

**ENHANCEMENT OF RESILIENCE OF COASTAL
COMMUNITY IN BANGLADESH THROUGH CROP
DIVERSIFICATION IN ADAPTATION TO CLIMATE
CHANGE IMPACTS**



A Dissertation for the Degree of Masters in Disaster Management

By
Md. Mizanur Rahman
Student ID# 11268019

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Postgraduate Programs in Disaster Management
BRAC University, Dhaka

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ABSTRACT

The coastal region covers almost 29,000 km² or about 20% of the country and more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The dominant crop grown in the coastal region is local transplanted Aman rice crop with low yields. The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted Aman Rice. IPCC estimates predict that due to the impact of climate change, sea level in Bangladesh may rise by 14 cm by 2025, 32cm by 2050 and 88 cm by 2100. Salinity is a current problem, which is expected to exacerbate by climate change and sea level rise. Salinity intrusion due to reduction of freshwater flow from upstream, salinisation of groundwater and fluctuation of soil salinity are major concern of Bangladesh. Cyclones and tidal surge is adding to the problem. Tidal surge brings in saline water inside the polders in the coastal area. Due to drainage congestion, the area remains waterlogged that impede improved land productivity and food security. Agriculture is a major sector of Bangladesh's economy and is true for the coastal area of Bangladesh. Increase in salinity intrusion and increase in soil salinity will have serious negative impacts on agriculture. Presently cultivated rice varieties may not be able to withstand and produce optimum yield with the increased salinity. The food production does not seem to have a better future in the event of a climate change. In Bangladesh, rice production may fall by 10% and wheat by 30% by 2050 (Climate change in Asia 'too alarming to contemplate'-report, IPCC, 2007).

To combat the above adverse effects and also to develop climate resilient agriculture for the coastal regions of Bangladesh, BRAC had implemented a gigantic study in the coastal regions of Bangladesh with the financial assistance from the European Union. For this study, data were collected from the block demonstration implemented by BRAC, analyzed and compared with the local farmers' practices. It was observed that average yield of local rice was about 2.4 t/ha. The yield of improved high yielding varieties (HYV) of rice (inbred and hybrid) demonstrated by BRAC with farmers' participation was 2-3 times higher than local rice, mostly due to more number of effective tillers per hill meaning more number of plants per unit area, longer panicles and more filled grains per panicle that was observed in improved varieties over the traditional rice varieties cultivated by the farmers. Yield of hybrid rice was 1-2 t/ha higher than HYV rice, and about 3-4 t/ha higher than traditional rice varieties cultivated by the farmers.

The cropping intensity was increased from 178% to 280% due to the project intervention. Major shift from local to improved variety is noted. Several new crops are introduced and intensity of crops is increased in all cases. Average yield has increased due to varietal improvements. Yield increased up to 250% in case of hybrid paddy of Alloran in comparison with other local (Godaila, Moinamati) varieties. Hybrid and HYV crops suitable for plain land as well as suitable for selected coastal areas may change cropping patterns, cropped area, cropping intensity, yield, production, and income. This will help in better resilience of the coastal farming communities in combating disasters arising from the climate change phenomenon.

There are some areas in Barisal division where three rice crops can be cultivated by utilizing rainfall and river water. The farmers could get an annual production of about 18.0 t/ha by investing about BDT 120,000 per ha per year. With such investment they can earn about BDT 316,000 per ha annually. In areas, where sufficient water was not available for boro rice cultivation, the farmers cultivated different rabi crops by adopting aus-aman-rabi pattern, as rabi crops are less water demanding and can tap residual soil moisture better for their growth and development. The farmers of Kachua, Barguna sadar, Jhalokathi sadar, Patuakhali sadar

and Nazirpur upazilas harvested an annual production of 12-18 t/ha by adopting (a) Rice-Rice-Maize, (b) Rice-Rice-Sunflower and (c) Rice-Rice-Mungbean patterns in Aus, Aman and Rabi seasons. Water resources in these upazilas are favourable for three crop cultivation (two rice and a rabi crop). By investing an amount of BDT 94,600-116,700 per ha in a year, the farmers could get an annual income of BDT 249,700-324,800 per ha.

Therefore, in a populace and land-scarce country like Bangladesh, cultivation of hybrid rice should be promoted to achieve food security when climate change is supposed to pose serious threat to our agriculture, especially in coastal regions of the country. In water scarce areas like the coastal regions of Bangladesh, maize could an alternative option to be pursued in the rabi season for higher productivity and income. Sunflower can also be adopted as rabi crop in the water-scarce coastal regions of Bangladesh for not only to meet-up edible oil requirement, but also for higher farm income and also to save foreign currency by reducing import of edible oil.

To improve resilience of the coastal farming communities, some measures could be taken to increase cropping intensity and food security in the coastal salinity areas of Bangladesh. Firstly, fresh/non-saline river water should be conserved in the polder canals to irrigate boro/rabi crops. Secondly, single and double crops areas could be converted to double/triple crop areas by utilizing residual soil moisture, non-saline river water and conserved fresh water from the canals inside the polders and by introducing short duration and high yielding stress tolerant crop varieties. Thirdly, dissemination of appropriate modern and climate resilient technologies through block demonstration should be promoted to achieve food security of the coastal communities.

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List of Acronyms

Av - Average
BRAC - BRAC
BARI - Bangladesh Agriculture Research Institute
BACS- Bangladesh Center for Advanced Studies
BBS-Bangladesh Bureau of Statistics
BRRI- Bangladesh Rice Research Institute
BINA- Bangladesh Institute of Nuclear Agriculture
BCR- Benefit Cost Ratio
BLOCK- block means a contiguous area of 10-20 ha of 50-60 farmers' land
BDT- Bangladesh Taka
BWDB-Bangladesh Water Development Board
Cm- Centimeter
CI- Crop Intensification
CIP: Crop Intensification Project
DRR-Disaster Risk Reduction
Ds/m-Desicymole/meter
EU- European Union
EC-European Commission
FSRD- Farming System Research and Development
FAO-Food Agriculture Organization
FGD-Focus Group Discussion
GOB- Government of Bangladesh
Gm- Gram
GCDIC-Global Change Data and Information Centre
HYV- High Yielding Variety
HH-Household
Ha- Hectare
IAEA- International Atomic Energy Agency
IRRI- International Rice Research Institute
ICEAB-International Conference on Environmental Aspects of Bangladesh
IPCC- Intergovernmental Pannel on Climate Change
IGCI- International Global Change Institute
K- Potash
Kg- Kilogram
LLP- Low Lift Pump
Na- Sodium
NCA-Net Cultivable Area
NFPCSP-National Food Policy Capacity Strengthening Programme
NGO-Non-Government Organization
SARCCAB- Support to Agricultural Research for Climate Change Adaptation in Bangladesh
SAARC-South Asian Association for Regional Cooperation
SMRC-SAARC Metrological Research Council
S1- Very Slight Saline
S2- Slightly Saline

SRS-Simple Random Sampling
SOM-Soil Organic Matter
t/ha- Ton/hectare
TMO-Technology Mission Oilseeds
USAID-United State Agency for International Development

CHAPTER 1

INTRODUCTION

1.1 Background

Bangladesh is located between $20^{\circ}34'$ to $26^{\circ}38'$ North latitude and $88^{\circ}01'$ to $92^{\circ}42'$ East longitude. It is bordered on the west, north and east by India, on the south-east by Myanmar and on the south by the Bay of Bengal. The country occupies an area of 147,570 sq. km (BBS, 2005). The south-western coastal areas are sometimes inundated by high tidal surges. There are a large number of pockets in the southern coastal areas which are deliberately made free from 'normal tidal' flooding. Marginal areas outside the embankments are prone to tidal inundation. Sometimes excessive rainwater accumulates inside an embankment which does not have adequate drainage facilities, particularly the low-lying pockets of such an embankment suffer from flood caused by drainage congestion. People living in different coastal areas of Bangladesh have been suffering from lack of food security. There are many reasons behind that such as lower crop productivity and less cropping intensity due to increased salinity, increased incidences of pests & diseases, erratic rainfall, higher temperature, drought, tidal surges, cyclone, submergence, large fallow lands/water bodies, land degradation, poor road network, poor marketing facilities and unemployment with long-term cumulative effects of soil-related constraints, climate risks and socio-economic problems. The SAARC Meteorological Research Council (SMRC, 2010) carried out a study on recent relative sea level rise in the Bangladesh coast. The study has used 22 years historical tidal data of the three coastal stations. The study revealed that the rate of sea level rise during the last 22 years is many fold higher than the mean rate of global sea level rise over 100 years. The IPCC 3rd Assessment Report estimated that the global rise in sea level from 1990 to 2100 would be between 9 and 88 cm. The Third Assessment Report has also projected global sea level rise for the year 2020, 2050 and 2080 using different emission scenarios. A recent study of The SAARC Meteorological Research Council (SMRC, 2010) revealed that about 13% more area (469,000 ha) in Bangladesh will be inundated in monsoon due to 62 cm sea level rise for high emission scenario A2 in addition to the inundated area in base condition. The most vulnerable areas are the areas without polders like Patuakhali, Pirojpur, Barisal,

Jhalakati, Bagerhat and Narail. Due to increased rainfall in addition to 62 cm sea level rise, the inundated area will be increased; and about 16% (551,500 ha) more area will be inundated in the year 2080. On the contrary, in the dry season due to 62 cm sea level rise about 364,200 ha (10%) more area will be inundated (inundation more than 30 cm) for A2 scenario in the year 2080. However, 15 cm sea level rise has insignificant impact on inundation in dry season.

Since people do not have ample employment opportunities round the year, their food security situation is vulnerable and is a matter of great concern for the policy makers. Majority of the people in coastal areas are involved in crop cultivation and fishing and they remain frequently unemployed due to tidal flooding and other natural disasters resulting food insecurity in the areas. With technical support from the National Food Policy Capacity Strengthening Programme (NFPCSP) of the FAO and the Ministry of Food and Disaster Management and financial support from USAID/EC, the present study **“Assessing Long-term Impacts and Vulnerabilities on Crop Production due to Climate Change in the Coastal Areas of Bangladesh”** was undertaken to analyze the climate impacts on crop production systems and to suggest appropriate coping strategies and adaptation options for improving coastal agriculture for increased agricultural production and better livelihood of the vulnerable farming community.

Bangladesh has made a remarkable progress in the last three decades towards achieving self-sufficiency in food grains due to substantial intensification of cropping, introduction of high yielding crop varieties, expansion of irrigated areas and increased use of chemical fertilizers. But recently, declining or stagnation of major crop yields have been recorded due to cumulative effects of many soil-related constraints and climatic risks viz. depletion of soil organic matter, imbalanced use of fertilizers, nutrient mining, degradation of soil physical and chemical properties, erratic rainfall, temperature rise, droughts, floods, soil salinity, water salinity, tidal surges, water-logging, cyclone, scanty use of bio and organic fertilizers and poor management practices. The proportion of different nutrients used in agriculture without soil testing in recent years is highly deleterious to soil productivity. Nitrogen alone constitutes about 83 percent of total nutrient use in the country, while the use of phosphorus and potassium is limited to only about 7.75 and 9.10 percent, respectively (BCAS, 2010).

The present challenges for plant nutrient management are to maintain (and where possible to increase) for sustainable crop productivity to meet the growing demands for food and raw materials and to enhance the quality of land and water resources. Bangladesh is presently facing a serious challenge in agricultural production to feed the growing population in the context of shrinking agricultural land and climate change impacts. The population has been projected to grow to 191 million in 2030 from the current 150 million. The major challenges for increased growth and production for agriculture sector are:

- Arresting conversion of good agricultural land into non-agricultural purposes, Reduction of yield gap and large scale adoption of proven agro-technologies at farm level,
- Utilization of remarkable areas of agricultural land (30-50% of NCA in concerned districts) that remains fallow or seasonal fallow in drought prone, flood prone and coastal areas due to environmental stress factors which will be aggravated further due to climate change,
- Introduction of location specific production packages and agricultural adaptation technologies to facilitate the growth of agriculture sector,
- Making adequate quality seeds available at farmers' level,
- Developing suitable salt-tolerant crop varieties for coastal region and coastal char lands, drought-tolerant varieties for drought prone areas and floodplain char lands and submergence tolerant varieties for water-logged soils,
- Reversing trend of nutrient mining and depletion of soil organic matter (SOM) due to intensive crop agriculture,
- Improving marketing facilities and formation of Farmer's Group in agro-processing using value added crops.

