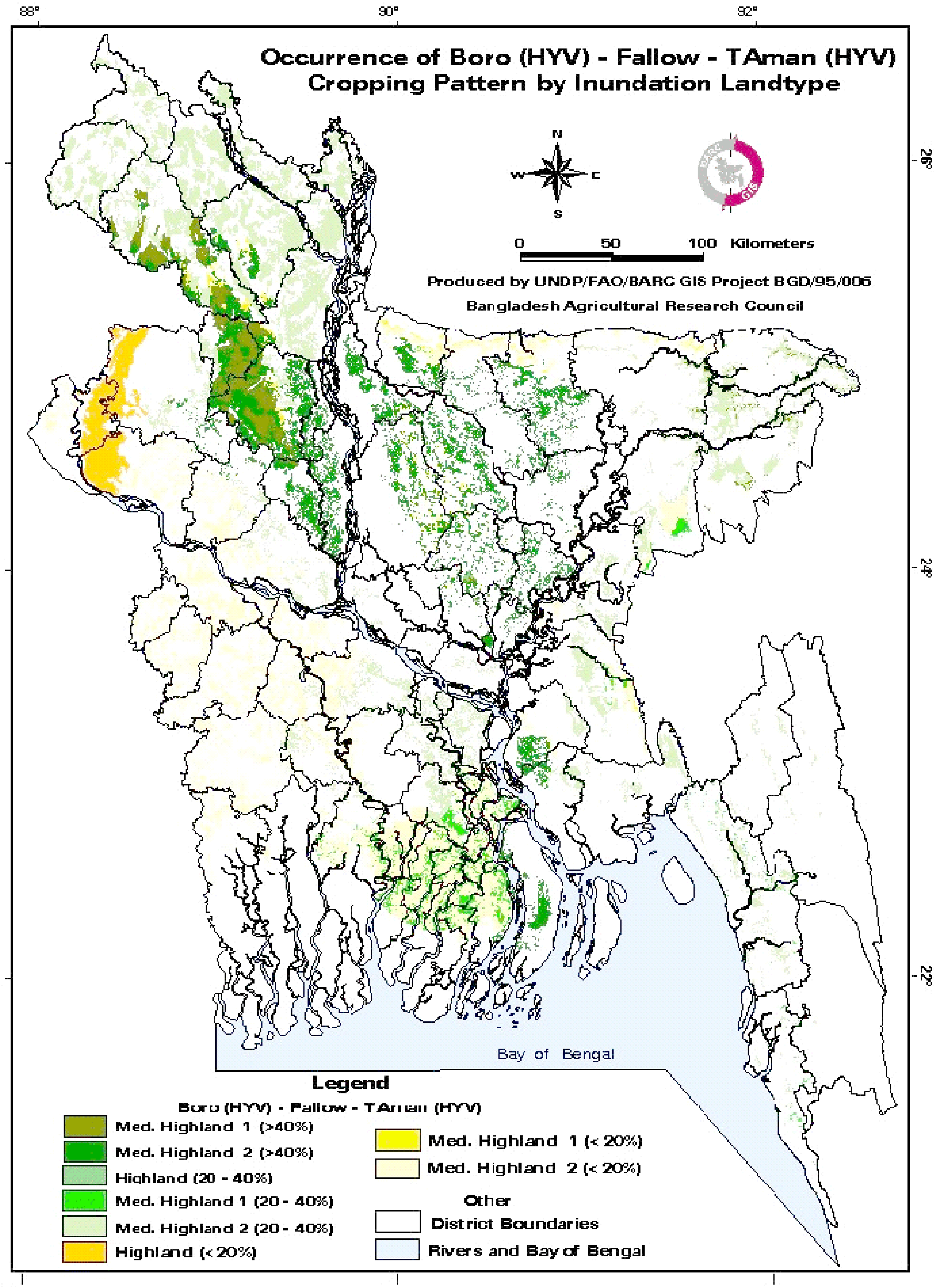
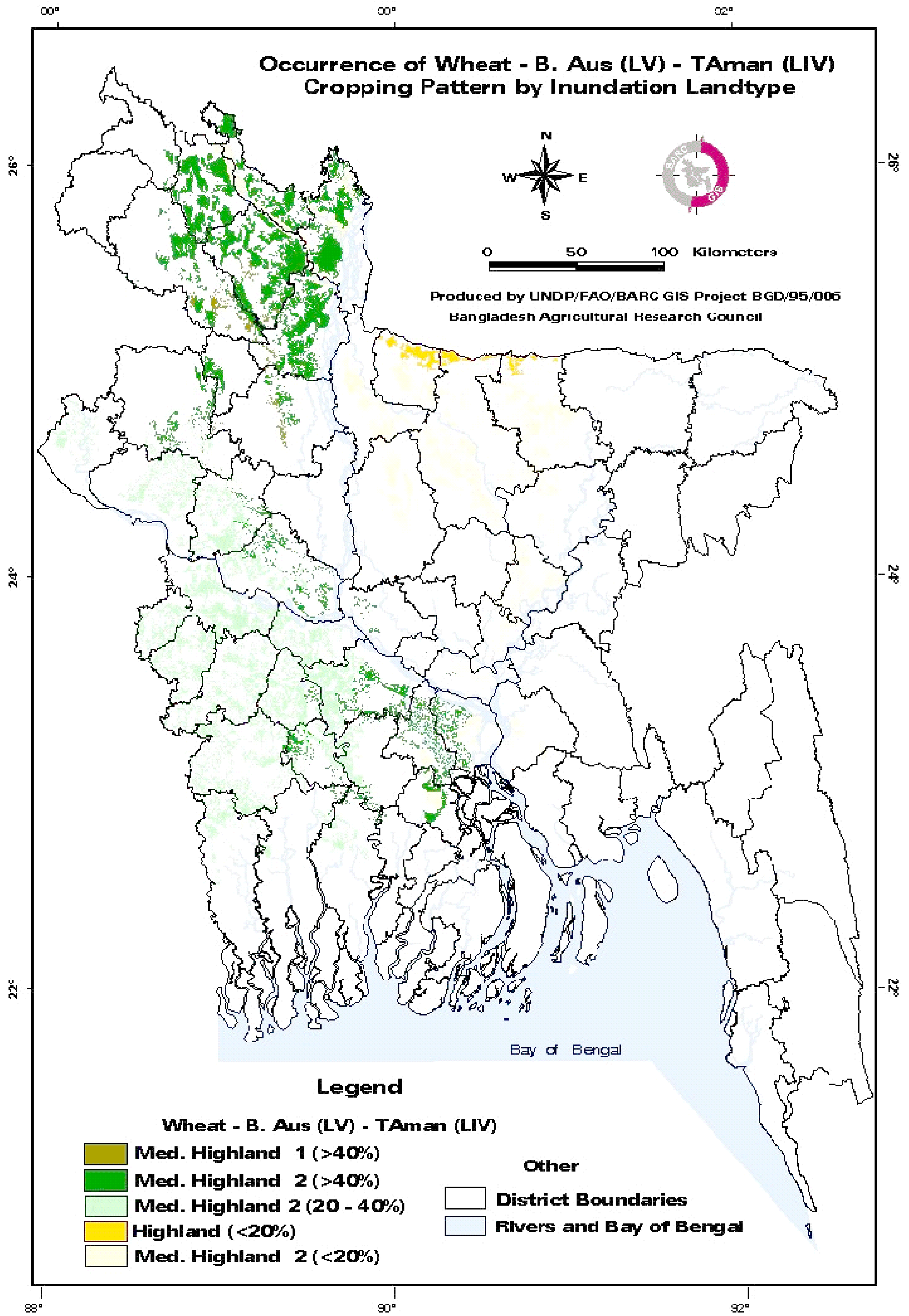


Figure 10: Cropping pattern: wheat - B. Aus - T. Aman in the study area (source: GIS Project, BGD /95/006, BARC).



3.5 Exposure of the agricultural system to climate change

Between 1991 and 2000, 93 major climate-induced disasters were recorded in Bangladesh. As a result, several billion US dollars were lost. The agriculture sector is grievously affected by these events. A number of different studies by the IPCC and other groups have shown that climate-induced events are increasing in both frequency and severity.

Almost all natural calamities affect the state of agriculture. The implications of sea level rise on the sediment balance may alter the profile of areas inundated and thus increase salinity in the coastal areas, for example. The state of the Bangladesh agriculture sector relies on the characteristics of annual floods. Regular flooding of various types (such as flash, riverine, coastal, etc.) has proven to be beneficial. Often, however, Bangladesh is hit with extensive floods having high intensity, i.e., high water depth. These events adversely affect agricultural production, and hence rural livelihoods. The economic impacts of these extreme events are grave. Moreover, droughts and sea level rise in the coastal areas also yield negative impacts.

The IPCC AR4 Global Climate Change Models show the changes in temperature to be positive for all months and seasons, even as early as the 2030s. Median warming of 0.75^{o}C, 1.55^{o}C, and 2.4^{o}C by the 2030s, 2050s, and 2080s respectively is estimated. By the 2050s, the annual precipitation during the wet season is estimated to increase (the simulations for the dry season do not show increases in precipitation over that time). Variations across model experiments are large. Median annual precipitation increases of 1 per cent, 4 per cent, and 6 per cent by the 2030s, 2050s, and 2080s respectively are estimated. Greater uncertainty (in terms of magnitude and direction) exists with respect to future precipitation than with future temperature.

As well as affecting the regional climate, climate change is expected to affect Bangladesh indirectly in two ways: through an increase in river discharge entering the north of the country, and through a rise in sea level, affecting the south of the country. Using three scenarios of sea level rise (15cm, 27cm and 62cm), total flooded area will increase 6 per cent, 10 per cent, and 20 per cent respectively. A trend toward a warmer and wetter future climate will impact the agriculture sector, particularly if the state of the climate goes beyond the variations found in the historical record. The estimated future temperature changes significantly separate from the background temperature variations. Precipitation is subject to large existing inter-annual and intra-annual variations.

Studies such as the World Bank's 2009 draft *Implications of Climate Change Risks on Food Security in Bangladesh* have indicated that the climate is changing and becoming more unpredictable every year in Bangladesh. Variability and extreme weather events are being experienced more frequently than ever before. Hazards like floods, droughts, cyclones and salinity intrusion are likely to be aggravated by climate change and sea level rise. Floods and waterlogging in the central region, flash floods in the northeast region, drought in the northwest and southwest regions, and salinity intrusion and coastal inundation in the coastal regional, would be more acute problems in future. All of these will have an extra bearing on the agriculture sector.

3.5.1 Climate change impacts on agriculture

Agriculture in Bangladesh is influenced by seasonal characteristics and climatic variables such as temperature, rainfall, humidity, day length, etc. The table below highlights the impact of different climate hazards on different sectors. It shows that crop agriculture is often constrained by different hazards and disasters such as floods, droughts, soil and water salinity, cyclones and storm surges.

Table 4: Sectoral vulnerability by hazard (Source MoEF 2009b).

Physical vulnerability context								**Sectoral vulnerability context**
Extreme temperature	Sea level rise		Drought	Flood		Cyclone and storm surges	Erosion and accretion	
	Coastal inundation	Salinity intrusion		River	Flash			
+++	++	+++	+++	+	++	+++	-	Crop agriculture
++	+	+	++	++	+	+	-	Fisheries
++	++	+++	-	-	+	+++	-	Livestock
+	++		-	++	+	+	+++	Infrastructure
++	+++	++	-	++	+	+	-	Industries
++	+++	+++	-	++	-	+	-	Biodiversity
+++	+	+++	-	++	-	++	-	Health
-	-	-	-	-	-	+++	+++	Human settlement
++	+	-	-	+	-	+	-	Energy

Key: +++ refers to high; ++ refers to moderate; and + refers to low-level relationship.

Different models predict different level of impacts for yield reduction under different climate change scenarios. The Geophysical Fluid Dynamics Laboratory (GFDL) model predicted an approximate 17 per cent decline in overall rice production for Bangladesh and as high as a 61 per cent decline in wheat production under a 4^{o}C change in temperature. The highest impact would therefore be on wheat followed by rice (Aus variety). Of the three types of rice grown in Bangladesh, the Aus rice (grown during the summer monsoon period under rainfed conditions) seems to be the most vulnerable. The Canadian Climate Change Model (CCCM) also predicted a significant fall in food-grain production.

Extreme temperature due to climate change would affect livestock. High temperatures cause great discomfort, decrease feed intake and alter nutrient metabolism, leading to high loss of energy. The combined effects of discomfort and nutrient metabolism reduce animals' productivity, resulting in financial losses for the farmers. Apart from extreme temperature, natural disasters such as cyclones and tidal surges, as mentioned previously, cause immense loss and suffering to livestock through destruction of forage crops as well as shelter.

The impact of climate change on many other food and non-food goods, (such as jute) is something of an unknown in Bangladesh currently. In terms of impacts, risks and vulnerabilities, Bangladesh could be divided into regions.