More than 30% of the cultivable land in Bangladesh is in the coastal area, about 1.0 million ha of which is severely affected by varying degrees of salinity during the dry season and flooding/submergence during the wet season each year (Karim *et al.*, 1990). Traditionally the farmers cultivate rice in the Aman season, while multiple cropping is an opportunity in securing food sufficiency. Farmers mostly grow low-yielding traditional rice varieties only during the monsoon (Aman) season spanning July to December. Most of these lands remain fallow in the dry (Rabi/Boro) and pre-

monsoon (Aus) seasons because of perceived high soil and water salinity and lack of good quality irrigation water (Karim *et al.*, 1990, Mondal *et al.*, 2004a). While farmers of the other parts of Bangladesh benefit from higher farm productivity and have some option to cover their losses from more or less secure high yields from Boro rice, about 1.6 million farm families in the coastal saline areas of Bangladesh have very limited options as they continue to farm under rainfed condition and having above constraints. Crop yields, cropping intensity, production levels and peoples quality of livelihood are much lower in this region than in other part of the country (BBS, 2009). Improvement of Aman rice yields, crop intensification by adding either an Aus or a suitable non-rice crop before or a Boro rice or a non-rice crop after Aman rice can improve productivity, farmers' income, and enhance their livelihoods (Mondal *et al.*, 2004a). Productivity of Aman rice is particularly low in most of these coastal areas because of excessive flooding (either partial or complete) and less adoption of suitable high yielding varieties (HYV) of rice. Farmers rely on traditional rice varieties that are tall, do not respond to inputs and have low yields of 2-2.5 t/ha (Mondal *et al.*, 2004a). Farmers are reluctant to use HYV because they are short stature, easily submerged and damaged by tidal fluctuations. But the excess water could easily be drained out during low tide through managing the sluice gates of the coastal polders constructed by the Bangladesh Water Development Board (BWDB). Unfortunately many of the sluices do not function properly and farmers do not have the knowhow to operate the sluices properly. Improving drainage in the monsoon season would help in cultivation of HYV Aman rice and also early establishment of rabi crops in the coastal areas of the country.

The coastal region of Bangladesh is deprived of the technological advancement in agriculture. Only very few agricultural technologies are suitable to adopt directly in the coastal saline areas of Bangladesh. So, it has become an urgent need to demonstrate modern agricultural technologies through "system approach" rather than seasonal or crop specific approach to that particular soil and micro-climatic conditions. However, there are some high value crops which could be grown through improved management practices. It was envisioned that through crop intensification and diversification, food security and farm income in the coastal areas could be increased significantly.

BRAC had implemented a crop intensification programme funded by European Union providing the farmers with the most appropriate and productive agricultural technologies to ensure their food security through the adoption of year-round cropping practices by utilizing available resources they have in and around their farms. On the basis of availability of the water resources, BRAC had identified 15 cropping patterns in participation with the farming communities and local agricultural extension providers of the Government of Bangladesh (GoB) and had organized participatory demonstration of those patterns in block (a contiguous area of 10-20 ha of 50-60 farmers' land) approach in the coastal regions of Bangladesh. In areas where non-saline water sources were available, the farmers were advised and motivated to grow Boro rice and in water shortage areas, farmers were suggested to adopt non-rice crops like Maize, Sunflower, Mungbean, Khesari, Sesame, Watermelon, Sweet Potato and Potato under rainfed environment by utilizing residual soil moisture and/or under supplemental irrigation from the canal water available in the coastal regions of the country. Choice of rice and non-rice crops was based on the farmers' preference for a particular area. BRAC (2010) reported that although all the crops and cropping patterns produced higher yield and income than the traditional cropping practices, the farmers could not adopt all the cropping patterns across the coastal regions of Bangladesh mainly due to variation in water salinity and availability of sufficient relatively non-saline water for year-round crop cultivation. The farmers of Bagerhat, Barguna, Jhalokathi, Patuakhali and Pirojpur districts adopted and cultivated three crops in a year, while those of Khulna and Satkhira mostly cultivated two crops per year.

The coastal region of Bangladesh is blessed with many tidal rivers and canals. Water of these rivers and canals in Barisal region remain useable for crop production for about 10 months. But the scenarios are quite different in Khulna region, where the river water remains saline during February to June. There are opportunities for growing three crops per year in Barisal region by utilizing rainfall, river and canal water resources, and a rabi crop in Khulna region after aman rice by utilizing residual soil moisture and rainfall that might lead to increased food production.

Since, the coastal region is prone to natural disasters, greater investments are needed to prevent and/or mitigate the impact of future disasters by mainstreaming DRR into

longer-term sustainable development, protecting the built environment such as agricultural or food supply chain (food storage, processing, transport) infrastructures. Investment is needed in sustainable models of food production that apply technologies and practices adapted to local conditions to raise yields and reduce risks of production failure. Firstly, better management of crop varieties, the adoption of crops and varieties those are more resilient to salinity, submergence/floods or drought and adapted to new climate patterns, plant breeding to develop new adaptive and productive varieties, and development of efficient seed delivery systems for improving farmers' access to adequate varieties. Secondly, sustainable water management to increase water use efficiency and productivity, such as rainwater harvesting, river water storage and conservation techniques and irrigation efficiency; agro-forestry systems that make use of trees and shrubs as shelterbelts, windbreaks and live fences to diminish the effects of extreme weather events; conservation agriculture which uses minimal soil disturbance, permanent soil cover and crop rotations, thereby contributing to crop diversification, high water infiltration for reduced surface runoff and soil erosion.

1.2 Objectives of the study

The overall objective of this study was to develop appropriate climate resilient agricultural systems for enhancing food security and improving income and livelihoods of the coastal farming communities of Bangladesh. The specific objectives were:

- To explore possibilities of increasing cropping intensity and crop production per unit of land, per unit of time and per unit of available coastal water resources by introducing stress tolerant crop varieties.
- To increase yearly food production and food availability of the coastal area farmers of Bangladesh through technological intervention, crop intensification and diversification.

For the study the following two questions were taken into consideration:

- Is it possible to intensify and diversify agriculture by utilizing available land and water resources of the coastal regions of Bangladesh?
- Can we increase productivity and resilience by introducing new crops, new technologies and by manipulated agronomic practices?

1.3 Organization of the thesis

Chapter 1 introduces the problem, defines the objective and specifies the research questions.

Chapter 2 presents relevant literature related to Bangladesh and other parts of the world.

Chapter 3 explains the methodologies used for data collection and it discusses the scope.

Chapter 4 contains main results and the results are discussed and analyzed.

Chapter 5 presents conclusion and recommendation for future development.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of agriculture in coastal belt

A research report entitled on The Impacts of Climate Change on the Coastal Belt of Bangladesh reported that the climate in Bangladesh is changing and it is becoming more unpredictable every year. The impacts of higher temperatures, more variable precipitation, more extreme weather events, and sea level rise are already felt in Bangladesh and will continue to intensify. Climate change poses now-a-days severe threat mostly in agricultural sector and food security among all other affected sectors. Crop yields are predicted to fall by up to 30 per cent, creating a very high risk of hunger and only sustainable climate-resilient agriculture is the key to enabling farmers to adapt and increase food security (ICEAB, 2010).

A research report entitled on Assessing Long-term Impacts and Vulnerabilities on Crop Production due to Climate Change in the Coastal Areas of Bangladesh (BCAS, 2010) reported that Bangladesh is one of the worst affected among countries that are facing the early impacts of climate change particularly in agricultural sector. In Bangladesh, over 30 percent of the net cultivable area is in the coastal region out of 2.85 million hectares of the coastal and off-shore areas, about 0.828 million hectares of the arable lands, which constitutes about 52.5 percent of the net cultivable area in 64 upazilas of 13 district. But these vast cultivable areas are under great threat of vulnerabilities of the climate change and crop production is rapidly declining. The coastal area of Bangladesh is naturally susceptible to disaster whereas climate change asserts a new depressing effect to the lives and agronomy. Coastal livelihoods are largely dependent on agricultural crops, mainly rice; thus, agriculture predominates. Important factors affecting land use for agriculture are flooding, physiography, soil salinity, and drainage congestion and irrigation facilities. Agricultural land in the coastal area is limited to wet season cropping because soil salinity is high in the dry season. Medium-high land dominates the coastal area, followed by highland, medium-low land and lowland. At present, coastal regions contribute approximately 16 percent of the total rice production of the country. In coastal districts rainfed monsoon paddy

is the dominant crop, covering about 70 percent of the total paddy-cropped area. About 60 percent of the paddy-cropped area is planted with local varieties adapted to poor water management that results in water logging and salinity. The cropping intensity is 170 percent. The coastal zone produces a relatively high proportion of pulses, oilseeds, betel nuts and leaves, winter vegetables and potatoes (BCAS, 2010).

2.2 Impacts of climate change in coastal belt

BCAS (2010) reported that coastal agriculture is being seriously affected by different levels of climatic risks caused by integrated effects of the following factors: soil salinity, water salinity, sea level rise, tidal surge, cyclone, heavy soils, soil wetness/water stagnancy, fallow/seasonal fallow land, incidence of pests and diseases, poor marketing infrastructure, problem of agro-based industries, poor health, livelihood, fishermen's are jobless, migration to cities, unsafe drinking water, etc. The coastal belt is highly vulnerable due to the climate change. The intensity of disasters like sea level rise, tidal surge, salinity intrusion and cyclone in coastal belt is being increased. The salinity intrusion is a major factor which impedes the crop production at large in the coastal belt. Water and soil salinity is a common hazard in many parts of the coastal zone. Consequently, the crop area is reducing and the cultivation of boro and aus rice, boro and other rabi crops are being restricted.

The study report of BCAS (2010) has drawn the long term impacts and vulnerability of coastal agriculture. Presently, coastal agriculture is being seriously affected by cumulative effects of soil and water related constraints, climatic risks and socio-economic problems. These are:

- Problems of increasing soil salinity and water salinity
- Scarcity of quality irrigation water during dry season
- Heavy soil consistency due to swelling/cracking clays
- Problems of tillage operations for land preparation
- Soil wetness and late drainage conditions in early dry season
- Large fallow lands or water bodies/seasonal fallow lands
- Iron (Fe) toxicity and arsenic (As) contamination
- Water-logging and drainage congestion
- High temperature, erratic rainfall and droughtiness

- Sea level rise, tidal surges/flooding and intrusion of salt water
- Incidences of pests and diseases
- Poor marketing infrastructure
- Problems of road network and communication
- Problems of agro-based industries
- Poor human health and nutrition
- Lack of employment opportunities
- Problems in fishing activities
- Population migration
- Unsafe drinking water

BCAS (2010) also reported that the crop yield would be negatively impacted by rise in temperature, erratic rainfall, flooding, droughts, salinity etc. and among which water logging and drainage congestion are the major problems. The ecological conditions are more vulnerable which is very likely to be alerted though slowly but surely due to climate change and sea level rise. The major impacts of climate change in agriculture sector described by BCAS (2010) are:

i) Utilization of land in crop agriculture and changes in crops/cropping patterns:

Average cropping intensity in the coastal areas has not much increased during 1975-76 to 2005-06 and ranges from 155-181 % except Bhola and Noakhali districts due to climate change.

ii) Fallow lands: A sizeable amount of cultivable land (about 30-50 % of NCA of concerned districts) remains fallow in rabi and aus seasons. The main reasons of which are: soil wetness/water stagnancy, tidal surges, late harvest of T. Aman rice, drought and increased salinity, expansion of shrimp culture, poultry farm and brick field.