In the **coastal region**, degradation of productive land (including a reduction in quality as well as physical losses) is of key concern for coastal agriculture due to salinity intrusion and sea level rise. Recent assessments have suggested that about 13 per cent more land (469,000ha) will be inundated in the monsoon season due to a 62cm sea level rise Due to increased rainfall, in addition to the 62cm sea level rise, the inundated area will be increased by about a further 16 per cent (551,500ha). In the dry season, a 62cm sea level rise will account for about 364,200ha (ten per cent) more land inundated in the year 2080 (IWM and CEGIS 2007).

3.5.2 Direct impacts of climate change on agriculture

A. Future impacts on agriculture due to change of temperature and precipitation

Various studies indicate that a temperature rise of 1 to 2°C, in combination with lower solar radiation, causes sterility in rice spikelets. High temperature was found to reduce yields of high-yielding varieties (HYVs) of Aus, Aman and Boro paddy in all study locations and in all seasons. The effect was particularly evident at a rise of temperature by 4°C. Climate change indicators (temperature, humidity and radiation) have significant effects on the incidence of insect pests, diseases and micro organisms. A change of 1°C changes the virulence of some races of rust infecting wheat.

The production of crops in Bangladesh is constrained by too much water during the wet season and too little water in the dry season. At present, the total irrigated area is 4.4 million ha, which is more than 50 per cent of the potentially irrigable area of 7.12 million ha cultivated area. This area is being irrigated through surface and groundwater. Irrigation coverage through shallow tube wells (STWs) during the dry period has grown very swiftly following a policy of privatization and deregulation. As a result, the groundwater table in Bangladesh is declining at a rapid rate, causing STWs to become non-operational in many parts of the country during the dry period. Lack of surface water during the dry season limits the functioning of low lift pumps (LLPs) too.

The Geophysical Fluid Dynamics Laboratory (GFDL) model predicted an approximate 17 per cent decline in overall rice production and as high as a 61 per cent decline in wheat production compared to the baseline situation of 1990 under a 4°C change in temperature. The highest impact would be on wheat followed by rice (Aus paddy varieties). This translates to a reduction of 4.5 million tons of rice at the 2002 level of production. Of the three types of rice grown in Bangladesh, the Aus rice (grown during the summer monsoon period under rainfed conditions) seems to be the most vulnerable.

The other model, the Canadian Climate Change Model (CCCM), predicted a significant fall in food grain production. (It should be noted, however, that this scenario was based on projecting existing cropping patterns into the future, which is not necessarily what will happen as there are signs of significant changes already taking place in cropping patterns.) It was noted under this model that a temperature increase of 4°C would have severe impacts on food grain production, especially for wheat production. A rise in temperature would cause a significant decrease in production of 28 per cent and 68 per cent for rice and wheat respectively.

A shortfall in food grain production would severely threaten food security in this poverty-ridden country. On the other hand, carbon dioxide fertilization could facilitate food grain production. Moreover, doubling of atmospheric concentrations of CO_2, in combination with a similar rise in temperature, could result in an overall 20 per cent rise in rice production and 31 per cent decline in wheat production. It has been proposed that Boro rice would enjoy good harvests under a severe climate change scenario with the doubling of atmospheric concentration of CO_2 (Karim *et al*. 1999).

The apparent increase in yield of Boro (dry season paddy generally grown under irrigated conditions and including high-yielding varieties) and other crops might be constrained by moisture stress, however. A 60 per cent moisture stress on top of other effects might cause as high as a 32 per cent decline in Boro yield, instead of having an overall 20 per cent net increase. It is feared that moisture stress would be more intense during the dry season, which might force Bangladeshi farmers to reduce the area for Boro cultivation.

Under a severe (4^{o}C temperature increase) climate change scenario, the potential shortfall in rice production could exceed 30 per cent from the trend, while that for wheat and potato could be as high as 50 per cent and 70 per cent respectively (Karim 1996).

B. Future impacts on agriculture due to change in flooding

The Bangladesh *Climate Change Country Study* (BCAS 1997) assessed the vulnerability of water resources considering changes in flooding conditions due to a combination of increased discharge of river water during the monsoon period and sea level rise for the two projection years, 2030 and 2075. It is the F0 land followed by F1 land which would experience much of the changes in the north-central region in 2030. From the analysis it was also found that much of the impact in the year 2075 would be for F0 land followed by F1 land – where embankments played an important role in restricting the extent of flood affected areas. A combination of development and climate change scenarios revealed that the Lower Ganges and the Surma floodplain would become more vulnerable compared to the rest of the study area. On the other hand, the north-central region would become flood-free due to embanking of the major rivers (Alam *et al.* 1999). Tables 5 and 6 show changes in land type in 2030 and 2075 due to climate change and sea level rise.

Table 5: Changes in land type in 2030 (Source: Alam *et al*. 1999).

Land type	Existing area km^2	Transformed in 2030			
		F0	F1	F2	F3F4
F0[4] (0 - 30cm)	43,060	23,415	16,033	3,442	170
F0 + F1	1,184	592	592	0	0
F1 (30 - 90cm)	31,986	4,399	9,519	17,672	396
F1 + F2	260	0	130	130	0
F2 (90 - 180cm)	15,572	2,440	162	7,903	5,067
F2 + F3 + F4	362	0	0	127	235
F4 (> 180cm)	14,076	2,080	9	155	11,836
Urban area	757	757			
River bank/sand bar etc.	1,539				
Forest	5,546				
Mixed land	178				
No data	647				
Total	**115,167**	**33,683**	**26,445**	**29,429**	**17,704**

[4]F0 stands for the lowest flood level whereas F5 represents the highest flood level.

Table 6: Changes in land type in 2075 (Source: Alam *et al*. 1999).

Land type	Existing area km^2	Transformed in 2075			
		F0	F1	F2	F3F4
F0 (0 - 30cm)	43,060	19,588	16,203	6,730	537
F0 + F1	1184	592	592		
F1 (30 - 90cm)	31,986	7,884	4,160	17,589	2,354
F1 + F2	260		130	130	
F2 (90 - 180cm)	15,572	4,735	429	3,552	6,857
F2 + F3 + F4	362			127	235
F4 (> 180cm)	14,076	3,088		46	10,946
Urban area	757	757			
River bank/sand bar etc.	1,539				
Forest	5,546				
Mixed land	178				
No data	647				
Total	**115,167**	**36,644**	**21,514**	**28,174**	**20,929**

C. Future impacts on agriculture due to change in drought conditions

The Bangladesh Agricultural Research Council (BARC) has delineated different areas of the country under several categories of drought for two periods: *kharif* (roughly March - October) and *rabi* (roughly October - March) (BARC 1990). During the *kharif* season, precipitation exceeds evapotranspiration. Droughts in this season refer mainly to shortage of rainfall in the late growing period of T. Aman rice, which causes serious yield reduction and shifts in harvesting time (which subsequently affects the *rabi* cultivation after T. Aman). During the *rabi* period, evaporation exceeds rainfall and soil moisture depends heavily on the remaining water after the *kharif* season. Water stress is felt frequently after mid-*rabi* season. During the pre-*kharif* period, drought conditions depend on the rainfall pattern, which tends to be erratic during this period.

Future drought conditions were studied under two different sets of scenarios. It was found that the intensity of droughts will increase in both the scenarios. About 12,220km^2 will be transformed to the very severe drought class (i.e., lowest soil moisture level) as compared with the existing 3,639km^2 (i.e., more than a three-fold increase in area) under severe changes in the climatic systems during the *rabi* season.[5] During the *kharif* season, four times more area will be changed to very severe class from the severe and moderate areas. The worst affected regions would be north-west, north-central and south-west, where both irrigated and rainfed crops would be affected. The spatial distribution of present and future drought-prone areas in *rabi* and pre-*kharif,* and *kharif* seasons are given in Figures 11 and 12 respectively.

[5] Drought classification is based on temperature and soil moisture levels.

Figure 11: The spatial distribution of present and future drought-prone areas in *rabi* and pre-*kharif* seasons (Source: BARC 2003).

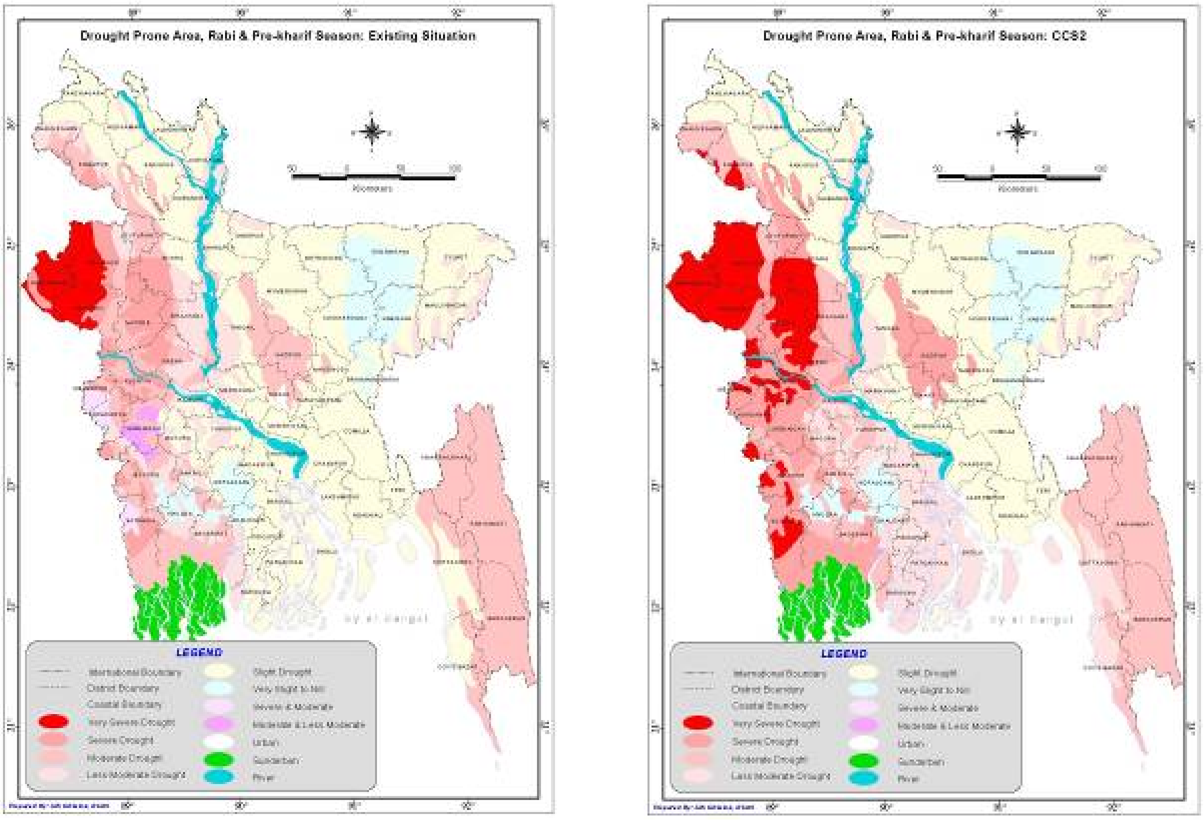
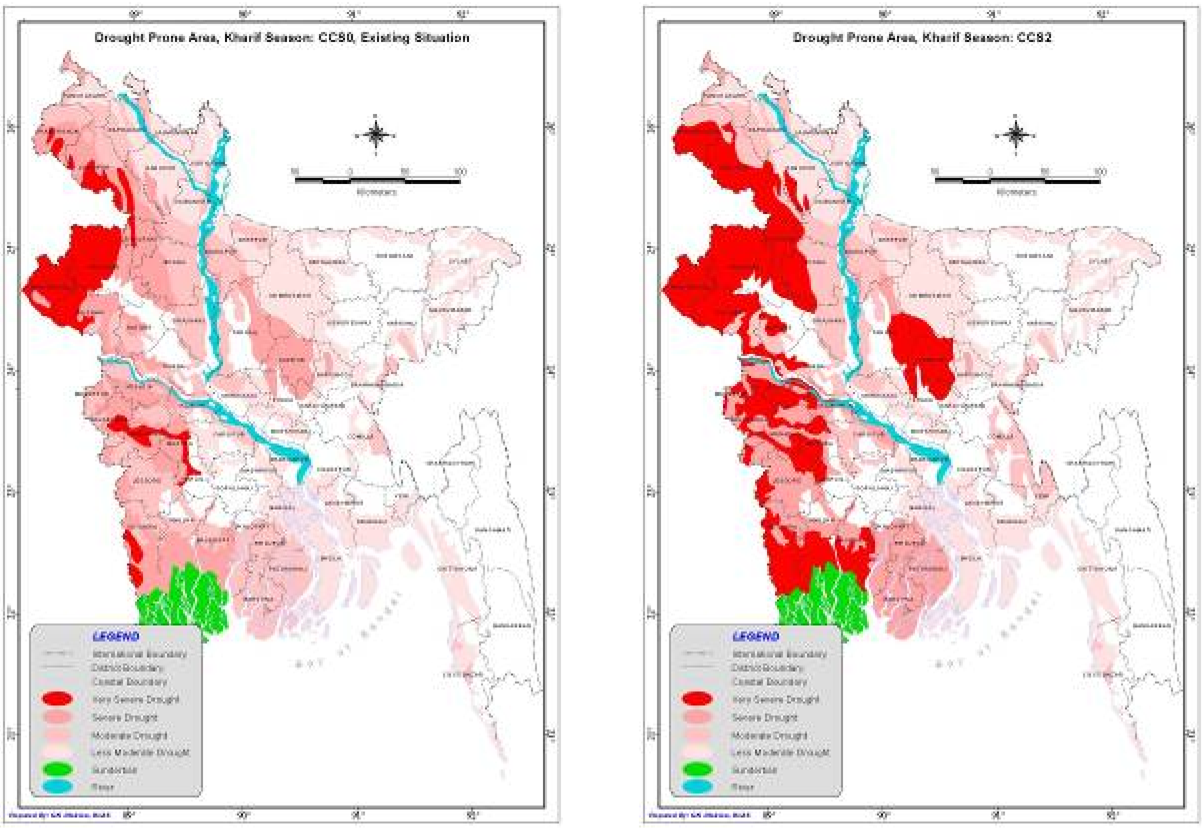


Figure 12: The spatial distribution of present and future drought-prone areas in *kharif* seasons (Source: BARC 2003).



3.5.3 Indirect impacts of climate change on agriculture

A. Future impacts on agriculture due to change in sea level rises

The coastal belt of Bangladesh already suffers from high levels of salinity as a result of saltwater intrusion. Figure 5 shows this to be increasing. The levels of salinity are expected to rise further under various climate change scenarios, as sea levels rise and saltwater intrudes even more.

Under a moderate climate change scenario, the crop loss due to salinity intrusion (as a result of sea level rise) could be about 0.2 million metric tonnes (Habibullah *et al*. 1999). The loss of production due to such effects may be relatively high compared to that due to floods. However, the loss incurred in other sectors could be much higher in the case of floods than due to direct climatic change. The effect of low-flow on agricultural vulnerability is considered to be much less intense compared to other effects.

By using the MIKE21 two-dimensional estuary model ((IWM and CEGIS 2007) for the 15cm, 27 cm, and 62 cm sea level rise scenarios, the changes in total flooded land type area are given in Table 7. Of an approximate total of 33,000km^2 in these coastal areas, over half is annually flooded. With an extreme rise of 62cm, an increase of ten per cent of flooded areas is anticipated. The geographic distribution of this is shown in Table 5. Districts where it is estimated that with a 62cm sea level rise the flooded area will increase by more than ten per cent include: Bagerhat (22 per cent), Barisal (23 per cent), Bhola (14 per cent), Cox's Bazar (10 per cent) and Noakhali (12 per cent). In general, with a sea level rise, the total flooded area increases by 6, 10 and 20 per cent for each of the scenarios respectively. The largest percentage increases in area are observed for the F4 (90-180 cm) flood land class.

Table 7: Sea level rise impacts on flood land types (km^2) (Source: IWM and CEGIS 2007).

SLR	F0 (0-30 cm)	F1 (30-60 cm)	F2 (60-90 cm)	F3 (90-180 cm)	F4 (180 + cm)	Flooded area (F1+F2+F3+F4)	Per cent of total
Base	15,920	4,753	4,517	5,899	1,759	16,928	52
15 cm	14,841	4,522	4705	6,765	2,015	18,007	55
27 cm	14,189	4,345	4488	7,456	2,370	18,659	57
62 cm	12,492	3,967	3818	8,977	3,594	20,356	62

4. Planning and costing adaptations for salinity-prone rice production

4.1 Background information on the case study area

The chosen study area for this project comprises the districts of Bagerhat, Khulna and Satkhira, which are coastal districts heavily affected by climate-induced effects.

Table 8: Areas of household survey.

Name of district	Name of *upazila*	Name of village	Number of households	Per cent of households
Bagerhat	Chitolmari	Sare Charani	11	3.7
		Santashpur	33	11.0
		Kathipara	6	2.0
		Sub-total	*50*	-
	Kochua	Purbo Mokhia	50	16.7
		Sub-total	*50*	-
		District total	**100**	-
Khulna	Dacope	Kamarkhola	50	16.7
		Bererkhal	50	16.7
		Sub-total	*100*	-
		District total	**100**	-
Satkhira	Shyamnagar	Bon Bibitola	50	16.7
		Jelekhali	21	7.0
		Harinagar	9	2.9
		Muthurapur	15	5.0
		Kultoli	5	1.6
		Sub-total	*100*	-
		District total	**100**	-
		Grand total	**300**	**100.0**

The selected households were rice-cultivating families in areas that are highly prone to salinity rise. In Bagerhat District, 50 households in Kochua *upazila* and 50 in Chitolmari *upazila* took part. In Khulna District, 100 households in Dacope *upazila* were interviewed (the salinity level is extremely high here). In the district of Satkhira, 100 households in Shyamnagar *upazila* were studied.

4.2 Importance of agriculture to the case study populations

It can be seen from Table 9 that the main occupation of the household heads is agriculture. Of the total population, 82 per cent are dependent on agriculture as their main occupation and source of income. Agro-labour is the main source of income of only ten per cent of the study population. In Khulna District, it can be seen that there are some share croppers as well as service holders. As Khulna is the regional hub, there tends to be diversification of occupations in the area.

Table 9: Main occupation of household heads by study area (i.e., answering 'Yes').

Main occupation	Percentage			
	Bagerhat	Khulna	Satkhira	All
Agriculture	73.0	78.0	98.0	82.9
Agro-wage labour	10.0	6.0	-	5.4
Non-agro labour	1.0	-	-	0.3
Sharecropping	-	6.0	-	2.0
Service	4.0	4.0	2.0	3.3
Business	7.0	3.0	-	3.4
Handicrafts	1.0	-	-	0.3
Rickshaw/van puller	1.0	-	-	0.3
Others	3.0	3.0	-	2.1
Total	**100.0**	**100.0**	**100.0**	**100.0**

While the primary occupation of the respondents is concentrated towards agriculture, it can be seen from Table 10 that the secondary occupation is not as skewed as the primary occupation in this study. Agro-labour is practised by 36 per cent of the heads of the households in Bagerhat as secondary occupation. Only 14.6 per cent use agriculture as the secondary mode of occupation. In Satkhira District, 14 per cent are involved in business, while only 11.6 per cent of the study area as a whole uses the latter as a mode of income. Fishing is conducted by 4.5 per cent of the population under the study. More than 9.1 per cent are involved in shrimp/crab culture as the secondary occupation.

Table 10: Secondary occupation of household heads by study area (i.e., answering 'Yes').

Secondary occupation	Percentage			
	Bagerhat	Khulna	Satkhira	All
Agriculture	36.2	13.3	2.6	14.6
Agro-wage labour	21.3	25.4	21.3	22.9
Non-agro labour	17.0	10.7	15.8	14.2
Share cropping	-	8.0	-	3.0
Service	-	1.3	3.9	2.0
Business	14.9	6.6	14.4	11.6
Fishing	2.1	6.7	3.9	4.5
Fish culture	2.1	4.0	6.6	4.5
Shrimp/crab culture	2.1	12.0	10.5	9.1
Livestock rearing	-	2.7	2.6	2.0
Rickshaw/van puller	4.3	-	3.9	2.5
Household work	-	-	5.3	2.0
Others	-	9.3	9.2	7.1
Total	**100.0**	**100.0**	**100.0**	**100.0**

While secondary occupations act as a form of risk-spreading, it is clear that agriculture remains of critical importance to the case study population.

4.2.1 Household income and expenditure

Table 11 shows the average annual income and expenditure of the area, which highlights the economic profile of households. The average annual income per household is BDT137, 451 in the total study area. The mean expenditure is BDT94,079, which connotes a large savings rate amongst the study population. The spread of household incomes varies from less than BDT50,000 to over BDT300,000 annually. The mode income is BDT50,000 to BDT100,000, as shown in Table 12.

Table 11: Average income, expenditure and surplus.

Study area	Average total annual income per household (BDT)	Average total annual expenditure per household (BDT)	Average savings (BDT)
Bagerhat	102,740	61,286	41,454
Khulna	148,157	119,553	28,964
Satkhira	161,454	101,397	60,057
All	137,451	94,079	43,372

Table 12: Percentage distribution of households according to annual income.

Annual income (BDT)	Study area			
	Bagerhat	Khulna	Satkhira	All
Up to 50,000	29.0	12.0	6.0	15.7
50,000 - 100,000	37.0	27.0	25.0	29.7
100,000 - 150,000	19.0	18.0	23.0	20.0
150,000 - 200,000	5.0	16.0	24.0	15.0
200,000 - 250,000	3.0	11.0	7.0	7.0
250,000 - 300,000	4.0	9.0	4.0	5.7
300,000+	3.0	7.0	11.0	6.9
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 13: Percentage distribution of households according to the balance of income and expenditure.

Balance of income and expenditure	Study area			
	Bagerhat	Khulna	Satkhira	All
More income than expenditure	67.0	77.0	75.0	73.0
Income and expenditure are equal	3.0	4.0	6.0	4.3
More expenditure than income	30.0	19.0	19.0	22.7
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 13 shows that in Bagerhat, 67 per cent of the study households saves after meeting typical expenditures per annum. About 30 per cent of households in the district have higher expenditure than income. In Khulna and Satkhira, 77 per cent and 75 per cent respectively spend at rates lower than their incomes, while expenditure beyond income is 19 per cent. This shows the majority of the study population live within their means. Those who suffer from a deficit fulfil their requirements by different means. Table 14 shows that budget deficits are met by obtaining loans. Reducing family expenditure is another way of meeting requirements. Relatives also help to fulfil the needs of the family.

Table 14: Percentage distribution of strategies to address budget deficit.

Strategy to address deficit income	Study area			
	Bagerhat	**Khulna**	**Satkhira**	**All**
To take loan from bank	4.3	4.8	11.8	7.6
To take loan from NGO	2.2	9.5	3.8	4.2
To take loan	80.5	19.0	41.2	52.7
To take loan from relatives	-	19.0	19.6	11.9
To reduce family expenditure	4.3	47.7	15.7	16.9
To take loan from cooperative	-	-	5.9	2.5
Mortgaged land	2.2	-	2.0	1.7
Others	6.5	-	-	2.5
Total	**100.0**	**100.0**	**100.0**	**100.0**

The households with a deficit would require extra borrowing to cope and adapt to climate change impacts. Access to such loans, however, may be difficult given the constrained credit facilities and low credit-worthiness of the poor households in the coastal belt. This may further exacerbate the poverty situation of the households carrying a deficit.

Both rapid onset climate events (such as cyclones and storm surges) and slow onset events (such as salinity intrusion or sea level rises) are likely to be further intensified with a changing climate and for adaptation to these events, certain sectors of the population would need additional resources.

4.3 Farming practices in the case study system

Most household income in the study area in the coastal region of Satkhira, Bagerhat and Khulna districts derives from agriculture, which includes crop cultivation, fisheries and livestock rearing. Due to frequent natural disasters, fish culture is made difficult. Inundation of pond water due to floods and cyclones generates huge losses for those investing in fisheries in the coastal areas. Due to high salinity in the area, cattle do not thrive either as the lack of vegetation forces cattle to migrate to areas where vegetation is more abundant. As a consequence, crop agriculture forms the basis of the majority of the population's livelihoods. As in the majority of agricultural areas in Bangladesh, rice is the predominant crop and farming in the coastal belt is largely rainfed. Respondents tend to grow traditional rice varieties as well as saline-resistant varieties.

4.3.1 Land holdings

The average size of land holding per household in Satkhira District is 215.5 decimals while in Khulna it is 148.2 decimals and in Bagerhat it is 127.2 decimals; the average land size per household is 163.6 decimals.[6] Among the study population, it was reported that roughly 26 per cent falls under the category of 'functionally landless', i.e., possessing only 0 to 49 decimals. Furthermore, 'marginal' land owners consist of those who own 50 to 149 decimals. This group is the most populous as 37 per cent of the study population own roughly 50 to 149 decimals. 'Small-scale' land owners possessing 150 to 249 decimals comprise 16.7 per cent, and 19.3 per cent of the study population are medium-scale land holders who hold 250 to 749 decimals of land. Only 1.3 per cent of the respondents are large-scale farm owners, whose farm sizes are greater than 750 decimals, as seen in Table 15.

[6] 1 decimal = 40.48m^2.

Table 15: Average land holding size per household by study area.

Study area	Average land holding size per household (decimals)
Bagerhat	127.2
Khulna	148.2
Satkhira	215.5
All	163.6

Table 16: Percentage distribution of households by land holding.