iii) Yield reduction: Rice yield was reduced by 20-40% in T. Aman season due to erratic rainfall, increased intensity and frequency of drought, increased salinity, tidal surges, floods, cyclone, use of local varieties, and increased incidences of pests and diseases. Total yield loss of T. Aman crop has been estimated to about 6.93 lakh ton per year based on last 5-10 years of climate change scenarios. Similarly, average yield

level of Boro rice is being affected (30-40 % yield loss) by high temperature (causing sterility) and increased salinity and that of Aus rice is being affected (20-40 % yield loss) by tidal surges. Vegetables, pulses, oilseed and fruit crops are being affected (20-40 % yield loss) by drought, increased salinity, soil wetness, excessive rainfall and water-logging and tidal surges in most coastal districts. BCAS (2010) reported that total crop loss for major crops (cereals, potato, pulses, oil seeds, vegetables, spices and fruit crops) due to different climate risks was about 14.05 lakh tons per year based on last 5-10 years of climate change scenarios within the areas of ten coastal districts.

iv) Changes in annual rainfall: Erratic nature of rainfall, number of days without rainfall and more rain is occurring in short duration. Total rainfall in Kharif season is decreasing that affects the cultivation of rainfed crops in the coastal region. But the total rainfall during rabi season is increasing in Noakhali, Cox's bazaar and Khulna districts that affecting the cultivation of rabi crops.

v) Changes in temperature: Temperature is generally increasing in the monsoon, average monsoon maximum and minimum temperatures showed an increasing trend annually 0.05°C and 0.03°C respectively. Level of maximum temperature in rabi season is increasing compared to minimum temperature affecting winter crops.

vi) Increasing soil salinity: There is an increasing trend of pH level due to increasing salinity. The salinity level has increased almost doubled (EC: 2.8-18.5 to 4.0-42.8 dS/m) in Sharankhola upazila of Bagerhat district, Dumuria upazila of Khulna district and Shyamnagar upazila of Satkhira district.

vii) Increasing salt affected areas: Salt affected areas were 750,350 hectares in 1973, significantly increased to 950,780 hectares in 2009 (26.71 % increase).

viii) Increasing river water salinity: There is an increasing trend of river water salinity (12.9 to 24.5% increase) in Bishkhali river at Pathorghata point, Andarmanik river at Kalapara point and Payra river at Taltali point during 2001 to 2009.

ix) Groundwater salinity: There is an increasing trend of groundwater salinity (5.8 to 25.6 % increase) in Pirojpur and Bhola districts during 2005 to 2009.

xii) Increasing vulnerable areas of droughts, floods, river bank erosion and tidal surges: The study report showed that the vulnerable areas of drought prone, flood prone, river bank erosion and tidal surges have remarkably increased to 152,285 ha, 114,365 ha, 95,324 ha and 130,588 ha respectively, in 2008-09 compared to 1975-76 due to climate change.

FAO (2007) in its research report on adaptation to climate change for sustainable development of Bangladesh agriculture mentioned that tidal flooding during wet season (June-October), direct inundation by saline or brackish water and upward or lateral movement of saline groundwater during dry season (November-January) are the causes of soil salinity development in Bangladesh. FAO (2010) reported that in 1973, about 1.5 million ha of land had moderate salinity that has gradually expanded to 2.5 million ha in 1997 and it may reach more than 3.0 million ha in 2007. The severity of salinity problem in Bangladesh increases due to shortage of rainfall. Bangladesh has a coastal area of 2.5 million ha. Of which about 1.0 million ha, along the coastal belt, are under salinities of different magnitudes. It is predicted that Bangladesh may lose a major portion of the coastal areas to sea (BARI, 2007).

Miah et. al. (2003) mentioned that drought is a very well known natural disaster to the people of Bangladesh. Every year, 3-4 million ha of land are affected by drought of different magnitudes. Average rainfall becomes less during the critical growth stages of crops and the crops suffered from soil moisture deficits. During drought, a heavy loss to aman production affects the farmers' economy. About 5.0 million ha of lands are cultivated with aman rice, of which 4.2 million ha of lands are prone to drought of different intensities.

Md. Moslem Uddin Miah (2010) studied on "Assessing Long-term Impacts and Vulnerabilities on Crop Production due to Climate Change in the Coastal Areas of Bangladesh" suggested that appropriate coping strategies and adaptation options for improving coastal agriculture for increased agricultural production and better livelihood of the vulnerable farming community (BCAS, 2010)

The World Watch Institute an International Research Organization, published a report on 22 October 2007 (Prothom Alo, 2007) where it was mentioned that due to rise of

sea water level for climate change 21 countries of the world including Bangladesh are under serious risk. During last 100 years, the rise of sea water level has been recorded to be 9-20 cm. This level may further rise to about 88 cm by 2100. The main reasons mentioned in the report were climate change, and frequent small or large disasters have become evident. These lead to sufferings as well as financial losses to human beings.

According to Intergovernmental Panel on Climate Change (IPCC, 2010) is slated to lose the largest amount of cultivated land globally due to rising sea level and Bangladesh agriculture is very sensitive to impact of climate change. Only a meter rise in sea level would inundate 20% of the country's landmass. The Panel reported that prolonged inundation, increased drought, salinity and loss of land due to erosion are the enhanced risk that agriculture is facing due to climate change. Increased drought and salinization in the dry season and prolonged inundation in the wet season will change the areas suitable for growing crops.

A research report on climate change, its impacts and possible community based responses in Bangladesh (Pender, 2010) highlighted that food production will be particularly sensitive to climate change, because crop yields depend directly on climatic conditions (temperature and rainfall patterns). In tropical regions, even small amounts of warming will lead to declines in the amount of crops harvested. In cold areas, crop harvests may increase at first for moderate increases in temperature but then it will fall. Higher temperatures will lead to large declines in cereal (e.g. rice, wheat) production around the world (Pender, 2010).

2.3 Crop diversification

Gunaseena (2012) in a research report on intensification of crop diversification in the asia-pacific region reported that crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. Crop diversification can be a useful means to increase crop output under different situations. Crop diversification can be approached in two ways. The main form and the 157 commonly understood concept is the addition of more crops to

the existing cropping system, which could be referred to as horizontal diversification. For instance, cultivation of field crops in rice fields or growing various types of other crops in uplands have been defined as crop diversification. However, this type of crop diversification means the broadening of the base of the system, simply by adding more crops to the existing cropping system utilizing techniques such as multiple cropping techniques coupled with other efficient management practices. The systems of multiple cropping have been able to increase food production potential to over 30 t/ha, with an increase of the cropping intensity by 400-500 percent (Gunasena, 2012). The other type of crop diversification is vertical crop diversification, in which various other downstream activities are undertaken. This could be illustrated by using any crop species, which could be refined to manufactured products, such as fruits, which are canned or manufactured into juices or syrups as the case may be. Gunasena, 2012 mentioned that vertical crop diversification will reflect the extent and stage of industrialization of the crop. It has to be noted that crop diversification takes into account the economic returns from different crops. The level of diversification will also be different in various countries. Diversification at farm level will involve growing of several crops for achieving self-sufficiency, but it may be a totally different approach at the national level. Crop diversification at national level will demand more resources and require selection and management of a specific crop or a group of crops sold freshly or value added to achieve higher profits (Gunasena, 2012).

Gunasena (2012) identified several advantages of crop diversification; those are (1) comparatively high net return from crops, (2) higher net returns per unit of labour, (3) optimization of resource use, (4) higher land utilization efficiency, and (5) increased job opportunities.

Oleke et al. (2012) observed that intercropping coconut with cassava, maize, cashew nut, sorghum and pineapples were the alternatives used by farmers to cope with declining coconut production caused by coconut mite and lethal yellowing disease in Tanzania. Land ownership and size, income from crops, non-farm income and family size were the main factors that influenced the farmer's decision to diversify crops. Although farmers diversify their cropping systems in order to be self-reliant, there is still a need to promote policies and programmes that will address coconut production constraints (Oleke, 2012).

The honorable Minister for Agriculture emphasized that the government would put highest emphasis on southern areas including the coastal belt in the next fiscal year's budget to increase food production (Daily Star, 2010). She told that coastal areas have many untapped prospects and the government will take various steps like, digging canals and introducing saline-tolerant hybrid crops to increase land productivity of the coastal regions of Bangladesh. She emphasized to utilize the coastal lands through livestock farming and fisheries, and producing cereal crops through judicious use of surface water and quality seeds, and agricultural mechanization to turn again the Barisal region as the rice basket of Bangladesh.

Rahman (2004) used the Probit model to analyze the impact of diversified production in Bangladesh and showed that crop diversification is positively influenced by the developed infrastructure of a region such as education, experience, farm asset ownership, and non-income ownership of a farmer.

Barghouti et al. (2004) treated diversification as a differentiated form of agricultural development and recognized its role to spur sustainable growth in the rural sector. They mainly aimed to outline practical ways to adopt diversification activities and focused on how diversified production could remove poverty of a country. They made a six point structure which influences the diversification such as (1) feasibility, (2) policy, (3) infrastructure and markets, (4) research, extension, and training (5) private sector and supply chains, and (6) natural resources.

Mahmud et al. (1994) aimed at outlining the policies and issues of crop diversification that are likely to influence the growth and sustainability of agricultural production in

Bangladesh and concluded that crop diversification needs to be addressed as part of the broader agricultural development strategy.

2.4 Resilience to disaster

Lin (2011) has conducted a study on Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change and found that climate change could have negative consequences on agricultural production and has generated a desire to build resilience into agricultural systems. One rational and cost-effective method may be the implementation of increased agricultural crop diversification. Lin (2010) mentioned that crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events. Such benefits point toward the obvious value of adopting crop diversification to improve resilience. However, crop diversification can be implemented in a variety of forms and at a variety of scales, allowing farmers to choose a strategy that both increases resilience and provides economic benefits (Lin, 2011).

Diversification of crop systems provides an opportunity to introduce varieties that are more resilient and may also provide economic benefits (FAO 2012). Monoculture (the cultivation of the same species year after year in the same place) increases pests, diseases and certain weeds; reduces yields; has greater economic risk; results in inadequate distribution of labour throughout the year; increases toxic substances or growth inhibitors in the soil; and reduces biodiversity. Change in climatic conditions and length of growing periods will require planning for cropping patterns and varieties which make the most of the new conditions, preserving productivity and soil fertility. Diverse crop production and crop rotations (cultivation of slow-forming terraces and crop subsistence, cash or green manure/cover crops with different char-diversification, including maize, banana and vegetable cropping activities on the same field during successive years, may provide higher resilience in Rwanda (FAO, 2012).

FAO (2012) mentioned that an integrated system of fish and crops (rice, maize, sunflower and vegetables) together with poultry and goats was studied in Karnataka, India, on land previously farmed with a rice mono-cropping system. In this system, poultry droppings provided nutrients for natural food organisms in the water for the fish. After harvesting the fish, the nutrient-rich water was used to irrigate the crops, which produced fodder for the goats as well as food and income for the farmer. The results were improved crop yields, higher income and lower energy use compared with the traditional mono-cropping system.

A research report of FAO (2011) on Resilient Livelihoods showed that the promotion of more productive and resilient rural livelihoods, disaster risk reduction (DRR) for food and nutrition security requires policy support, capacity development, transformations in agriculture, livestock and fisheries/aquaculture, and improvements in the management of natural resources such as land, forests, water, soil nutrients, and genetic resources. In this report, FAO (2011) highlighted that greater investments are needed to prevent and/or mitigate the impact of future disasters by mainstreaming DRR into longer-term sustainable development, protecting the environment such as agricultural or food supply chain (food storage, processing, transport) infrastructures. Investment is needed in sustainable models of food production that apply technologies and practices adapted to local conditions to raise yields and reduce risks of production failure. FAO (2011) cited some examples, such as better management of crop varieties, the adoption of crops and varieties that is more resilient to floods or drought and adapted to new climate patterns, plant breeding to develop new adaptive and productive varieties, and development of efficient seed delivery systems for improving farmers' access to adequate varieties. Other examples cited in the report were sustainable water management to increase water use efficiency and productivity, such as rainwater harvesting, river water storage and conservation techniques and irrigation efficiency; agro-forestry systems that make use of trees and shrubs as shelterbelts, windbreaks and live fences to diminish the effects of extreme weather events; conservation agriculture which uses minimal soil disturbance, permanent soil cover and crop rotations, thereby contributing to crop diversification, high water infiltration for reduced surface runoff and soil erosion, among other benefits; and natural resource management practices to restore degraded grasslands through grazing

management, re-vegetation and supplementing poor quality forages with fodder trees, as in agro-silvo-pastoral systems and land tenure to secure land access and rights.