Land group (decimals)	Study area			
	Bagerhat	Khulna	Satkhira	All
Functionally landless (up to 49)	35.0	29.0	14.0	26.0
Marginal (50-149)	33.0	38.0	39.0	36.7
Small-scale (150-249)	18.0	16.0	16.0	16.7
Medium-scale (250-749)	14.0	15.0	29.0	19.3
Large-scale (750+)	-	2.0	2.0	1.3
Total	**100.0**	**100.0**	**100.0**	**100.0**

4.3.2 Cropping patterns and the seasonal calendar

A rice-dominant cropping pattern is prevalent because of soil characteristics, weather and climate, and availability of irrigation water. Paddy (Aus, Aman and Boro) may be grown in the study area in the *rabi* and *kharif* seasons, but the erratic behaviour of rainfall and the availability (or otherwise) of surface water for irrigation affects the cultivation of Boro paddy in the *rabi* season and in the *kharif* season affects Aus and Aman paddy cultivation. Furthermore, any inundation of low land and medium highland and delay in the waters receding will affect the cultivation of Aman paddy. In a similar manner, the erratic behaviour of the rainfall and high temperatures in the *rabi* and *kharif* I seasons affects the cultivation of Boro and Aus paddy due to increase soil salinity, decreasing their yields

The seasonal cropping pattern is shown in Table 17.

Table 17: Seasonal calendar in the study areas.

	***Rabi*: mid-October to mid-March**					***Kharif* I: mid-March to mid-July**				***Kharif* II: mid-July to mid-October**		
Crop name	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
T. Aman												
Boro												
Wheat												
Potato												
Jute												
Maize												
Winter vegetables												
Summer vegetables												
Pulse crops												
Oil crops												
Shrimp cultivation												
Shrimp + Aman. paddy	paddy growing stage			stocking	culturing period					seed sown and transplantation		
Livestock rearing												

Note:

- Seed sowing/transplantation period
- Vegetative/reproductive period
- Ripening /harvesting period

4.3.3 Current adaptations to high levels of soil salinity

The salinity of the study areas in the coastal districts impacts considerably on crop cultivation in the area. There are two mains ways salinity is addressed:

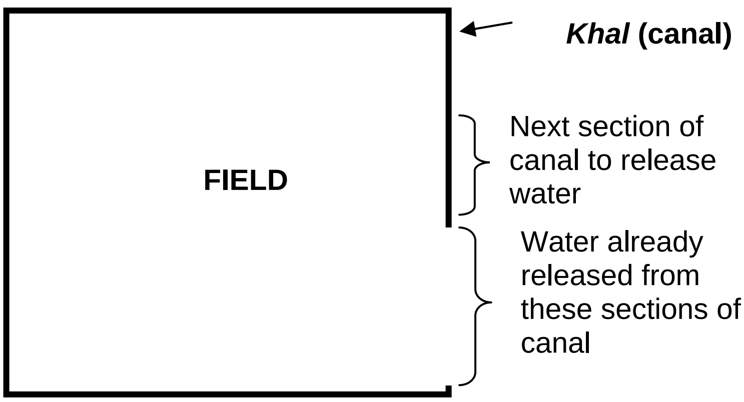
1. Using crop varieties that are able to withstand high levels of salinity.

2. Using water management to lower the level of salinity in the soil.

Very recently, government agricultural agencies (including BRRI, BINA and BARI) have developed rice, maize and vegetable cultivars to address the salinity issue, though these cultivars are not yet available at the community level. Some demonstration plots have been established in the study area by the DAE in collaboration with on-farm research divisions of BRRI, BARI and BINA, to demonstrate results and to motivate farmers to cultivate these salt-resistant cultivars. The Bangladesh Agriculture Development Corporation (BADC) is continuing its seed multiplication programme to ensure quality seeds and to make them available to the farmer community during the production period, thus encouraging them to cultivate saline-resistant cultivars as well as harvesting more crops.

At the community level, the farmers of the study area are practising excavation and re-excavation of mini-ponds, or '*disks*', on their land to store water during the monsoon and to irrigate their crop fields during the dry period. In addition, they are also using surface water (freshwater) from excavated and re-excavated *khals* and other sources that are available near their fields to irrigate them during the dry period – but these sources are not sufficient. The influx of water acts to flush out salts from the soil, thus lowering salinity. Some of the cultivable lands however remain fallow due to a lack of freshwater supply.

Figure 13: Excavation of *khal* (canal*)* around the crop land for irrigation.



People in the communities of the study area mentioned that a huge area of canal had been excavated once, but it has not been re-excavated for a long time. The canal had silted up, thus constraining the sources of irrigation. Initiatives taken to re-excavate the canal will allow more water to be stored during the monsoon, which could be used in dry periods for irrigation purposes, thus helping to increase the cultivation area and raise production as well.

4.4 Vulnerability to natural disasters and climate change

As we expect climate change to increase the magnitude and frequency of natural disasters, vulnerability to current disasters gives a good indication of a population's vulnerability to future climate change. However, climate change may bring new impacts that cannot be extrapolated from current variabilities.

4.4.1 Exposure

Table 18 shows the frequency of different natural calamities in the respective study sites. Floods severely affect the area as does salinity. Heavy rainfall, increased temperature, river erosion and droughts are other indications of climate strains.

Table 18: Per cent of households having experienced different hazards.

Type of natural disasters/hazards	Study area			
	Bagerhat	Khulna	Satkhira	All
Flood	99.0	99.0	90.0	96.0
Drought	76.0	97.0	95.0	89.3
Tornado	2.0	45.0	1.0	16.0
Salinity	64.0	98.0	97.0	86.3
Sea level rise	-	16.0	2.0	6.0
Heavy rainfall	60.0	84.0	57.0	67.0
Increased temperature	20.0	55.0	89.0	54.7
River erosion	-	12.0	12.0	8.0
Waterlogging	-	22.0	23.0	15.0
Tidal surge	2.0	64.0	9.0	25.0
Cyclone	97.0	96.0	95.0	96.0
Soil erosion	5.0	1.0	1.0	2.3

Floods and cyclones are the most common hazards/disasters encountered by the highest percentage (96 per cent) of the households. The next common hazard/disaster is drought, encountered by 89.66 per cent households. Drought is followed by salinity (86 per cent). Other hazards have affected relatively small numbers of households.

Soil salinity levels in the study area

Salinity levels are already high across the three districts of Satkhira, Khulna and Bagerhat. The current salinity levels are, however, expected to increase due (in part) to rising sea levels and increased inundation as a result of global sea level rises due to climate change. This is consistent with Figure 14, which shows that salinity is rising across the coastal belt of Bangladesh as the salinity iso-lines move further inland.

Figure 14: Soil salinity status of Satkhira District areas (Source: SRDI, regenerated by GIS Division, BCAS).

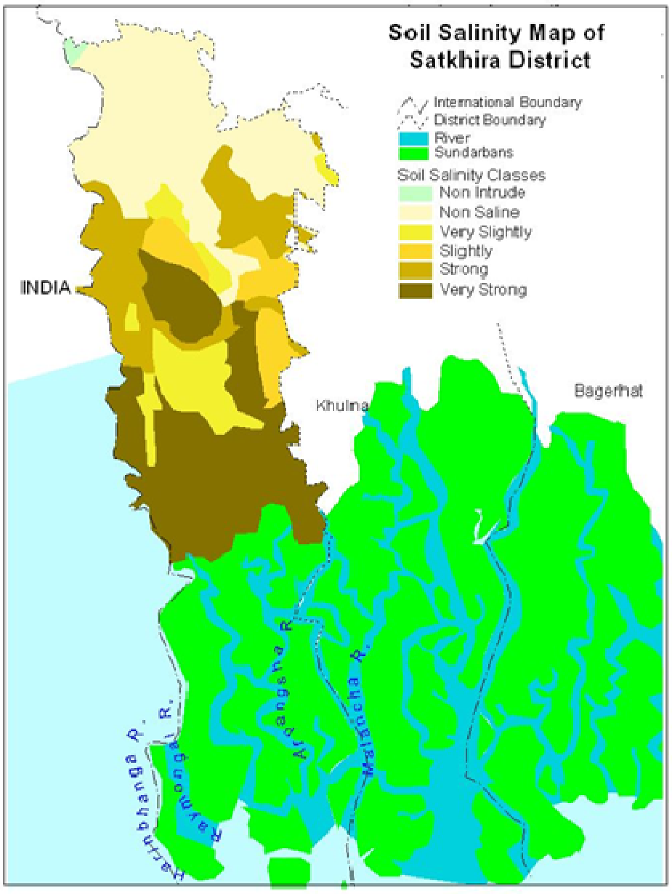


Figure 14 shows the location of Satkhira District. The district borders India. Much of Satkhira (29 per cent) is covered by the Sundarbans. The map colour codes the areas affected by the different magnitudes of salinity. Table 19 presents the status of soil salinity in Satkhira District in 2009. The table indicates that 23.45 per cent of the total area was 'Very Strongly Saline'; roughly 23 per cent of Satkhira District faces 8 to 16 dS/m and 11.75 per cent of the total area of Satkhira experienced 'Strongly Saline' conditions. Only 10.79km^2, or 0.27 per cent of the whole area, is characterised as a 'Non-Intrude' area. The high rates of salinity are threatening to the agriculture in this area.

Table 19: Soil salinity in Satkhira District, 2009 (Source: SRDI 2010).

Salinity type	Area (in sq km)	Percentage (per cent)
Non-Intrude	10.79	0.27
Non-Saline	885.53	22.95
Very Slightly Saline	268.58	6.96
Slightly Saline	209.33	5.43
Strongly Saline	452.95	11.75
Very Strongly Saline	904.84	23.45
Sundarbans	1,126.31	29.19
Total	**3,858.33**	**100.00**

Figure 15: Soil salinity status of Khulna District areas (Source: SRDI, regenerated by GIS Division, BCAS).

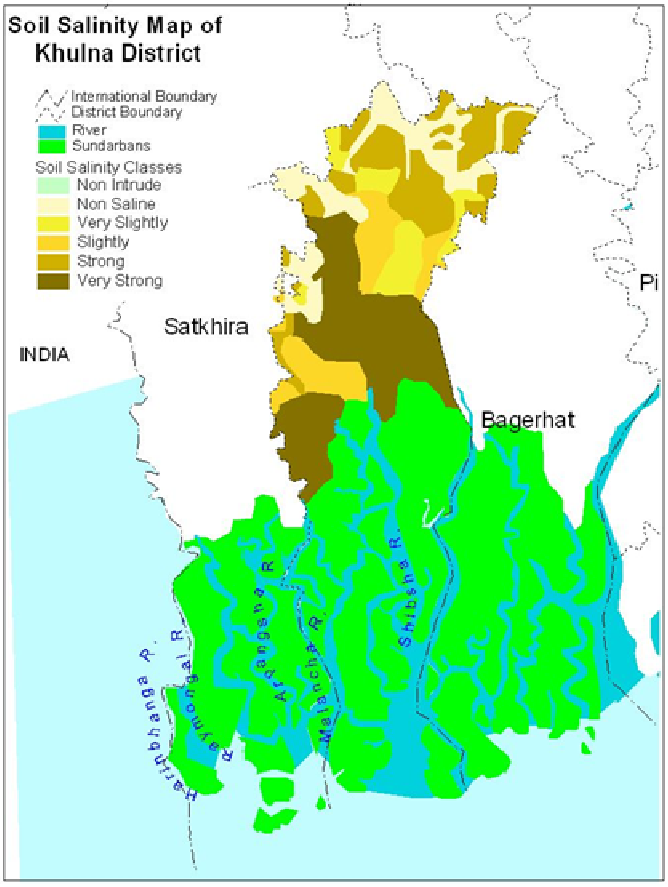


Figure 15 illustrates the location of Khulna District in relation to Bangladesh. The coastal proximity is shown. The Sundarbans area lies in between mainland Khulna and the Bay of Bengal. The areas bordering the Sundarbans represent the most dramatic extreme of salinity. A small portion only represents a 'Non-Saline' area, and in a total area of 4,394.46km^2 any 'Non-Intrude' areas are now absent. The extent of the 'Very Strongly Saline' area is 17.39 per cent of the total area. Another 527.49 km^2 of area is characterised as 'Strongly Saline', ranging between 8 to 16 dS/m (12 per cent of the total area of Khulna District). 'Very Slightly Saline' areas equal 7.96 per cent of the total area, as shown in Table 20.

Table 20: Soil salinity status in Khulna District, 2009 (Source: SRDI 2010).

Salinity type	Area (in sq km)	Percentage (per cent)
Non-Intrude	0	0
Non-Saline	385.24	8.76
Very Slightly Saline	349.99	7.96
Slightly Saline	312.87	7.13
Strongly Saline	527.49	12.00
Very Strongly Saline	764.13	17.39
River	645.17	14.68
Sundarbans	1,409.57	32.08
Total	**4,394.46**	**100.00**

Figure 16: Soil salinity status of Bagerhat District (Source: SRDI, regenerated by GIS Division, BCAS).

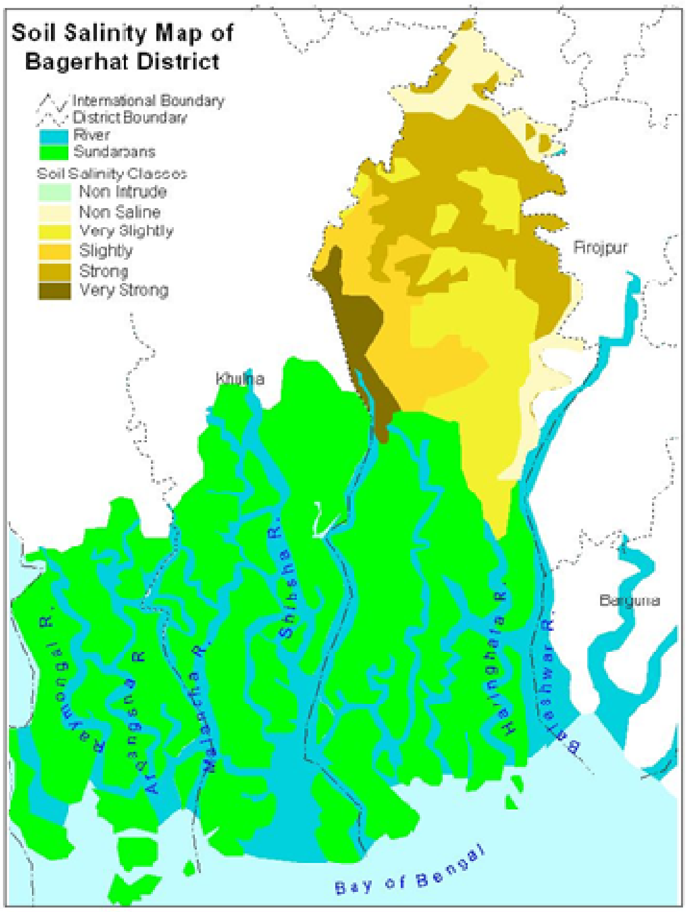


Figure 16 shows the location of Bagerhat District; 34 per cent of the 3,959.11km^2 area consists of the Sundarbans. The map shows that the problems of salinity are intense here as well. The map shows that most of the area is either 'Very Strongly Saline' or 'Strongly Saline'. Table 21 below shows that while there is an absence of any 'Non-Intrude' area, 'Slightly Saline' areas make up about 8.41 per cent of the total area; 18.68 per cent of the total area is 'Very Strongly Saline'; and 17.75 per cent is 'Strongly Saline'.

Table 21: Soil salinity status in Bagerhat District, 2009 (Source: SRDI 2010).

Salinity type	Area (in sq km)	Percentage (per cent)
Non-Intrude	0	0
Non-Saline	267.39	6.75
Very Slightly Saline	0	0
Slightly Saline	333.08	8.41
Strongly Saline	702.60	17.75
Very Strongly Saline	739.42	18.68
River	567.80	14.34
Sundarbans	1,348.83	34.07
Total	**3,959.11**	**100.00**

4.4.2 Impacts

The respondents unanimously agreed that wealth and income are adversely affected by natural disasters. The wealth and livelihoods of 86.3 per cent of the population are vastly affected by salinity. Roughly 96 per cent were affected by both floods and cyclones. Droughts were also part of the problem faced by the respondents, while heavy rainfall affects 67 per cent of the population.

Figure 17: Percentage of households that indicated that natural disasters had an impact on their wealth and income.

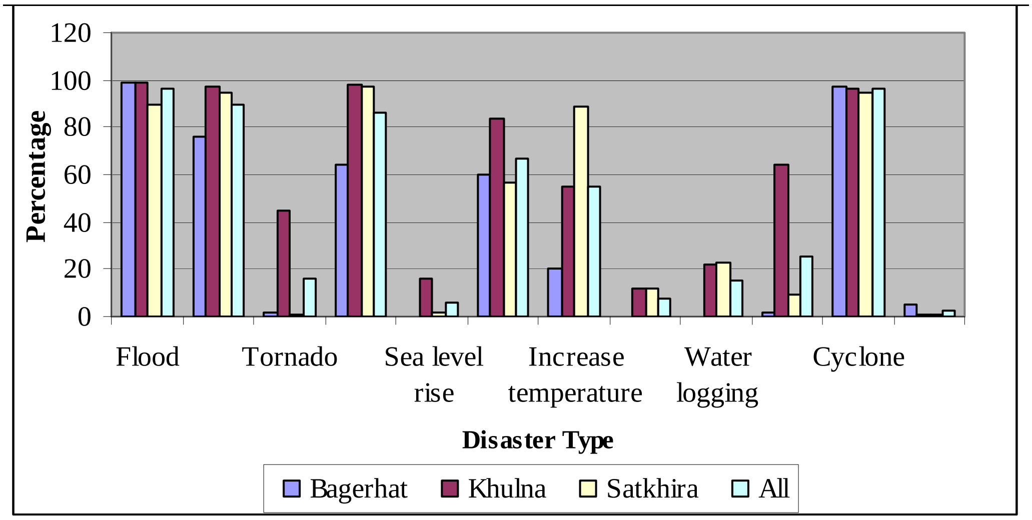
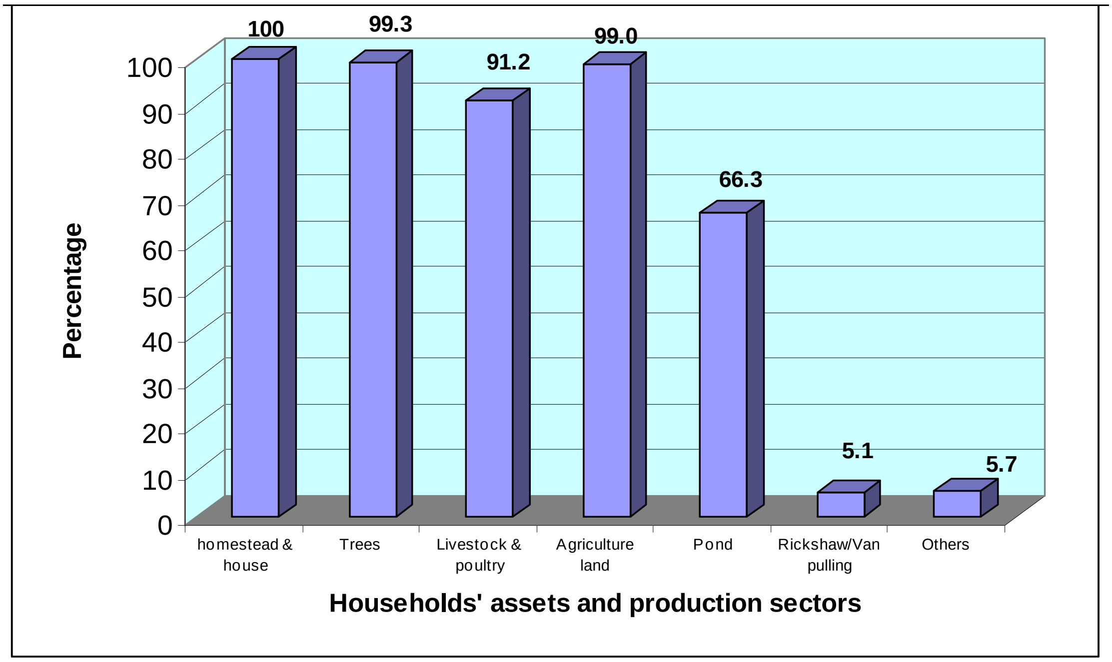


Figure 18: Percentage distribution of households that indicated that natural disasters had an impact on their wealth and income.



Among the households surveyed, 100 per cent reported that their homestead/housing had been damaged by natural disasters, including cyclones/floods. Damage/loss of trees has been reported by 99.3 per cent of households. Natural disasters have caused damage to the agricultural land of 99 per cent households. Other assets that were damaged by natural disasters included livestock and poultry (91.2 per cent of households) and ponds (66.3 per cent of households).

As climate change manifests itself, livelihoods are gravely affected because income sources are devastated. The respondents were asked about the sector-wide effects of respective natural disasters. In terms of paddy cultivation, it was found that floods and cyclones impacted the most. Approximately 58.3 per cent of the respondents found that salinity severely affected their income source. Salinity also moderately affects livestock and poultry in the study area. Floods severely impact those areas as well. Sea level rise severely affects half of other agricultural crops. The sale of agro-labour is severely affected by floods.

4.5 Agricultural adaptation to climate change

The previous subsection has shown that there are a multitude of both direct and indirect ways in which climate change impacts on coastal agriculture. However this study has chosen to focus on adapting to increasing salinity, caused by rising sea levels, because this is a crucial and urgent climate change impact facing the local population. As such, the remainder of the report focuses on adapting to rising salinity levels.

4.5.1 Current coping measures

The two main coping measures adopted by farmers in Satkhira, Bagerhat and Khulna are digging *khals* (canals) – which allow them to flush freshwater through their fields, reducing the salinity – and cultivating saline-resistant crops, as discussed previously. Whereas fewer than a third of farmers surveyed dig *khals*, the majority of farmers in the case study area cultivate saline-resistant crops. Coping strategies vary between the districts however, with the table below showing that while 42.6 per cent of Satkhira respondents dig canals and drain freshwater to use for irrigation, only 14 per cent use this practice in Bagerhat and 27 per cent in Khulna.

Table 22: Percentage distribution of households that indicated that they dig *khal* for the irrigation of fresh water.

Study area	Yes	No	Total
Bagerhat	14.9	85.1	100.0
Khulna	27.6	72.4	100.0
Satkhira	42.6	57.4	100.0
All	31.0	69.0	100.0

In the household survey (as shown in Figure 19 below) roughly 48 per cent of the population in Bagerhat, 91 per cent in Khulna and 85 per cent in Satkhira adapted to increasing salinity by cultivating saline-resistant crops. Overall, 75 per cent of the study population adapted to salinity by cultivating saline-resistant crops.

Figure 19: Percentage distribution of households that indicated that they cultivate saline-resistant crops.

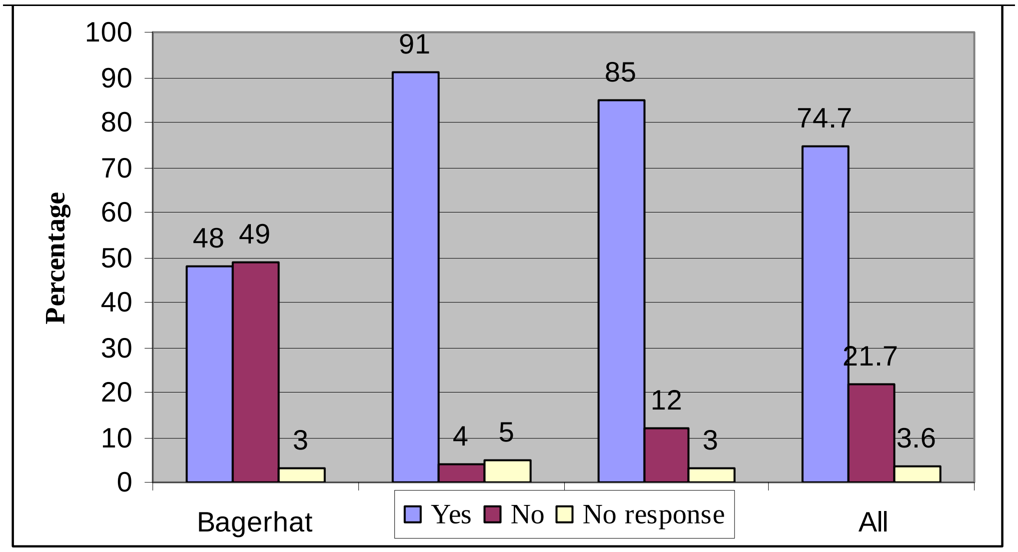


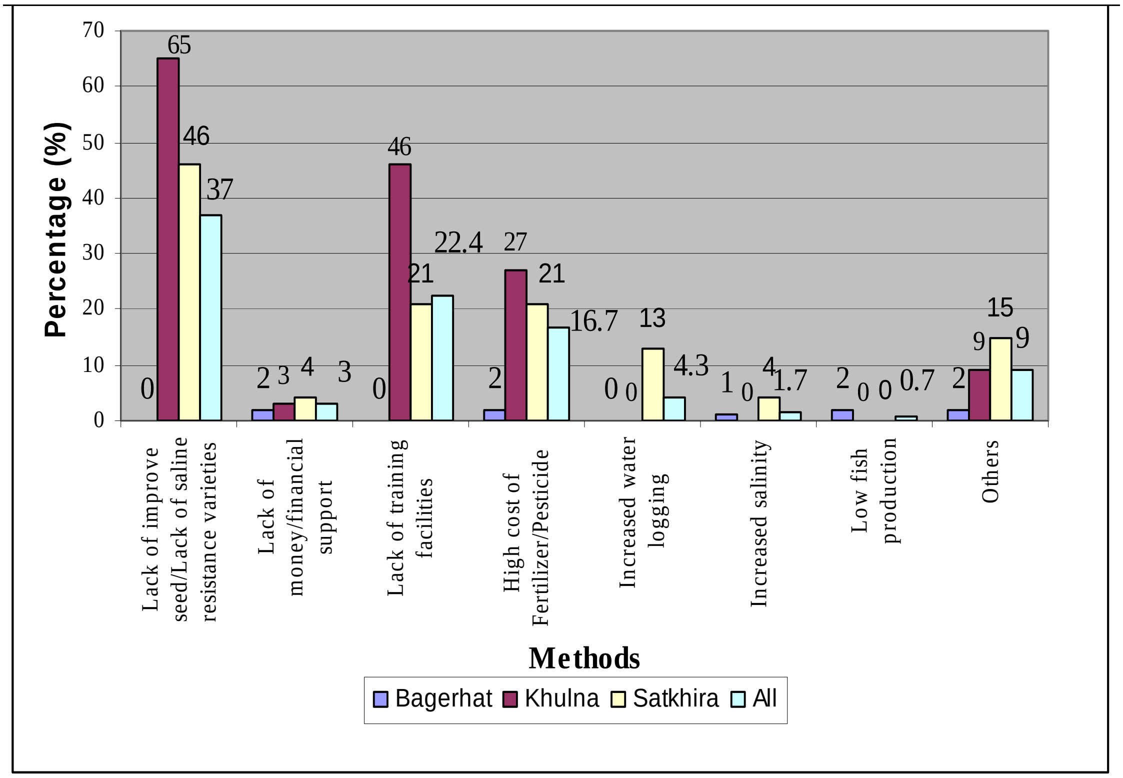
Table 23: Average cultivated land under saline-resistant crops at the initial stage when they were introduced and at present.