FAO (2011) emphasized that at the national level, preparedness planning must be developed more consistently for the agriculture-related sectors. The national DRR/M system must integrate preparedness measures addressing FNS. Technical support must be given to line ministries and departments in order to ensure that appropriate response measures are in place. Preparedness planning also requires a corporate-wide effort to strengthen FAO's capacity to assist its by member countries to effectively respond to crisis, particularly in view of the multiple and simultaneous emergencies that threaten to increase in coming years.

A research report of FAO (2001) on Crop Diversification in Asia-Pacific Region reported that coastal areas in the southern part of Bangladesh constitute a specific ecological zone having specific problems and possibilities. Cyclones, tidal bores, salinity, etc., affecting agricultural output frequently visit these areas. Therefore, there is need for developing a salinity resistant variety of rice, for example, for these areas. Coconut, betel nut, palm and mangrove are major cash crops in these areas. Location specific research, extension and other programmes will be developed and provided for the purpose of exploiting the potentials.

The World Bank (2011) report highlighted that climate-smart agriculture seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to climate change by reducing greenhouse gas emissions and increasing carbon storage on farmland. The report underlined that climate-smart agriculture includes proven practical techniques in many areas, especially in water management but also innovative practices such as better weather forecasting, early warning systems, and risk insurance. It was about getting existing technologies into the hands of farmers and developing new technologies such as drought or flood tolerant crops to meet the demands of a changing climate.

Lin (2010) mentioned that diversified agro ecosystems have become more important for agriculture as climate fluctuations have increased. The crop yields are quite

sensitive to changes in temperature and precipitation, especially during flower and fruit development stages. Temperature maximums and minimums, as well as seasonal shifts, can have large effects on crop growth and production. Greater variability of precipitation, including flooding, drought, and more extreme rainfall events has affected food security in many parts of the world (Parry et al. 2005). Such observed agricultural vulnerabilities to changes in temperature and precipitation point to the need to develop resilient systems that can buffer crops against climate variability and extreme climate events, especially during highly important development periods such as anthesis (Lin, 2010)). Lin (2010) also highlighted that there are variety of ways that diversified agricultural systems exemplify that more structurally complex systems are able to mitigate the effects of climate change on crop production. Developing policy that incentivizes the diversification of agricultural crops and landscapes may be a more rational strategy for developing resilient agricultural systems and protecting food production in the future under climate changes.

A research report on Socio-economic implications of climate change for Bangladesh, the process of long-term adaptation and short-term adjustment to the land-water regime suggested that the traditional rice-growing society of Bangladesh is quite resilient to adverse change (IGCI, 1997). Coping strategies have been developed to deal with the environmental variations (like floods and droughts) that have always occurred in the local climatic and water regimes. IGCI (1997) cited an example, where the farmers in the Gopalganj district of the Faridpur region responded to the very serious floods of 1987 and 1988 by adjusting the acreage and timing of crops so that they were less exposed to the flood risk. This was done by devoting much more land to dry season boro rice and pulses than in previous years. The acreage of boro rice and pulses almost doubled by 1989 (IGCI, 1997).

2.5 Experience of crop diversification to face climate change

Practical Action (2011) in one of the research report on Technologies for Climate Change Adaptation in Agriculture Sector stated that farmers have introduced new and improved species over centuries, mainly in regions that constitute world centers of cultivated crop diversification, such as Meso-America, the Andes, Africa and parts of Asia, in response to environmental stress conditions. There are many thousands of

existing varieties of all of the important crops, with wide variation in their abilities to adapt to climatic conditions. Agricultural researchers and extension agents can help farmers identify new varieties that may be better adapted to changing climatic conditions, and facilitate farmers to compare these new varieties with those they already produce. Practical Action (2010) highlighted that the farmers may participate in crossing and select seeds from plant varieties that demonstrate the qualities they seek to propagate to develop new varieties with the characteristics they desire. When farmers only cultivate one crop type they are exposed to high risks in the event of unforeseen climate events that could severely impact agricultural production, such as emergence of pests and the sudden onset of frost or drought. Introducing a greater range of varieties also leads to diversification of agricultural production which can increase natural biodiversity, strengthening the ability of the agro-ecosystem to respond to these stresses, reducing the risk of total crop failure and also providing producers with alternative means of generating income. With a diversified plot, the farmer increases his/her chances of dealing with the uncertainty and/or the changes created by climate change. This is because crops will respond to climate scenarios in different ways (Practical Action, 2011).

Lin (2011) reported that agricultural diversity increased the resilience of the production systems. In an example Lin (2010) explained that Sweden suffered from cold-tolerance issues, whereas Tanzania suffered from problems of heat tolerance. Both locations experienced greater seasonal drought. In these cases, research showed that successful management practices able to buffer systems from climate variation and protect production those were generally more ecologically complex, incorporating wild varieties into the agricultural system and increasing the temporal and spatial diversity of crops

Global Change Data and Information Center (2002) reported that in Africa, climate change will affect some parts of Africa negatively, although it will enhance prospects for crop production in other areas. Some regions could experience temperature stress at certain growing periods—necessitating shifting of planting dates to minimize this risk. Because a large portion of African agriculture is rainfed, however, heat-related plant stress may reduce yields in several key crops—such as wheat, rice, maize, and potatoes. Ultimately, climate change is a global issue—even more so for traded

commodities such as agricultural products. Some regions, for example, may be less competitive in national and global agricultural markets, with corresponding impacts on exports and imports. Africa, in particular, may be sensitive to changes in world prices and stocks because many countries rely on food imports. African economy depends on natural resources and the impact of changing natural resources affects several sectors of the economy (GCDIC, 2002).

In China, climate change would occur against a steadily increasing demand for food, which is expected to continue through at least 2050 (GCDIC, 2002). The increased annual cost of government investment only (excluding farmers' additional costs) in agriculture in response to climate change through 2050 was estimated at US\$3.48 billion (17% of the cost of government investment in agriculture in 1990).

(Liverman and O'Brien, 1991) cited that in Mexico, any shift toward warmer, drier conditions could bring nutritional and economic disaster because agriculture already is stressed by low and variable rainfall. More than one-third of the Mexican population works in agriculture - sector whose prosperity is critical to the nation's debt-burdened economy. (Liverman and O'Brien, 1991) mentioned that although only one-fifth of Mexico's cropland is irrigated, this area accounts for half of the value of the country's agricultural production, including many export crops.

FAO (2001) in a research report of Crop Diversification in Asia-Pacific region mentioned that a shortage of water supply for agricultural activities has been a major problem facing Thai farmers. The impact is severe for the agricultural areas, which rely heavily on rainwater. Unfortunately, such areas where there is little precipitation constitutes a predominant part of the country with mostly rice and field crop farming being implemented. Such a condition limits farmers from carrying out their cultivation to only once a year during the rainy season. Moreover, farmers are exposed to high risks and damage due to adverse environmental conditions of soil, climate, and inconsistent rainfall patterns. Although efforts have been made to tackle water shortage problems, for example, by digging ponds to store water, appropriate sizes or systems have never been determined. There are still other factors which magnify the shortage of water such as unsystematically planned crop cultivation or mono-cropping farming systems.

FAO (2001) in a research report of Crop Diversification in India reported that the crop shift (diversification) also takes place due to governmental policies and thrust on some crops over a given time, for example creation of the Technology Mission on Oilseeds (TMO) to give thrust on oilseeds production as a national need for the country's requirement for less dependency on imports. Market infrastructure development and certain other price related supports also induce crop shift. Often low volume high-value crops like spices also aid in crop diversification. Higher profitability and also the resilience/stability in production also induce crop diversification, for example sugar cane replacing rice and wheat. Crop diversification and also the growing of large number of crops are practiced in rainfed lands to reduce the risk factor of crop failures due to drought or fewer rains. Crop substitution and shift are also taking place in the areas with distinct soil problems. For example, the growing of rice in high water table areas replacing oilseeds, pulses and cotton; promotion of soybean in place of sorghum in verticals (medium and deep black soils) etc. FAO (2001) also mentioned that India has made tremendous progress in the agricultural sector over the last 50 years. From 'hand to mouth' conditions in the early sixties, we have not only become self reliant in food grains but have acquired sufficient resilience to tide over the adverse conditions. Wheat production has increased around 10 times and rice production 4 times during this period. These achievements are the result of a policy framework of improving rural infrastructure including irrigation, research, extension, provision of agricultural inputs at reasonable prices, and marketing support through minimum price mechanism.

2.6 Experiences crop diversification in Bangladesh to face climate change

BRAC (2011) monitored the crop intensification project in the coastal regions of Bangladesh. The monitoring report consisting of 405 sample farmers from 12 blocks showed that 242 (60%) of the beneficiary farmers used to cultivate only one crop per year and 163 (40%) farmers cultivated double crops in a year before the crop intensification project. After the implementation of the project, 298 (74%) farmers have adopted three crops and 107 (26%) farmers have adopted two crops per year. Most of the sample farmers showed their interest to cultivate different rabi crops for higher income. Before intervention the production cost per acre was BDT 6,697 but after the implementation of the project, the production cost was increased up to BDT

10,230 due to improved cultivation practices. The farmers produced 22 kg of rice per decimal after the intervention of the project where as the farmers produced only 12 kg per decimal before the intervention indicated that farmers' production has doubled. They have expressed their satisfaction on the activities of the crop intensification approach, especially with the new knowledge and higher production that they had gained during the project period. The sample farmers earned BDT 26,477,891 due to cultivation of two/three crops per year whereas before the intervention the farmers used to earn only BDT 6,350,195 cultivating one crop per year. Almost all the farmers showed their interest to cultivate hybrid/HYV rice even after the completion of the project. All the sample farmers informed that their household income has increased considerably and they will buy different agricultural equipments such as power tiller, sprayers etc. with the increased income aside from investing a portion of it on health care and education of their children and other family members (BRAC Monitoring Report, 2011).

The completion report of BRAC entitled on "Crop intensification for achieving food self-sufficiency in the coastal regions of Bangladesh" reported that 15 cropping patterns were identified for the coastal regions of Bangladesh in participation with the farming communities and local agricultural extension providers of the Government of Bangladesh and has organized participatory demonstration of those patterns in block approach (block means a contiguous area of 10-20 ha of 50-60 farmers' land). Of the 15 cropping patterns, six patterns were demonstrated in Khulna and Satkhira districts and nine patterns were demonstrated in Bagerhat, Barguna, Jhalohathi, Patuakhali and Pirojpur districts. Although Bagerhat is in Khulna division, availability of water resources in this district relatively match with the districts of Barisal division; and the demonstrated cropping patterns were the same in the districts of Barisal division and Bagerhat district. The cropping patterns of Khulna and Satkhira districts were the same, where rice cultivation in boro and aus seasons is not possible due to high salinity in river water. But there are some water reservoirs where fresh water can be conserved for rice cultivation in boro and aus season and BRAC suggested the nearby farmers to cultivate rice in both the seasons. They cultivated boro and aus rice in a limited scale by utilizing reservoir water (BRAC 2012).

The farmers of Barisal region including Bagerhat district were able to produce about 12-19 t/ha per year by adopting (a) Rice-Rice-Maize, (b) Rice-Rice-Sunflower, (c) Rice-Rice-Kheshari, (d) Rice-Rice-Mungbean and (e) Rice-Rice-Rice cropping patterns. Investing an amount of BDT 85,000-117,000 per ha, the farmers earned an annual gross income of BDT 218,000-315,000 per ha. On the other hand, in Khulna and Satkhira districts the farmers produced 6-13 t/ha per year by adopting (a) Rice-Maize, (b) Rice-Sunflower, (c) Rice-Kheshari and (d) Rice-Mungbean cropping patterns (in Aman and rabi seasons) in their farms as water resources in these districts are highly unfavourable for three crops cultivation in a year. Investing an amount of BDT 46,000-72,000 per ha, the farmers of Khulna and Satkhira districts were able to earn an annual gross income of BDT 134,000-264,000 per ha (BRAC, 2012).