Study area	Average saline-resistant cultivated land (decimal) per households	
	At the initial stage	At present (2010)
Bagerhat	112.9	91.0
Khulna	90.7	195.6
Satkhira	96.5	114.0
All	97.0	143.0

The survey reveals that household land under cultivation of saline-resistant varieties has increased over time in the study area. Per household land under saline-resistant varieties has increased to 143 decimals (1.43 acres) at present, compared to 97 decimals (0.93 acres) in the initial period when saline-resistant varieties were adopted. The largest increase (115 per cent) from 90 to 195 decimals has happened in Khulna District, followed by an 18 per cent increase in Satkhira District. The average household land under saline-resistant varieties is, however, marked by a decline of 19 per cent in Bagerhat District.

Although the uptake of saline-resistant varieties has been reasonably high, there are several barriers to this. In this context, a common phenomenon is the lack of *khals* and the lack of freshwater as general obstacles. Fertilizer and pesticide costs are too high, thus some adaptation mechanisms cannot be realized. Removing salinity is also expensive, which is another obstacle to adaptation. Another pressing issue is that there is a lack of capacity or training. About 20 per cent of respondents face this issue in Khulna District, while overall ten per cent of the households surveyed face this problem. The lack of quality seeds is also a problem faced by 16 per cent of households surveyed. However households have attempted to overcome these barriers in different ways.

Figure 20: Percentage distribution of households by different types of barriers to adapting to salinity.



4.5.2 Future climate change adaptation measures

Adapting to rising salinity levels in the future will require an extension of the coping measures currently employed – primarily the use of *khals* and of saline-resistant varieties. For example, 95 per cent of all respondents agreed that in the future *khals* need to be dug in order to irrigate freshwater for crop cultivation. A lack of *khals* and/or a lack of freshwater sources were a commonly-cited barrier to adopting saline-resistant varieties. Other adaptation measures include:

- Draining out of saline water by using power pumps.
- Using underground water through deep and shallow tube wells.
- Building dykes and embankments to resist saline water intrusion.
- Using additional fertilizer/chemicals.
- Using green manure.

In order to overcome the barriers that obstruct the uptake of saline-resistant varieties, 65 per cent of the households studied excavate *khals* or canals, set up shallow tube-wells and manage drainage systems. Fifty per cent of the study population also feel that the development of saline-resistant crops, improving the quality of seeds, and facilitating seed distribution are necessary to reach the adaptation benchmarks. Some also feel that the supply of fertilizer and pesticides is necessary. Furthermore, 12.7 per cent of the households feel that building embankments is key to overcoming obstacles to adaptation. Training has also been mentioned by a quarter of the households surveyed as a method of overcoming the barriers to adaptation.

The uptake of saline-resistant varieties and building *khals* requires inputs from a range of stakeholders at different levels. The required actions can be classified as:

- Developing saline-resistant varieties.
- Disseminating saline-resistant varieties.
- Adopting saline-resistant varieties.

4.6 Costs of adapting to climate change

The cost estimates that have been done in the study include the private costs to the households of cultivating different rice varieties, as well as other crops. Household costs for cultivation include the costs of land preparation, seeds, fertilizer, irrigation, labour and harvesting. Other cost estimates derive from the public sector agencies engaged in research, extension, marketing and development of the agriculture sector.

- The average cost of re-excavating canals or making water tanks is BDT368,128 per household.
- Cost of production per decimal of traditional varieties ranges from BDT85 to BDT173, and the cost of production per decimal of saline-resistant varieties ranges from BDT135 to BDT259.
- The yield per decimal of traditional rice varieties (excluding hybrids) ranges from 9.7kg to 18.2kg, and that of saline-resistant rice varieties from 14kg to 24.2kg.
- The net value (profit) per decimal of traditional rice varieties varies between BDT88 and BDT219, while that of saline-resistant varieties varies between BDT157 and BDT278.

Table 24: Average yield, cost of production, and gross value per decimal for traditional rice crops.

Traditional varieties of rice crops	Yield per decimal (kg)	Cost of production per decimal (BDT)	Gross value of production (BDT)	Net value of production (BDT)
BR-30 (Rupa Aman)	14.7	129	342	219
BR-28 (Boro)	13.4	140	315	175
BR-23	14.0	134	281	147
BR-22	13.7	144	308	164
BR-21	13.0	118	325	207
BR-11	16.2	140	324	184
BR-10	14.9	173	334	161
Aloron (hybrid)	18.2	138	303	165
Hira (hybrid)	15.7	85	282	197
Vojon (local)	13.7	123	211	88
Red/white fat Aman (local)	9.7	97	194	97
Basmati (local)	11.1	106	262	156
Morisail (local)	11.4	152	271	119
Chapsail (local)	10.9	130	269	139
Balam (Rupa Aman)	11.8	142	269	127
Others crops	19.0	149	399	250

BR-30 is an Aman variety. The rice is moderately slender and white in colour. BR-28 is a Boro variety and thus requires irrigation. The rice is a moderate, slender type and the colour is white. The plant grows up to 90 cm.

Other varieties that are grown by the respondents are BR-22 (also known as Kiron) and BR-23 (also known as Dishari). Both are Aman varieties. The difference between the two is that the rice from BR-22 is short, thick and white while BR-23 is slender, tall and white. Both varieties mature late, as the lifespan of the plants is 150 days. BR-21 is an Aus variety, the lifespan of which is 100 days and the rice is medium thick. An interesting characteristic of this plant is that it can be directly transplanted. BR-10 (also called Progati) and BR-11 (which is also named Mukta) are Aman varieties and are mostly rainfed. The Progoti rice type is moderately slender, while Mukta is moderately thick. The lifespan of both the plants is 115 days.

Table 25: Average yield, cost of production, and gross value per decimal for saline-resistant rice crop varieties.

Saline-resistant rice crop variety	Yield per decimal (kg)	Cost of production per decimal (BDT)	Gross value of production (BDT)	Net value of production (BDT)
BR-41	14.1	135	310	175
BR-47 (Boro)	15.0	190	318	128
BINA-8	24.2	259	485	226
IT	18.8	236	393	157
Jamai babu	21.2	173	451	278

BR-41 – an Aman variety – has been developed to resist salinity. It is recommended that this variety is used in coastal areas, especially where salinity levels are constantly rising. It can sustain salinity up to 8 to 10 dS/m. The yield per decimal of BR-41 is 14.1kg.

BR-47 is another widely popular saline-resistant rice crop; this variety can tolerate 8 to 10 dS/m of saline levels. The life of the plant is 152 days. BR-47 yields 15kg per decimal.

BINA-8 has been developed by BINA using gamma radiation; it can resist higher levels of salinity and yields 24.2kgs per decimals. It is farmed in both Boro and Aman seasons. Though the cost of production is BDT259, almost double that of the BR adaptive varieties, the total profit returned is BDT226.

For traditional saline-resistant rice varieties, the highest yield (18.2 kg/decimal) is found for Aloron (a hybrid) and the lowest (9.7kg/decimal) for red/white fat Aman (local). The highest net value is derived from BR-30, which is BDT219 per decimal, and the lowest is for Vojon (local), which is BDT88 per decimal.

It can be seen from Table 26 that the largest input costs are spent on labour. Some crops, such as BR-23, Basmati and thick local Aman, are extremely labour-intensive as almost 70 per cent of the costs incurred are for labour charges. Amongst the traditional rice varieties, BR-22 induces the least labour cost at 52 per cent of the total. However, BR-22 requires its expenditure to be spent on fertilizer, pesticides and manure. In general, roughly 20-35 per cent is spent on these basic inputs. Basmati and red/white thick traditional Aman incur costs of ten per cent or less. In terms of production, the seed cost is only 10 to 15 per cent of the total production cost. In the case of BR-28 cultivation, the irrigation cost is more than the other rice varieties.

Table 26: Division of input costs for traditional varieties of rice crops.

Traditional varieties of rice crops	Per decimal cost (BDT)				
	Labour cost	Production inputs (fertilizer /manure/ pesticide) cost	Plants and seed cost	Irrigation cost	Other costs
BR-30 (Rupa Aman)	78.0	41.7	11.9	10.7	-
BR-28 (Boro)	86.6	46.4	13.2	39.3	4.0
BR-23	95.9	35.5	13.8	11.3	2.5
BR-22	81.8	54.8	12.1	-	-
BR-21	73.0	30.0	5.0	10.0	-
BR-11	83.3	46.1	11.8	15.2	-
BR-10	86.6	45.4	11.7	8.1	-
Aloron (hybrid)	101.9	39.7	18.3	-	-
Hira (hybrid)	116.2	65.1	15.6	-	-
Vojon (local)	83.0	25.8	17.4	-	-
Red/white thick Aman (local)	70.9	14.4	15.5	-	-
Basmati (local)	64.3	11.6	19.6	-	-
Morisail (local)	113.1	37.8	23.3	-	-
Chapsail (local)	99.0	26.3	17.8	-	-
Balam (Rupa Aman)	93.2	29.1	12.6	-	-

Table 27: Division of costs of traditional rice varieties.

Traditional varieties of rice crops	Percentage				
	Fertilizer/manure/ pesticide cost	Labour cost	Plant and seed costs	Irrigation cost	Other costs
BR-30 (Rupa Aman)	31.0	59.9	8.8	0.3	-
BR-28 (Boro)	24.9	54.0	8.1	12.3	0.7
BR-23	23.2	66.3	10.0	0.5	0.05
BR-22	37.9	52.8	9.3	-	-
BR-21	25.4	61.9	4.2	8.5	-
BR-11	31.6	59.1	9.1	0.2	-
BR-10	32.3	59.3	8.1	0.3	-
Aloron (hybrid)	24.9	63.7	11.4	-	-
Hira (hybrid)	33.5	59.0	7.5	-	-
Vojon (local)	22.1	65.3	12.6	-	-
Red/white thick Aman (local)	15.1	71.6	13.3	-	-
Basmati (local)	10.3	70.7	19.0	-	-
Morisail (local)	25.6	63.2	11.2	-	-
Chapsail (local)	20.4	68.1	11.5	-	-
Balam (Rupa Aman)	23.0	67.8	9.2	-	-
Others crops	24.0	65.0	9.7	1.2	0.1

Table 26 shows the cost per decimal of utilising labour, production inputs, seed, plant and irrigation costs. It can be seen that the Rupa Aman variety of BR-30 costs BDT78 per decimal in labour costs, BDT41.7 for fertilizer/manure/pesticide, BDT11.9 for plants and seed costs, and BDT10.7 per decimal in irrigation costs whereas Boro varieties are slightly more expensive as expenditure on labour costs is BDT86.6, inputs are BDT46.4, seed is BDT13.2 and irrigation is BDT39.3. Boro crops are irrigated varieties and as a result quite a lot has to be spent on this component. Aloron, Hira and Morisail each account for over BDT101 in labour costs. Input costs for Hira are also high at BDT65 while the lowest input price is BDT25.8 for the Vojon variety.

Table 28: Division of input costs for saline-resistant rice crop varieties.