The completion report of the Cyclone SIDR livelihoods rehabilitation project of BRAC highlighted scope of rice cultivation by using tidal river water in the Barisal region, BRAC encouraged the farmers to cultivate high yielding variety (HYV) and hybrid rice in pre-monsoon (*Aus*) and monsoon (*Aman*) seasons in traditional single-crop areas. Compared to traditional practices, the implementation showed an increase in productivity of nearly three times and profitability gains of nearly four times than the farmers' traditional practice (BRAC, 2010).

BRAC also introduced maize, sunflower, and other vegetables as new crops in areas with limited non-saline water as part of the rehabilitation of SIDR victims and to develop climate resilient agriculture for the coastal regions of Bangladesh so that the farming communities could face SIDR type cyclones and other disasters. Participating farmers identified large profitability of these practices and with them BRAC demonstrated year round cropping in the untapped coastal regions instead of the traditional single rice (BRAC, 2010).

The observations of the EuropeAid on crop intensification program implemented by BRAC (2011) were as follows:

- 28,000 beneficiaries were provided with the financial and technical support they needed to grow 2 to 3 crops per year in their traditionally single-cropping area.

- 73,021 farmers (both husband and wife) and 3,121 government extension officials were provided with hands-on training in crop intensification.
- Crop intensification created new jobs in farming for landless people. Other stakeholders (seed and fertilizer dealers, power tiller owners, etc.) also benefited from higher incomes.
- The beneficiary farmers in the 7 coastal districts of Bangladesh produced an additional 34,687 tonnes of paddy.

A narrative report of BRAC (2012) entitled “Support to agricultural research for climate change adaptation in Bangladesh (SARCCAB)” showed that upscaling activities are integrated with crops and fisheries technologies into sustainable farming systems, in which 6 rice-based cropping patterns including integrated Vegetable-Vegetable-T. Aman(MV)+Fish pattern are being demonstrated in Batiaghata and Dacope upazilas of Khulna district since December 2010. The report found that integrated rice-fish-vegetable cropping pattern is more profitable than Boro-Fallow-T. Aman (MV) and Rabi-Fallow-T. Aman(MV). The cropping pattern seems to be climate resilient and is highly acceptable to the farmers of the most disaster-prone coastal regions of Bangladesh field (BRAC, 2012).

A research report of IRRI (2010) on rice intensification showed that crop intensification may also be a prime culprit in yield stagnation, especially for rice. Today, it is common for farmers to produce two or even three rice crops per year where only one or two were grown in the past. This is possible because some new rice varieties mature more quickly than traditional varieties, in addition to yielding more grain per plant. For example, the rice known as IR8, one of the early “miracle rice” varieties introduced in 1966 by plant breeders at the International Rice Research Institute (IRRI) in the Philippines, ripens 20 to 30 days ahead of unimproved varieties. Yet the extra crops that the newer varieties allow can place a heavy strain on soils, particularly those used in paddy rice production, where the growing medium is under water for long periods (IRRI, 2010).

A research report of IAEA (2010) in the coastal area of Bangladesh mentioned that around 90% of arable land remains unused for 6 to 7 months after the rice harvest, due to the shortage of fresh water and the high salinity of the soil. Soil salinization is

mainly due to sea water that moves inland along the tidal rivers, spills over to the land and salinizes soil and the shallow groundwater. However, potential exists to produce some additional food crops, such as mustard, mungbean and sesame, which need relatively less water following the early harvest of aman rainfed rice. To improve farmers' livelihoods, improved water and soil management and additional crop varieties are needed to reduce the long fallow period and to improve food security (IAEA, 2010).

Poulton (2008) reported that increasing staple food crop productivity requires governments, with private sector actors, farmers and civil society, to address a number of challenges. These are posed by specific technical constraints to productivity increases: lack of important public goods (principally infrastructure and institutions), dramatic increases in food and fertilizer prices; poor policy coordination, lack of complementary coordination in rural service development and provision (Poulton and Dorward, 2008).

Rahman (2006) in a research report on the "Growth and Yield of Tomato in the Coastal Area of Bangladesh under rainfed Condition" reported that from the average of two years results the study found that the highest yield (59.41 t/ha) and the highest gross margin (BDT 244,450 per hectare) were obtained by rice straw mulch followed by water hyacinth mulch with yield 52.5 t/ha and gross margin BDT 223,450 per hectare. The benefit cost ratio was found to be highest (5.65) in rice straw followed by water hyacinth (5.56), wastage of rice straw (5.01) and no mulch (4.51). However, tomato could be cultivated in coastal area minimizing soil salinity with application of mulch (Rahman et al. 2006).

Mondal (2004) in a research report on increasing land productivity at the coastal saline soil by introducing HYV rice in T. Aman season at Kismat Fultola village of Batiaghata upazila in Khulna district during 2002-04 reported that yield of 15 T. Aman rice varieties varied from 3.0 to 6.0 t ha⁻¹. Even aromatic rice produced (3.0-4.0 t ha⁻¹) much higher grain yield than that of the farmer used to harvest (2.0-2.5 t/ha) using their traditional rice varieties (Mondal et al. 2004a).

Haque (2001) in a research report on salinity problems and crop production in the coastal regions of Bangladesh reported that due to increasing degree of salinity of some areas and expansion of salt affected area as a cause of further intrusion of saline water, normal crop production becomes more restricted. In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman and Ahsan, 2001). Increased pressure of growing population demand more food. Thus it has become increasingly important to explore the possibilities of increasing the potential of these (saline) lands for increased production of crops (Haque, 2001).

Haque (2001) reported that during wet season, local aman rice is grown extensively in the coastal saline areas with normal yields between 2.5 and 3.0 tons per hectare. Transplanted aman-fallow is the most dominant cropping pattern in the Khulna, Barisal and Patuakhali regions. In Noakhali and Chittagong, aus-local transplanted aman pattern covers 25-28% area. Next to this is the transplanted aman-fallow pattern, represents about 18-20% area. Winter crops, such as wheat, potato and vegetables are grown, which cover a small area (11.5%). This is practiced in the district of Noakhali with transplanted aman-winter crop cropping pattern (Haque 2001).

From the above literature I can conclude that agriculture is the most vulnerable sector in the coastal regions of Bangladesh because of the productivity totally depends on climatic factors. Crop production is adversely influenced by erratic rainfall, temperature extremes, sea level rise and increased salinity, floods, river erosion, cyclone and storm surges, and drought. All of which are likely to increase as a result of climate change. Increased extreme weather events and sea level rise has the potential to increase the demand on the agricultural sector whilst limiting the amount of cultivatable land. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The effect of the tides is manifested in a regular alternation of rise and fall of the water level of the sea and the estuarine/tidal channels and creeks. The saline river water may also cause an increase in salinity of the groundwater and make it unsuitable for irrigation. Scarcity of fresh irrigation water would be a problem especially during the winter months which will again have negative implication of the yield of *Boro* rice. It affects crops

depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost.

But the most fortunate thing is that the scientists have developed short-duration and stress-tolerant high yielding and hybrid varieties of crops that could be adopted in the coastal regions of Bangladesh. Intelligent use of these crops round the year may improve resilience of the coastal communities that may lead to satisfy food demand of the expanding population of Bangladesh.

CHAPTER 3

METHODOLOGY

3.1 Introduction: Five coastal districts namely Patuakhali, Barguna, Jhalokathi, Pirojpur and Bagerhat districts were selected for this study. The whole study was conducted by collection of secondary information on various aspects related to agriculture from BRAC and livelihood particularly in the coastal region was done through literature review, socio-economic and statistical data from Bangladesh Bureau of Statistics. Climate data were collected from Bangladesh Meteorological Department. Crop considered under this study are rice (Aus, Aman and Boro), maize, sunflower and mungbean. A multi-disciplinary, participatory and interactive method has been followed in carrying out the study. Both primary and secondary data were reviewed and incorporated in the following ways:

- The secondary data collected and reviewed on land use, climate change and land degradation.
- Data/information on land use systems, major crops/cropping patterns, conversion of agricultural land, climatic parameter (rainfall, temperature etc.), land/soil data on different parts of the country etc. being collected from pertinent institutions.
- Collection of information/data from primary sources through focus group discussion and household survey- a total of 750 farmers were selected from 5 upazilas of 5 coastal districts for this study. From each upazila, 150 farmers' were sampled for data collection. The selected farmers were the beneficiaries of the BRAC's crop intensification project implemented after two cyclones SIDR and AILA. BRAC conducted the study in a cluster, named block involving 50-60 farmers in a contiguous area. Data on their cropping practices, productivity and profitability of the crops and cropping patterns, their adaptability in diverse climate and environment were collected from rice and non-rice crops growing farmers of the blocks using questionnaire. Information on the problems and prospects of coastal agriculture and documentation of farmers' experiences on innovative practices were also recorded. Focus Group Discussion (FGD) with 50 farmers were conducted (Photograph 3.1) to know about their cropping patterns, occupational changes and their future plan for

cultivation. Their thinking about the problems they face in cultivation and the way they are planning for solution of their problems were also addressed in this study. The farmers were also asked questions related to climate change specially the climate related hazards, livelihood, agricultural production, income generation, food security and adaptation techniques those were applied to overcome hazards in their locality. The household survey conducted in five upazilas of 5 coastal districts. In each upazila 60 sample households were interviewed and data were collected on soil salinity, tidal surges, water stagnancy, cyclone, expansion of shrimp culture and ground water salinity. The household survey dealt with farmers' response to questions on causes of poverty and food insecurity, long-term impacts of climatic risk factors affecting crop production, adaptation strategies and innovative practices and introduction of suitable crop varieties to mitigate the adverse effects of climate change. The questionnaire used for the survey is attached in the Appendix-1.



Photograph 3.1 Focus Group Discussion at Nazirpur upazila in Pirojpur district.

3.2 Study Location: The study was conducted in 5 upazilas (Barguna Sadar, Patuakhai Sadar, Jhalokathi Sadar, Nazirpur and Kachua) of 5 districts (Barguna, Patuakhali, Jhalokathi, Pirojpur and Bagerhat) of coastal regions of Bangladesh

(Figure 3.1). The locations were selected on the basis of BRAC's tested cropping patterns selected for the study.

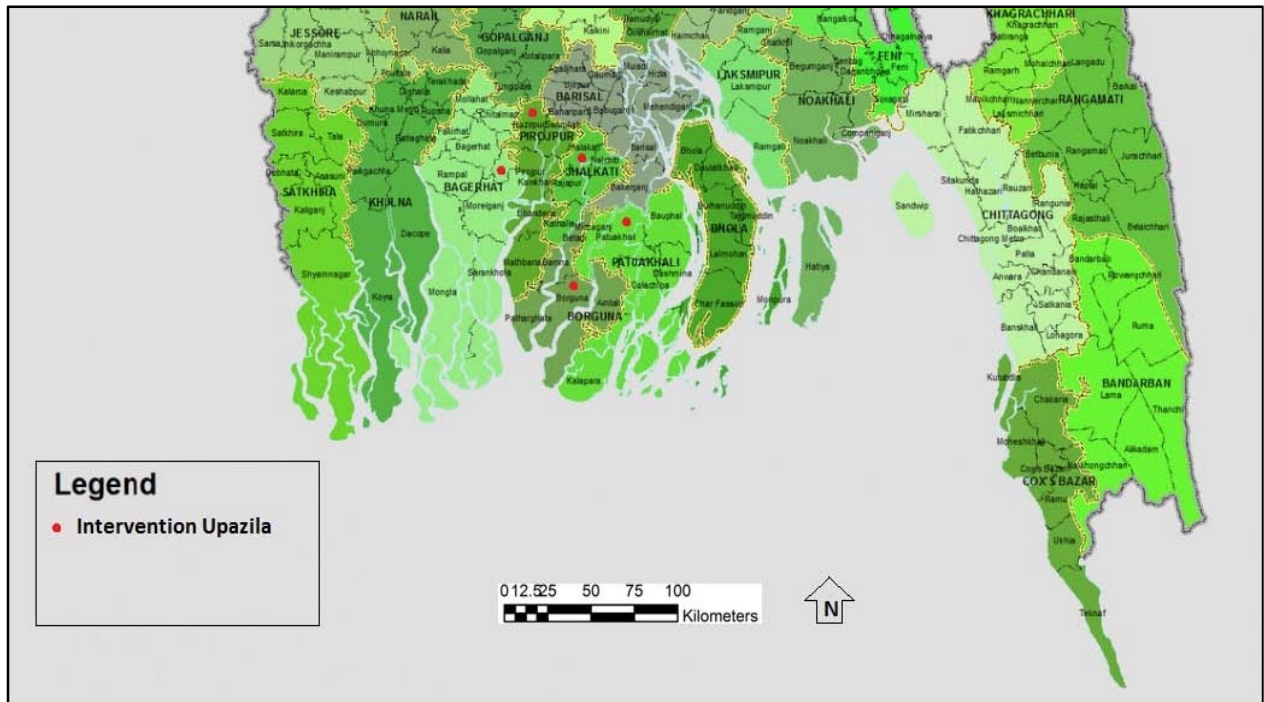


Figure 3.1 Map of the coastal upazilas of Bangladesh showing the study sites (BRAC, 2012).

3.3 Study Period: July 2012- December 2012.

3.4 Development of checklist for FGD: To obtain information from the FGDs a checklist was prepared. The checklist contained some indicators on which information was obtained. The major indicators are presented below:

- Site description
- Major crops and cropping patterns
- Causes of changing crops/cropping patterns
- Identifying factors of climate change those responsible for crop loss/yield reduction
- Assessing long-term impacts of climate change on crop production systems.
- Identifying the problems and prospects related crop production systems
- Estimation of problem areas (eg. coastal char lands, salinity/tidal surge or water stagnancy) due to climate change.
- Identifying different innovative farming practices in salinity/tidal surge areas.

- Identifying location-specific adaptation practices to cope up with vulnerabilities due to climate change.
- GO/NGO interventions to address climate change problems/hazards.
- How climate change is affecting food security
- Action /measures needed for vulnerable areas: immediate and mid-term measures.

3.5 Sampling Procedure and Sample Size: We have found two major categories of cropping patterns demonstrated in the project area (Table 3.1). These were Aus-Aman-Boro and Aus-Aman-Rabi. Under these, a total of 4 cropping patterns were demonstrated in different locations of the coastal region. We have selected 150 farmers each for rice-rice-rice, rice-rice-maize, rice-rice-sunflower and rice-rice-mungbean cropping patterns for this study. The Simple Random Sampling (SRS) procedure was followed for selecting the sample from the demonstrated cropping patterns.

Table 3.1 Cropping pattern and sample size

Broad Pattern	Cropping Pattern	Sample size
Pattern 1: Aus-Aman-Boro	Rice-Rice-Rice	150
Pattern 2: Aus-Aman-Rabi	Rice-Rice-Maize	150
	Rice-Rice-Sunflower	150
	Rice-Rice-Mungbean	150

3.6 Data Collection: The study was based on both primary and secondary data. Structured questionnaires were used to collect primary data. Primary data was also collected from farmer’s field during the crop cuttings in blocks by BRAC in presence of Government official, local leaders, mass media and neighboring farmers. Face to face interview was taken and put the data into the questionnaire. Interviews were taken very carefully and immediately rechecked for more accuracy. The information had been taken from different relevant books, articles, reports, maps, journals, research paper, website and daily newspapers

3.7 Tabulation: The collected data manually coded in accordance with the objective of the study. Data were managed and analyzed by using both tabular and functional

methods. To see the social impact of the project and socio-economic position of beneficiaries, tabular analysis was done. This technique was applied with the help of some statistical measures (like the sum, average, percentage etc.) to show the relationship between/among the selected variables. Benefit-Cost Ratio (BCR) was calculated to document the profitability of particular crop production and adoption of cropping pattern in the coastal regions of Bangladesh.

BCR was calculated by using the following formulas;

$$\text{BCR (Cash Cost basis)} = \text{Total return} / \text{Total cash cost}$$

$$\text{BCR (Total Cost basis)} = \text{Total return} / \text{Total cost (Cash + Non-cash)}$$

Cropping Intensity (CI) was calculated by using the following formula;

$$\text{Cropping Intensity} = (\text{Total cropped area} / \text{Net cropped area}) * 100$$

3.8 Time Frame: Time frame is very necessary to do the study smoothly. Time schedule of the study prepared depending on the priority of the thesis (Table 3.2).

Table 3.2 Time Frame July 2012-December 2012 for this study

Activity	July	August	September	October	November	December
1. Introduction						
2. Literature Review						
3. Methodology (including data collection)						
4. Result Discussion and Analysis						
5. Conclusion and Recommendation						
6. Report Submission						

CHAPTER 4

RESULT, DISCUSSION AND ANALYSIS

4.1 Introduction: It is predicted that climate change could have devastating impacts on agriculture. The predicted sea-level rise will threaten valuable coastal agricultural land, particularly in low-lying areas. Biodiversity would be reduced in some of the most fragile environments, such as Sunderbans and tropical forests. Climate change imposes higher level of vulnerability mostly in crop agriculture sector and then fisheries, livestock and health sector, respectively. Yield of most of the crops would be negatively impacted by rise in temperature and erratic rainfall, flooding, droughts, salinity, etc. As a consequence of climate change the trend shows that drier regions would be drier in the winter season. Therefore, possibility of growing rainfed crops would be diminished. During the dry months of March and April, salinity problems, resulting from seawater intrusion, are more acute and lands are commonly left fallow as crop productions restricted by the presence of salt. Yields of crops are drastically reduced when the threshold value for tolerance is crossed. More than 50% of the potential yields of most crops are reduced when the salinity (EC) is above 5 dS m⁻¹. However, the Bangladesh Rice Research Institute has developed varieties that can tolerate salinity level up to 8.0 dS m⁻¹. These varieties are: BRRI dhan40, BRRI dhan41 and BRRI dhan47, which can be grown in the Aman and Boro (BRRI dhan47) seasons in the coastal saline belt of the country.

4.2 Crop intensification: The prime objective of the study is to increase the cropping intensity as a means of improving the food security of the cyclone affected farmer households. An evaluation study found that the cropping intensity considerably increased due to the project interventions of BRAC. Before project single, double, and triple crop lands were respectively 29%, 64%, and 7% (in the blocks) in the study areas. During the project BRAC motivated the farmers to cultivate the land 2-3 times a year. As a result, while no land under the blocks has single crop land, rather 20% and 80% lands were used respectively for double and triple crops, meaning that cropping intensity has increased significantly. The cropping intensity was estimated at 178% before the project and 280% during the project. Intensity of land use for crop cultivation before and during project is presented in Table 4.1 and Figure 4.1.

The project not only brought back the farmers in proper cultivation practice and recovered the degraded lands but also ensure higher yields and production compared to the past. Farmers do not cultivate local variety as much that has low yield and take longer time to grow and are subjected to various risks. Land is used for cultivation of high yielding variety and hybrid varieties year round ensuring high cropping intensity and high yield.

Table 4.1 Cropping Intensity in the Existing Blocks

Number of crops cultivated per year	Before Project (Area Cultivated in ha)	During Project (Area Cultivated in ha)
1 Single crop	23 29%	0 0 %
2 Double crops	52 64%	16 20%
3 Triple crops	6 7%	64 80%
5 Total cropped area	81 100%	80 100%
6. Net cropped area	145	224
6 Cropping Intensity (%)	179%	280%

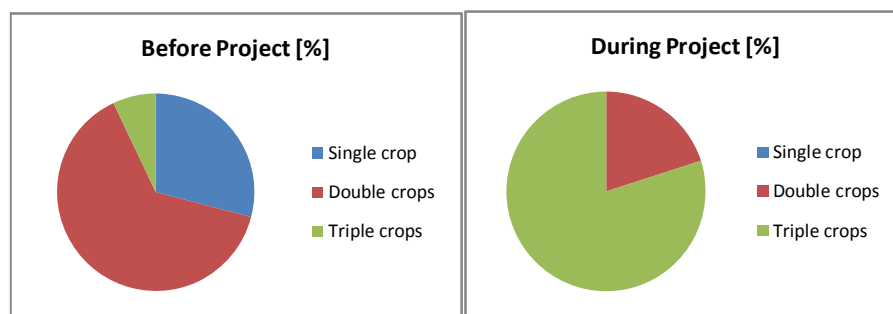


Figure 4.1 Cropping Intensity in the Existing Blocks

4.3 Productivity and profitability of rice: The participatory farmers of different blocks were trained to cultivate rice in Aus, Aman and Boro seasons where suitable growing conditions prevailed to increase food production and also to harness higher benefits from rice cultivation. BRAC had good experience on hybrid rice cultivation in Aus and Boro seasons, advised the farmers to cultivate hybrid rice in both the seasons to achieve higher productivity. The beneficiaries were also advised to adopt high yielding varieties (HYV) of rice in Aman season that farmers usually cultivate in some areas of the coastal (SIDR and AILA affected) districts. The project has provided BDT 9,000-10,000 per acre as cash grants to cultivate HYV and hybrid rice, respectively. The farmers used their own labour that was required in different cultural

practices for rice cultivation. It was estimated that the farmers provided about 40% of rice production cost, mainly in terms of labour and the project paid 60% to purchase inputs that demands cash money (during cyclone farmers lost all of their assets, hence the provision of cash was to improve productivity and their livelihoods). Aside from cash grants, the farmers were provided technical knowledge and hands-on training on rice cultivation and monitored their cropping activities regularly to reduce their mistakes and also to harness more benefits from cash grants, as they were accustomed to cultivate traditional rice in very traditional ways. Payment for rice inputs was made to 29,318 beneficiaries to a land area of 20,137 acres (8,055 ha) in different rice growing seasons. Results of the farmers' rice production practices are stated below:

Aus rice: The farmers of Barguna Sadar, Patuakhali Sadar, Jhalokathi Sadar, Nazirpur and Kachua upazilas were provided cash grants and hands-on training for rice cultivation in aus season and were advised to cultivate hybrid rice where suitable growing conditions prevailed to harness higher benefits from rice cultivation. As per technical input, the farmers cultivated hybrid rice (variety Alloran: Photograph 4.1) during mid-April to mid-August. They have provided irrigation at the beginning of the cropping season, mainly up to May for growth and development of rice. Later on the crop field received tidal water that came naturally during high tide, which was sufficient to meet up crop water requirements, in most cases no pump irrigation was needed for aus rice cultivation. The farmers applied recommended doses of fertilizer and adopted integrated pest management approaches to cultivate aus rice.

The yield of hybrid rice in aus season varied from 5.63 to 6.78 t/ha with an average value of 6.29 t/ha (Table 4.2 and Figure 4.2). Hybrid rice produced almost similar yield across the coastal regions of Bangladesh. Like the yield, production cost of hybrid rice in aus season was almost similar (about BDT 40,000 per ha), but the gross income varied considerably (BDT 89,416-100,355 per ha) may be due to variation in the market price from one location to another. Overall benefit-cost ratio of hybrid rice cultivation in aus season was 2.35 that varied from 2.15 to 2.57, indicated its profitability.

Table 4.2 Productivity and profitability of rice in the coastal regions of Bangladesh.

Crop	Yield (t/ha)	Production Cost (BDT/ha)	Gross Benefits (BDT/ha)	Benefit-Cost Ratio (BCR)
Aus Rice	6.29	40,167	93,839	2.35
Aman Rice	4.62	36,964	110,664	3.01
Boro Rice	6.91	45,628	131,668	2.77
Average	5.94	39163	112,057	2.71

Source: Crop cut data from BRAC block in aus-aman-boro seasons 2010-11.