Saline-resistant rice crop variety	Percentage				
	Fertilizer/manure/ pesticide cost	Labour cost	Plants and seed cost	Irrigation cost	Other costs
BR-41	30.5	60.8	8.7	-	-
BR-47 (Boro)	32.1	47.6	6.3	13.8	0.2
BINA-8	52.6	32.2	5.8	9.4	-
IT	29.6	39.5	7.4	22.1	1.4
Jamai babu	35.1	45.1	8.8	11.0	-

Like traditional rice crops, saline-resistant crops also expend the most on labour costs. BR-41 uses up 60 per cent of input costs on labour. Of the input costs for producing the BINA-8 crop, 52.6 per cent is used for fertilizer/manure and pesticide costs, but the labour cost is fairly low at 32.2 per cent. The cost of seeds accounts for approximately 6 - 8 per cent of all input costs for all crops. BR-47 utilises 47.6 per cent of the budget for labour costs, 32 per cent for fertilizer/manure and pesticides, and 13.8 per cent for irrigation costs. It can be noted that the highest spending on irrigation is for the variety IT.

Table 29: Division of production costs of saline-resistant rice crop varieties.

Saline-resistant rice crop variety	Per decimal cost (BDT)				
	Labour cost	Production input (fertilizer/ manure/ pesticide cost)	Plants and seed cost	Irrigation cost	Other costs
BR-41	80.1	41.3	11.8	-	-
BR-47 (Boro)	100.0	64.9	13.1	50.8	24.2
BINA-8	83.3	136.4	15.2	24.2	-
IT	92.6	69.7	17.2	50.4	18.4
Jamai babu	77.9	60.6	15.2	18.9	-

Table 29 shows the various costs per decimal of cultivating saline-resistant varieties. In terms of labour cost, the highest amount (BDT100) is used for BR-47 and the lowest amount (BDT77.9) is used for Jamai babu paddy cultivation. The highest amount (BDT136.4) is used for input costs (fertilizer/manure/pesticide) for BINA-8 and the lowest amount (BDT60.6) is used for Jamai babu cultivation.

Table 30: Average yield, cost of production, and gross value per decimal for traditional non-rice crops.

Traditional non-rice crops	Yield per decimal (kg)	Cost of production per decimal (BDT)	Gross value of production (BDT)	Net value of production (BDT)
Potato	44.4	184	316	132
Vegetables	15.2	170	331	161
Watermelon	n/a	209	431	222
Mustard	4.3	127	261	134
Pulse	3.2	82	169	87
Oil seed	1.0	90	170	80
Sesame seeds	4.4	101	150	49
Spices	7.3	122	240	118
Chillies	23.0	210	372	162

Traditional non-rice crops that are popular in the study area include potatoes, sesame seeds, chillies and mustard. The potato crop gives the highest yield per decimal (44.4kg) and the lowest yield was given by oil seed. Chilli required the highest per decimal production cost (BDT210) and the lowest (BDT82) is for pulse cultivation. In respect to net profit per decimal, farmers got the highest (BDT222) from watermelon and the lowest (BDT49) for sesame seeds.

4.6.1 Awareness of saline-resistant adaptations

Table 31, below, shows the distribution of respondents who received training on saline-resistant adaptations in agricultural production. Eleven per cent in Bagerhat, 25 per cent in Khulna and 63 per cent in Satkhira were trained on saline-resistant crops. Since Satkhira is the most affected by salinity, action to train the affected farmers is more critical there and accounts for the higher levels of trainings. Overall, however, fewer people had received training than had not in the study area (65 per cent). Though only 35 per cent of the respondents were trained on saline-resistant cropping systems, 97 per cent of all respondents wished that there were training programmes on saline-resistant agriculture. At the stakeholder workshop it was mentioned that some areas are inaccessible by any kind of transportation. Such areas lack infrastructural facilities as a result of which training is scarce, despite the fact that it is much needed in those areas.

Table 31: Percentage distribution of households surveyed that received training on saline-resistant crop cultivation.

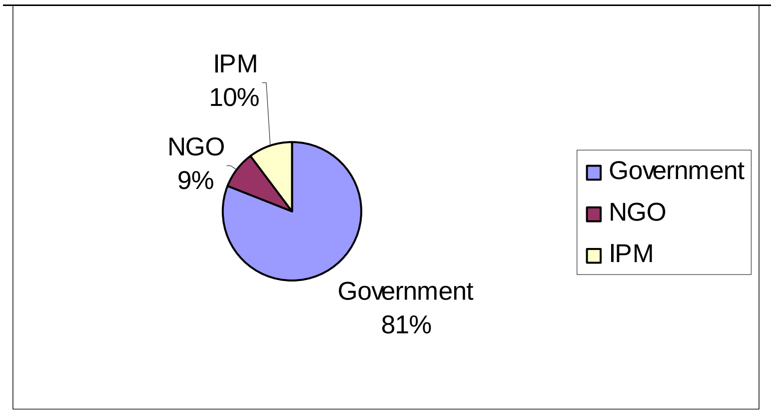
Study area	Yes	No	Total
Bagerhat	11.4	88.6	**100.0**
Khulna	25.0	75.0	**100.0**
Satkhira	63.2	36.8	**100.0**
All	35.1	64.9	**100.0**

Table 32: Percentage distribution of the source of information on saline-resistant crop cultivation.

Source	Study area			
	Bagerhat	**Khulna**	**Satkhira**	**All**
Nearest farmers	53.4	59.6	29.8	47.0
Government agricultural officers	27.6	36.4	59.6	43.0
NGO	19.0	3.0	3.2	6.8
Others	-	1.0	7.4	3.2
Total	**100.0**	**100.0**	**100.0**	**100.0**

Awareness of saline-resistant crops is indeed vital to securing adaptation options. Table 32 shows the source of knowledge on saline-resistant crops. In the whole survey area generally, the respondents claimed that farmers tended to learn about coping mechanisms from each other and from their personal experiences with local conditions. In Satkhira, though, knowledge from other farmers ranked second; agricultural extension officers seemed to be the most common source of information in that district. Information from NGOs reaches seven per cent of households overall.

Figure 21: Percentage distribution of households surveyed indicating providers of training on saline-resistant crop cultivation.



Training on salinity-resistant farming was conducted by Department of Agricultural Extension services, NGOs, and under the Integrated Pest Management (IPM) programme conducted by both government and NGOs. DAE conducted 80.7 per cent of the trainings that had taken place. Trainings were largely held free of cost and only some trainings that took place had to be paid for (the average cost of training is BDT167 per training programme).

Table 33: Percentage distribution of households that plan to expand cultivation of saline-resistant crops.

Study area	Yes	No	Total
Bagerhat	75.5	24.5	**100.0**
Khulna	69.0	31.0	**100.0**
Satkhira	100.0	-	**100.0**
All	82.3	17.7	**100.0**

A large proportion of the study area's respondents plan to either start or increase their production of saline-resistant crops. As the most affected district, all respondents in Satkhira District wished to become further involved in saline-resistant cropping systems.

Table 34: Average chemical fertilizer per decimal for saline-resistant crop cultivation.

Study area	Average chemical fertilizer cost per decimal (BDT)
Bagerhat	70.6
Khulna	31.7
Satkhira	85.2
All	60.2

Often there is the added cost of chemical fertilizers for the growth of crops in saline areas. The use of such chemical fertilizers also mitigates the effects of salinity. In Satkhira District, the average per decimal expenditure of chemical fertilizer is BDT85.2 (the highest among three districts).

4.7 Roles and responsibilities of institutional actors

Various stakeholders and policymakers influence the state of agriculture in Bangladesh. Current adaptation practices are sometimes similar amongst the stakeholders but are often different, depending on the scale of the adaptation options being practised. As there have been various stakeholders and policymakers influencing the state of agriculture in Bangladesh over time, the costs of adaptation options differ. While some costs are related to research on developing climate-resilient agricultural systems that maintain livelihoods even as climate change becomes further exacerbated, others are relevant to the implementation of the adaptation measures. This subsection covers the costs to be currently borne and the costs projected for 2030.

4.7.1 Department of Agricultural Extension (DAE)

The Department of Agricultural Extension elaborated on the costs of adaptation for the three districts. The primary costs to the department relate to awareness-raising: crop farming demonstrations, farmers' rallies, field days, congresses, seminars and motivational tours.
Crop farming demonstrations are held when a new rice variety is being introduced to the users. This demonstration component costs BDT19.00 million per annum currently and the costs are expected to rise to BDT40 million in 2030. Farmer rallies are held a couple of times a year at the cost of BDT13.50 million now and BDT27 million in 2030. Field days are also organised by DAE and consist of visits to other farms, at a cost of BDT0.38 million currently. The cost is expected to reach BDT0.53 million in 2030.

Table 35: Estimated current and future costs of adaptation for DAE.

Activity	Current annual cost, 2011 (million BDT)	Future annual cost, 2030 (million BDT)	*Current annual cost, 2011 (US$)*	*Future annual cost, 2030 (US$)*
Farmers' trainings	23.60	114.00	316,354	1,528,150
Crop farming demonstrations	19.00	40.00	254,692	5,36,193
Farmers' rallies	13.50	27.00	180,965	3,61,930
Field days	0.38	0.53	5,027	7,038
Farmers' congresses	2.10	2.60	28,150	3,485
Farmers' seminars	0.23	0.45	3,016	6,032
Farmers' motivational tours	0.14	0.95	1,809	12,668
Staff capacity building	0.54	1.80	7,239	24,129
Technology fairs	0.92	1.26	12,386	16,890
FINA	0.53	0.00	7,038	0.00
IPM programme	1.15	1.72	15,416	23,056
Total	**62.09**	**190.31**	**827,064**	**2,519,571**

Several programmes fall under the broad category of 'capacity building'. A significant share of DAE's budget is spent on farmers' training programmes. Each *upazila* holds several training sessions disseminating the latest technological innovations to farmers to encourage their more widespread use. At present BDT23.6 million is spent per year on training sessions and as climate change impacts take hold, the number of trainings will have to increase and the intensity of the trainings must also escalate, thus taking the cost to BDT114 million. These trainings are provided by DAE staff, who will also need training (and their capacity needs to increase as well). Currently the cost of capacity building for staff is BDT0.54 million. This cost is estimated to peak at BDT1.8 million in 2030. DAE officials estimate that in order to fully understand the needs of Bangladeshi farmers, more large-scale FINA (Farmer's Information Need Assessment) needs to take place. Currently BDT0.53 million is spent on FINA per annum. Furthermore, integrated pest management is a vital part of sustainable agriculture. Many have complained that pests have increased as a result of climate change. DAE spends BDT1.15 million annually on the IPM programme. The cost is estimated to reach BDT1.72 million by 2030. The total annual budget for climate change adaptation is estimated at BDT62.09 million in 2011, which is projected to rise to BDT190.31 million in 2030.

4.7.2 Department of Agricultural Marketing (DAM)

The Department of Agricultural Marketing is another institution that has an influence on the state of agriculture. Vulnerabilities may arise by 2030 due to the absence of storage facilities; DAM officials therefore advocate the necessity for a grain storage facility in each of the three coastal districts of Khulna, Satkhira and Bagerhat. The total cost of building each of these sustainable structures is BDT20.84 million. Presently, BDT0.05 million is spent per annum on the operations and maintenance (O&M) of these structures. Every year, O&M costs will increase by 10 per cent. The O&M annual charge per storage facility will reach BDT0.35 million in 2030.

DAM also needs to undergo capacity building in the form of marketing facilities etc., which might cost BDT20 million now and in 2030 that cost will inflate to BDT122 million. The crop insurance programme for farmers is a method introduced by DAM to help farmers overcome the losses incurred from different kinds of crop failures. The cost of crop insurance is BDT1 million and in the future will rise to BDT6.1 million. DAM has also set up credit linkages with banks to help farmers with monetary support to fulfil their needs. DAM is also responsible for informing farmers about the linkages that are to take place. At present the cost is BDT0.5 million per year, but it will rise to BDT3.05 million in the future. If building of an Assembly

Centre is to cost BDT10 million now, that cost will rise to BDT60 million in 2030. Motivation and dissemination activities will cost BDT10 million annually now rising to BDT60 million annually by 2030. DAM also assesses that institutional capacity building is to take place. The total cost of that is BDT20 million now and is guesstimated to rise to BDT120 million in 2030.

Table 36: Estimated current and future cost of adaptation for DAM.

Activity	**Current annual cost, 2011 (million BDT)**	**Future annual cost, 2030 (million BDT)**	***Current annual cost, 2011 (US$)***	***Future annual cost, 2030 (US$)***
Building grain storage (250 tons)	20.84	166.40	*278,820*	*2,230,563*
Annual operations and maintenance (O&M)	0.05	0.35	*670.24*	*4,692*
Capacity building of DAM (market facilities, cool vans, etc.)	20.00	122	*268,097*	*1,635,389*
Crop insurance	1.00	6.10	*13,405*	*81,769*
Credit linkages with banks (motivational work)	0.50	3.05	*6,702*	*40,885*
Assembly Centre	10.00	60.0	*134,048*	*804,289*
Motivation and dissemination	10.00	61.0	*134,048*	*817,694*
Institutional capacity building through staff training and development	20.00	122.0	*268,097*	*1,635,389*
Total	**41.55** (ex. building and infrastructure costs)	**540.9** (inc. building costs)	***825,067.24*** *(ex. building costs)*	***7,250,670*** *(inc. building costs)*

4.7.3 Bangladesh Institute of Nuclear Agriculture (BINA), headquarters

The Bangladesh Institute of Nuclear Agriculture has increasing responsibilities as a result of climate change. At the moment, the current cost for varietal improvement of abiotic stress-tolerant crop varieties through induced mutation is BDT0.10 million annually. In 2020 that cost will rise to BDT0.14 million and in 2030 the cost will further rise to BDT0.18 million.