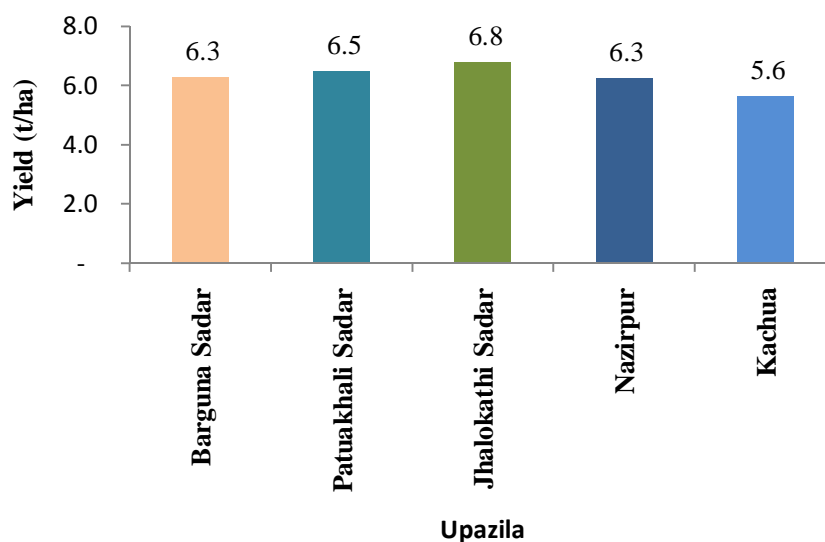


Figure 4.2 Yield of hybrid rice in the SIDR and AILA affected five upazilas of coastal Bangladesh during Aus season (average of 2010 and 2011).



Photograph 4.1 Hybrid rice (variety Alloran) at maturity in Barguna district, Aus season 2010 (BRAC Final Report of CIP, 2012).

Aman rice: In aman season, the farmers were advised to cultivate HYV rice. They were provided hands-on training and cash grants to cultivate rice as was done in aus season. They mostly cultivated BR11, BRRIdhan33, BRRIdhan41, BRRIdhan44 and Allaron (hybrid). Yield data were collected and the average yields of different rice varieties grown in different upazilas are presented in Figure 4.3. Among the HYVs, BRRIdhan41 produced the highest grain yield (4.64 t/ha) followed by BR11 (4.61), BRRIdhan44 (4.59) and BRRIdhan33 (4.01 t/ha). Data was collected from 7 farmers who cultivated hybrid rice in aman season 2010, obtained the highest yield (5.27 t/ha) that varied from 4.91-5.63 t/ha. Average yield of aman rice was 4.62 t/ha (Table 4.2) that varied from 4.01 to 5.27 t/ha across the coastal regions of Bangladesh. The yield was almost similar that is usually harvested by the farmers in other parts of the country.

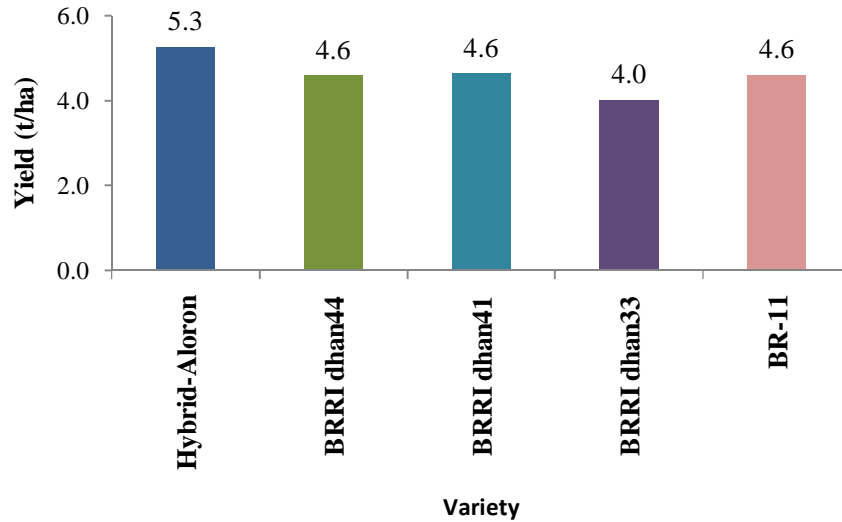


Figure 4.3 Yield of high yielding and hybrid rice varieties in Aman Season (2010).

Average production cost of aman rice (BDT 36,964 per ha) was lower than aus rice (BDT 40,167 per ha), mainly due to the extra cost of irrigation and hybrid seed used for aus rice cultivation (Table 4.2). Overall benefit-cost ratio for aman rice was 3.01, higher than that of aus rice cultivation. Aman rice is cultivated under rainfed condition and generally irrigation is not required. But during the project period, the farmers have to provide 1-2 supplemental irrigation due to late rainfall (may be an adverse effect of climate change) and for timely establishment in order to avoid yield loss (Photograph 4.2).



Photograph 4.2 Hybrid rice (variety Alloran) at maturity in Barguna upazila, Aman season 2010 (BRAC Final Report of CIP, 2012).

Boro rice: The farmers were advised to cultivate hybrid rice in boro season for higher productivity. They cultivated Allaron, a hybrid rice variety developed by BRAC, in 5 upazilas of the coastal region. Cash grant to purchase inputs and training on different aspects of rice cultivation were also provided to the famers as done in aus and aman seasons. The performance of hybrid rice in boro season was variable across the upazilas, yield varied from 5.42 to 8.00 t/ha (Figure 4.4). Average yield of hybrid rice that the farmers harvested in boro season was 6.91 t/ha, more than a ton higher than that they achieved in aus season (Table 4.2).

Overall production cost, gross income and benefit-cost ratio of boro rice was much higher than those of aus and aman rice (Table 4.2). Average production cost for boro rice cultivation was BDT 45,628 per ha (varied from BDT 42,295 to BDT 53,189 per ha), gross income was BDT 127,538 per ha (varied from BDT 96,650 to 153,693 per ha) and the BCR was 2.79 (varied from 2.24 to 3.15). The boro rice is fully irrigated crop and required more irrigation water than aus rice. As a result, the production cost was higher in boro season than rice cultivated in aus and aman seasons. As the yield of boro rice was higher than both aus and aman rice, the gross income was much higher than those obtained by the farmer in aus and aman seasons.

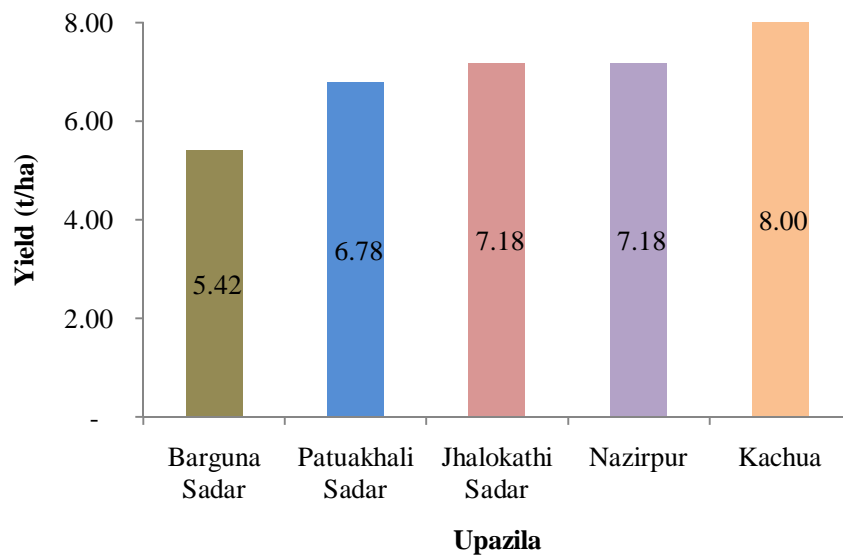


Figure 4.4 Yield of hybrid rice (Alloran) in Boro season 2011.



Photograph 4.3 Hybrid rice (variety Alloran) at flowering stage in Patuakhali Sadar, Boro season 2011(BRAC Final Report of CIP, 2012).

Comparison on the productivity of hybrid and inbred rice: Different rice varieties (hybrid and inbred) were cultivated by the farmers in 5 coastal upazilas of coastal Bangladesh during Aus, Aman and Boro seasons of 2010 and 2011 and their productivity were evaluated. Comparison of rice yields across the coastal regions of Bangladesh is presented in Figure 5. The hybrid rice varieties grown in aus season produced the highest yield in Jhalokathi sadar (6.78 t/ha) followed by Patuakhali sadar (6.48 t/ha), Barguna sadar (6.28 t/ha), Nazirpur (6.26 t/ha) and Kachua (5.63 t/ha) upazilas. During Aman season, HYV rice varieties were cultivated and the highest yield was obtained in Barguna sadar (5.27 t/ha) followed by Jhalokathi sadar (4.64 t/ha), Kachua (4.61 t/ha), Patuakhali Sadar (4.59 t/ha) and Nazirpur (4.01 t/ha). In boro season, hybrid rice varieties were cultivated and the highest yield was recorded in Kachua (8.00 t/ha) followed by Nazirpur (7.18 t/ha), Jhalokathi sadar (7.18 t/ha), Patuakhali sadar (6.78 t/ha) and Barguna sadar (5.42 t/ha) upazilas. Overall performance of the hybrid rice varieties was much better in Boro season than that of Aus season in almost all the upazilas, except in Barguna sadar.

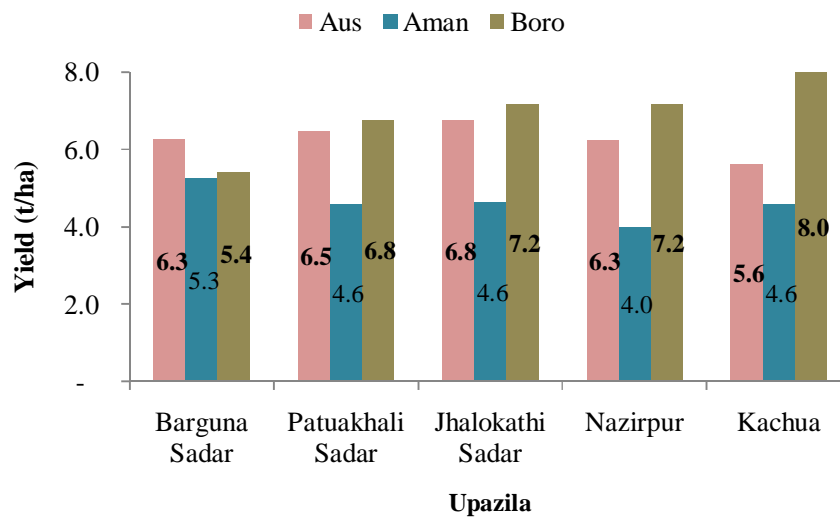


Figure 4.5 Productivity of rice in different upazilas of the coastal regions of Bangladesh.

Agronomic characteristic of improved and local rice variety: The yield and agronomic characteristics of rice grown by the farmers were collected and are summarized in Table 5. The crop cuts were taken from 86 blocks of the selected 5 upazilas. Two crop cuts were taken from each block and the yield was converted to

14% moisture content. In aus season, effective tillers of Alloran rice were high with an average value of 11.10 tillers per hill. Mean panicle length was 27.99 cm. We have observed an average of about 156 filled grains per panicle (94% filled grains per panicle). One thousand grain weight of Alloran rice was 30.02 gm. A view of the Alloran rice is shown in Photograph 1.

The agronomic information of high yielding varieties of rice (BR11, BRRI dhan33, BRRI dhan41, BRRI dhan44) were also collected from all the blocks and are summarized in Table 4.3. HYV rice produced an average 11.32 tillers per hill with the mean panicle length of 25.55 cm. The number of filled grains per panicle was 146.37. Overall 91% of the total grain was filled grains having average 1000 grains weight of 25.82 gm.

Hybrid rice, Alloran also performed well in Boro season. Average effective tillers per hill were 14.07, much higher than that observed in aus and aman seasons (Table 4.3). The mean panicle length of hybrid rice in boro season was 27.16 cm. About 96% spikelets were filled grains and in each panicle the number of filled grains was 190.80 per panicle, higher than that observed in both aus and aman seasons. Average weight of 1000 grains was 29.02 gm.

Table 4.3 Some agronomic characters of rice varieties (hybrid and HYV) grown by the farmers in Aus, Aman and Boro seasons of 2010 and 2011.