BINA is also looking at using biotechnology to improve the varieties of some crops – the cost is BDT0.15 million per year currently. In 2020, that cost will rise to BDT0.14 million and will cost BDT0.27 million in 2030. Management practices such as irrigation, weeding and fertilization using nuclear technology are also in need of further research. Research on this subject currently costs BDT0.13 million. In 2030 that cost will rise to BDT0.19 million, which is a slightly higher than the cost in 2020 (which is estimated to be BDT0.15 million).

Climatic stressors are another aspect that needs to be studied in order to best evaluate the options for adaptation. Therefore research on impact assessment of stress factors (such as salinity, droughts, submergence) has to be studied at the current cost of BDT0.08 million. In a decade the cost will further rise to BDT0.13 million and in another decade to BDT0.17 million. At the moment, demonstrations cost BDT0.15 million; that cost will increase by 40 per cent by 2030. Another cost that BINA bears is that of seed production, which is now BDT0.10 million. By 2030 the cost will rise by 80 per cent (BDT 0.18 million). Capital goods such as research equipment, chemicals, consumables and glassware cost BDT0.17 million now. In 2030 that cost will rise to BDT0.25 million. Furthermore, there are trainings and capacity-building activities that are currently priced at BDT1.20 million; in 2030 the cost will be BDT2 million.

Table 37: Estimated current and future costs of adaptation for BINA.

Activity	Current cost, 2011 (million BDT)	Future cost, 2020 (million BDT)	Future cost, 2030 (million BDT)	*Current cost, 2011 (US$)*	*Future cost, 2020 (US$)*	*Future cost, 2030 (US$)*
Varietal improvement of abiotic stress-tolerant crop varieties through induced mutation	0.10	0.14	0.18	*1,341*	*1,877*	*2,413*
Varietal improvement of some crops using biotechnological approaches	0.15	0.20	0.27	*2,011*	*2,681*	*3,619*
Management practices (irrigation, weeding, fertilization etc.)	0.13	0.15	0.19	*1,743*	*2,011*	*2,547*
Impact assessment of stress- (salt, drought and submergence) tolerant lines/varieties	0.08	0.13	0.17	*1,072*	*1,743*	*2,279*
Demonstration	0.15	0.18	0.22	*2,011*	*2,413*	*2,949*
Seed production	0.10	0.13	0.18	*1,341*	*1,743*	*2,413*
Equipment, chemicals, consumables and glassware	0.17	0.21	0.25	*2,279*	*2,815*	*3,351*
Training and capacity building	1.20	1.50	2.,00	*16,086*	*20,107*	*26,809*
Total	**2.08**	**2.64**	**3.46**	***27,882***	***35,389***	***46,381***

4.7.4 BINA, Satkhira

The BINA field office in Satkhira has the task of overseeing the use of BINA varieties at the field level. The costs that are borne by the BINA office in Satkhira include costs on:

Table 38: Estimated current and future costs of adaptation for BINA Satkhira Station.

Activity	Current annual cost, 2011 (million BDT)	Future annual cost, 2030 (million BDT)	*Current annual cost, 2011 (US$)*	*Future annual cost, 2030 (US$)*
Annual operational costs	3.50	n/a	*46,917*	*n/a*
Cost of equipment (EC meter and soil-testing kit)	33.00	n/a	*442,359*	*n/a*
Annual farmers' training	0.60	2.00	*8,043*	*26,809*
Annual advanced farmers' training	0.30	0.60	*4,021*	*8,043*
Annual demonstrations (per 33 decimals)	0.006	0.01	*80.43*	*134.05*
Annual demonstration (per acre)	0.02	0.03	*268.09*	*402.14*
Total	**37.426**	**2.64**	***501,688.52***	***35,388.19***

Note: n/a means data not available from BINA source.

The field office of BINA in Satkhira predicts that the current cost of research will only increase. Currently, the operating cost of BINA at Satkhira is BDT3.50 million per year. Capital costs (which include the cost of several salinity measurement tools and soil moisture kits) are BDT33.00 million. Currently, six general trainings for farmers are held each year at a cost of BDT0.10 million each. Advanced farmers' training courses are also offered three times a year at the cost of BDT0.10 million each. Demonstrations cost BDT0.006 million per 33 decimals. (each acre costs BDT18 - 20 thousand for demonstrations).

It is estimated that in the future, 20 general trainings will have to take place every year, which equates BDT2.00 million. Advanced farmers' trainings would have to double to six per annum, and will thus cost BDT0.60 million. The price of demonstrations would also increase to BDT10 thousand for 33 decimals (and BDT30 thousand for each acre). The current estimated total annual cost of adaptation for BINA is BDT4.43 million excluding the cost of equipment. The annual operational cost is projected to double in the future.

4.7.5 Bangladesh Rice Research Institute (BRRI)

The total amount of current adaptation costs for BRRI is an estimated BDT500 million, which is projected to rise to BDT1,000 million by 2030. The breakdown of present and future costs is shown in Table 39.

Table 39: Estimated current and future costs of adaptation for BRRI.

Activity	Current annual cost, 2011 (million BDT)	Future annual cost, 2030 (million BDT)	*Current annual cost, 2011 (US$)*	*Future annual cost, 2030 (US$)*
General research costs of laboratory +piloting + infrastructure	210	420	*2,815,013*	*5,630,027*
Technology development (variety)	230	460	*3,083,110*	*6,166,219*
Annual dissemination	060	120	*804,289*	*1,608,579*
Total	**500**	**1000**	***6,702,413***	***13,404,826***

4.7.6 Bangladesh Agricultural Development Corporation (BADC)

The Bangladesh Agricultural Development Council (BADC) is making seeds available to farmers at fair prices as well as assuring the transfer of technology, as per their mandated tasks. The current total budget of BADC is BDT269.80 million. Recently, BADC launched a project called Climate Change-Farmer's Risk Management and Maintaining Food Security in Coastal Bangladesh. The project will take place in 13 coastal districts and the total cost is BDT199.80 million for three years.

BADC officials also expect to construct salinity observation wells, and procure data collection equipment and tools for groundwater management. The total cost of that is near to BDT70 million currently. In the future, this cost will likely rise to BDT300 million.

Table 40: Estimated current and future costs of adaptation for BADC.

Activity	Current annual cost, 2011 (million BDT)	Future annual cost, 2030 (million BDT)	*Current annual cost, 2011 (US$)*	*Future annual cost, 2030 (US$)*
Climate Change-Farmer's Risk Management and Maintaining Food Security in Coastal Bangladesh project: 105 (70 each of 1 cusec and 35 each of 2 cusec) power pump installations; 50 km canal	199.80	1,110.90	2,678,284	14,891,039
Construction of salinity observation wells; procurement of data collection equipment; and preparation of groundwater management tools	70.00	300.00	938,338	4,021,448
Total	**269.8**	**1410.9**	**3,616,622**	**18,900,804**

Note: Cusec means cubic feet per second.

4.7.7 Ministry of Agriculture (MoA)

The Ministry of Agriculture (MoA) is also geared towards implementing climate change adaptation projects. In cooperation with the Department of Agricultural Extension, the MoA is implementing Comprehensive Disaster Management Program (CDMP) Phase II projects, including the Disaster and Climate Risk Management in Agriculture Project (DCRMA). Under this project, one component is Improving Adaptive Capacity to Climate Variability and Change for Sustainable Food and Livelihood Security in Drought-prone and Coastal Regions of Bangladesh. This project costs nearly US$7,000 per annum. The cost of the project is estimated to rise to US$16,506 by 2020 and US$42,811 by 2030 per annum.

Another component under DCRMA is raising awareness and acquainting farmers with adaptive technology. Table 41 below provides the breakdown of the different costs of adaptive practices in Dacobe, an *upazila* of Khulna. Six demonstrations on T. Aman cultivation (or the adaptive version BR-41) will be held at a cost of BDT4,308 each, and homestead vegetable cultivation demonstrations will each cost BDT2,990. Small-scale duck rearing and fish cultivation costs BDT18,390 per demonstration; *jujube* (a fruit variety) costs BDT10,714 for each demonstration, a couple of which are to be held. The total cost of the demonstrations at present is BDT74, 636.

It is estimated that the cost of this project will rise by ten per cent every year, thus the total cost would be BDT456,467 in the year 2030**.**

Table 41: Estimated current and future costs of adaptation measures under DCRMA.

Type of demonstration	**No. of demos**	**Unit budget BDT/demo**	**Current total, 2011 (BDT)**	**Future total, 2030 (BDT)**	***Unit budget (US $)/demo***	***Current total,2011 (US$)***	***Future total, 2030 (US$)***
T. Aman cultivation (BR-41, Jota balam, others)	6	4,308	25,848	158,084	*57.75*	*346.49*	*2,119*
Homestead vegetable cultivation	9	2,990	8,970	54,856	*40.08*	*120.24*	*735.34*
Small-scale duck and fish rearing	1	18,390	18,390	112,472	*246.52*	*246.51*	*1,508*
Jujube cultivation	4	10,714	21,428	131,052	*143.62*	*287.24*	*1,757*
		Total	**74,636**	**456,467**		***1,000.48***	***6,118.86***

5. Key messages and conclusions

5.1 Key messages

1. In order to better address climate change risks, adaptation measures need to be mainstreamed in general agricultural development plans at the local and national level, which would simultaneously also increase awareness of climate change and its adverse impacts on livelihoods, ecosystems and the economy.

2. Enhanced capacity building for government and non-government authorities, as well as restructuring existing institutional frameworks in order to make them more capable of responding to the challenges imposed by climate change, are essential and would facilitate the effective implementation of activities. In addition, coordination and communication among the respective governmental agencies has to be improved.

3. The implementation of a follow-up mechanism consisting of monitoring and evaluation procedures is also required in terms of efficiently scaling up project initiatives on climate change adaptation. An independent body comprising government and non-government representatives and topical experts operating in both national and sub-national administrative structures should conduct this.

4. Many farmers are currently using their traditional knowledge to cope with changes in climatic patterns. In order to achieve more efficient results regarding adaptation and benefit sharing, these local measures should be combined with advanced, scientifically-tested techniques, however. Thus, the information about new technologies and farming practices needs to be disseminated on a wider scale, for instance through farmer training programmes.

5. The fact that costs of using climate-smart varieties are approximately equal to those of traditional ones makes the adoption of new varieties favourable and facilitates the climate change adaptation process.

5.2 Conclusions

This research study has shown that climate change poses significant challenges to Bangladesh's agricultural sector and therefore to livelihoods and the country's overall economic development. Adverse impacts include increased soil salinity, saline water intrusion and massive declines in rice and wheat production, which are induced by an overall warmer, wetter and less predictable climate. New weather conditions will be particularly characterised by a rise in precipitation and sea levels, whereas extreme events such as floods, droughts and cyclones are also going to occur more frequently.

Climate variability and change devastate the predominant income source of the rural Bangladeshi population. Currently, farmers can apply two main coping mechanisms to counter these developments: digging canals (*khals*) for sourcing freshwater and using saline-resistant crops. The majority of farmers use the latter option as the other option is beyond the affordable capacity of marginal and small-scale farmers.

Several barriers to effective adaptation have been identified through the study, including the lack of: freshwater, quality seeds, capacity building, and training for farmers. Furthermore, fertilisers and pesticides are found to be too expensive and thus are not applied to the required extent.

Consequently, the following action steps on adaptation were agreed upon:

- Expanding research, especially on saline-resistant crop varieties and access to freshwater.
- Providing training for farmers.
- Improving capacity building and information sharing through intensified engagement with local and national governments and NGOs, as well as through farmer-to-farmer-networks.

Most of the stakeholders in Bangladesh who have an institutional or organisational role to play in the development of the country's agricultural sector are aware of climate change and its adverse impacts. Thus, some efforts for embedding adaptation into policy and long-term planning documents have already been initiated. The study has also revealed that research agencies in Bangladesh, especially those at the local level, are currently in the process of generating more innovative methods and varieties for agricultural adaptation.

Apart from these new research approaches, several adaptive farming techniques have already been implemented – for instance saline-resistant crops and different forms of irrigation (e.g., excavating canals to resist salinity). Although the cost of using adaptive varieties is expected to be similar to that of traditional rice varieties, financing adaptation in general remains the most pressing challenge, especially to scale up adaptation initiatives for addressing a wider part of the population.

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