Rice crop	Growing Season	Yield components				
		Effective tiller/hill	Panicle length (cm)	Filled grains/panicle	% filled grains	1000 grain weight (gm)
Hybrid	Aus	11.10	27.99	155.82	93.78	30.02
HYV	Aman	11.32	25.55	146.37	91.32	25.82
Hybrid	Boro	14.07	27.16	190.80	96.37	29.02

Source: Crop cut data from BRAC block in aus-aman-boro seasons, 2010-11.

Traditionally the farmers of the coastal regions of Bangladesh cultivate local rice varieties such as Kutiagni, Malachina, Dudkalam, Moulata, Sadamota, Lalmota Rajashail, Kajalshail, Asmantara, Jotai, Morichsail, Hoglapata, Jamaibaboo etc. We

have also collected yield and agronomic information of the local varieties grown by the neighbouring farmers of the BRAC project by using same methodology as used in HYV and hybrid rice. The results are summarized in Table 4.4.

Table 4.4 Yield and some agronomic characters of local rice varieties grown by the farmers in Aman season 2010 (outside of the BRAC block).

Rice Variety	Season	Yield and agronomic characters				
		Effective tiller/hill	Panicle length (cm)	Filled grains/panicle	1000 grain weight (gm)	Yield (t/ha)
Local	Aman	10.94	24.38	110.18	27.18	2.40

Source: Crop cut data from outside BRAC block in aman season 2010.

The number of effective tillers of local rice was 10.94 tillers per hill, which was less than the inbred and hybrid rice varieties grown by the beneficiary farmers. Mean panicle length of local rice was 24.38 cm and was also less than the improved varieties. The filled grains per panicle were about 110.18, and those of improved varieties varied from 146.37 to 190.80 filled grains per panicle. These characteristics contributed higher yield in improved varieties (hybrid and HYV) grown by the beneficiary farmers of BRAC block than the traditional rice varieties grown by the farmers of the coastal regions of Bangladesh. It was interesting to note that percentage of filled grains were almost similar in both local (89%) and improved rice (91-96%) varieties and 1000 grain weight of local rice (27.18 gm) was also close to the improved varieties (25.55-27.99 gm). But average yield of local rice was about 2.4 t/ha, much less than the varieties grown by the block farmers. It is apparent that yield of improved rice (inbred and hybrid) was 2-3 times higher than local rice, mostly due to more number of effective tillers per hill, longer panicles and more number of filled grains per panicle that was observed in improved varieties over the traditional rice varieties cultivated by the farmers of the coastal regions of Bangladesh.

Although the environmentalists and some civil society personnel criticized the cultivation of hybrid rice, Alloran was proved to be superior over the HYV rice and emerged an important rice variety for the coastal regions of Bangladesh owing to its

higher yield and bold grain that is preferred by the farmers of this region (especially the farmers Barisal region like bold grain). Yield of hybrid rice was 1-2 t/ha higher than HYV rice, and about 3-4 t/ha higher than traditional rice varieties (Tables 4.2 and 4.4) cultivated by the farmers of the coastal regions of Bangladesh. Moreover, a single variety can be grown in all the rice growing seasons with higher production potential than HYV and traditional rice varieties. Therefore, in a populace and land-scarce country like Bangladesh, cultivation of hybrid rice should be promoted to achieve food security when climate change is supposed to pose serious threat to our agriculture, especially in coastal regions of the country.

4.4 Productivity and profitability of non-rice crop: In the Rabi season (November-April), BRAC has chosen 272 satellite blocks in addition to 250 main blocks for different non-rice crops cultivation. The participatory farmers of different blocks were provided training to grow different non-rice crops. The farmers cultivated maize, sunflower and mungbean in both the main and satellite blocks in 5 coastal districts by utilizing residual soil moisture and limited canal and/or river water. As most lands remain fallow in the rabi season, the aim of introducing different rabi crops was to create awareness among the farming communities that different rabi crops can be grown by using residual soil moisture and limited amounts of fresh water available near their farm. BRAC has provided BDT 5,000-8,000 as cash grants per acre to cultivate different rabi crops. Like rice, the farmers used their own labour for non-rice crop cultivation. Aside from cash grants, the farmers were provided technical knowledge and advised them to cultivate hybrid, HYV and traditional varieties of rabi crops. The cropping activities regularly monitored to reduce their mistakes and also to harness more benefits of the cash grants, as they were not accustomed to cultivate rabi crops except kheshari and mungbean. In each block, the farmers were given 3-5 crops to observe the performance of different rabi crops in their locality. Payment for non-rice crop inputs was made to 26,796 beneficiaries (maize-12,260, pulses-12,959 and sesame-1,577) to a land area of 17,914 acres (7,253 ha) in the rabi season 2010-11. We have collected yield and some agronomic information from the selected 5 upazilas of coastal Bangladesh and the results of the farmers' non-rice production practices are stated below:

Maize: Maize is relatively a new crop that was introduced in the southern part of Bangladesh. Like rice, it was grown in Barguna sadar, Patuakhali sadar, Jhalokhati sadar, Nazirpur and Kachua upazilas in the rabi season, 2010-11 (Photograph 4.4). The farmers were advised to grow hybrid maize (variety: Pacific-984) in the rabi season, 2010-11 to get higher production and to demonstrate its performance and adaptability in the coastal regions of Bangladesh. The farmers applied recommended doses of fertilizer and adopted integrated pest management approaches to cultivate the crop. Average yield of maize was 7.40 t/ha that varied from 5.73 to 8.26 t/ha (Table 4.6 and Figure 4.6).

During crop cutting, we have taken data on yield and some plant characters to document its performance in the coastal regions of Bangladesh. Plant population was almost homogeneous across the upazilas (Table 4.5). Mean cob length was 22.33 cm that varied from 20.15 to 23.60 cm and the average perimeter of the cob in the middle section was about 14.58 cm. Total grains per cob varied from 469.40 to 644.10 with an average of 567.34 grains per cob, 99% of which was found filled grains. Average weight of 1000 grains of maize was 326.83 gm that varied from 254.15 to 387.36 gm.

Mean production cost of hybrid maize was BDT 42,797 per ha that varied from BDT 33,591 to 40,109 per ha (Table 4.6). Overall benefit-cost ratio of hybrid maize cultivation in the coastal region of Bangladesh in the rabi season was 3.23 (varied from 2.10 to 3.98) indicated that its profitability is higher than boro rice cultivation. Production cost of maize was lower than that of boro rice, mainly because of less irrigation required in maize compared to rice; but yield and gross margin were almost similar. Therefore in water scarce areas like the coastal regions of Bangladesh, maize could an alternative option to be pursued in the rabi season for higher productivity and income.

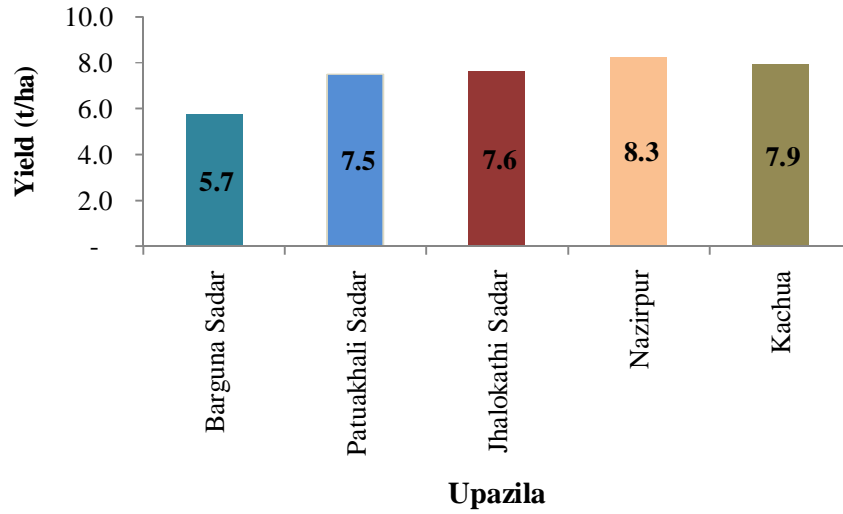


Figure 4.6 Yield of hybrid maize in the coastal regions of Bangladesh in the Rabi season of 2010-11.



Photograph 4.4 Hybrid Maize (variety: Pacific-984) cultivation in Patuakhali district in the rabi season, 2010-11 (BRAC Final Report of CIP, 2012).

Table 4.5 Yield and some plant characters of maize cultivated by the farmers in the coastal regions of Bangladesh in rabi season 2010-11 (average of 2 crop cuts per block).

District	Yield and some plant characters					
	Cob length (cm)	Grains per cob (no)	% of filled grains	Perimeter of cob (cm)	1000 grain weight (gm)	Yield (t/ha)
Barguna Sadar	20.15	597.05	97.65	12.70	254.15	5.73
Patuakhali Sadar	22.56	515.51	98.80	15.71	342.68	7.49
Jhalokathi Sadar	22.14	469.40	99.39	16.01	387.36	7.61
Nazirpur	23.60	644.10	100.00	14.60	337.62	8.26
Kachua	23.19	610.66	100.00	13.89	312.36	7.91
Mean	22.33	567.34	99.18	14.58	326.83	7.40

Source: Crop cut data from BRAC block demonstration from rabi 2010-11.

Table 4.6 Productivity and profitability of some rabi crops in the coastal regions of Bangladesh.

Crop	Yield (t/ha)	Production Cost (Tk/ha)	Gross Benefits (Tk/ha)	Benefit-Cost Ratio (BCR)
Maize	7.40	42,797	136,556	3.23
Sunflower	3.12	40,932	114,841	2.87
Mungbean	1.10	20,720	61,487	3.01

Source: Crop cut data from BRAC block demonstration from rabi season 2010-11

Sunflower: Like maize, the farmers were advised to grow hybrid sunflower (variety: Hi-Sun 33) in the rabi season, 2010-11 to demonstrate its performance and adaptability in the coastal regions of Bangladesh. The farmers of all the selected 5 upazilas cultivated sunflower. They applied recommended doses of fertilizer and adopted integrated pest management approaches to cultivate sunflower. Average yield of sunflower was 3.12 t/ha that varied from 2.50 to 3.57 t/ha (Table 4.7 and Figure 4.7).

Yield and some important plant characters of sunflower were recorded at harvest and are shown in Table 9. Overall plant population was 3.33 plants per m² that slightly varied from location to location, although the farmers were trained to use a spacing of

75 cm x 25 cm (the spacing was not strictly followed by the farmers). The average diameter of its flower was 22.10 cm, which varied from 18.50 to 26.47 cm. Such high variation was observed due to variable soil and management factors such as timely application of irrigation water and its quality as well. The number of seeds per flower varied from 988 to 1498, average of which was 1,295 seeds per flower, 98% of which was filled grains capable of producing oil. Average weight of 1000 sunflower seeds was 64.59 gm that varied from 58.83 to 69.50 gm. BRAC did not measure the oil content of sunflower but some farmers extracted oil by using locally available mustard oil extraction machine. They reported that the oil content of the sunflower was about 40% that has attracted the farmers to cultivate sunflower in the rabi season.

Production cost of sunflower was more or less similar across the upazilas, average of which was BDT 40,932 per ha (varied from BDT 32,810 to 49,216 per ha) (Table 4.6). But both the gross income and benefit-cost ratio varied considerably. The main reason for such variation was mainly due to the variable market price of this uncommon/new commodity. The gross income varied from BDT 95,867 to BDT 138,332 per ha, average of which was BDT 114,841 per ha. Overall benefit-cost ratio of sunflower cultivation in the coastal region of Bangladesh in the rabi season was 2.87 (varied from 2.26 to 3.89). It was observed that many farmers extracted oil from sunflower seed using the traditional oil extraction mills used to extract oil from mustard. Some farmers observed to sell sunflower oil in the local market; the price was similar to soybean oil. Although the market is not developed for sunflower, both gross income and benefit-cost ratio indicated that the crop is profitable even in an uncertain market situation. Therefore, sunflower can be adopted as rabi crop in the water-scarce coastal regions of Bangladesh for not only to meet-up edible oil requirement, but also for higher farm income and also to save foreign currency by reducing import of edible oil. BRAC has undertaken a pilot study to popularize sunflower and to develop local market for this crop, has established a mill for oil extraction (Photograph 4.5).

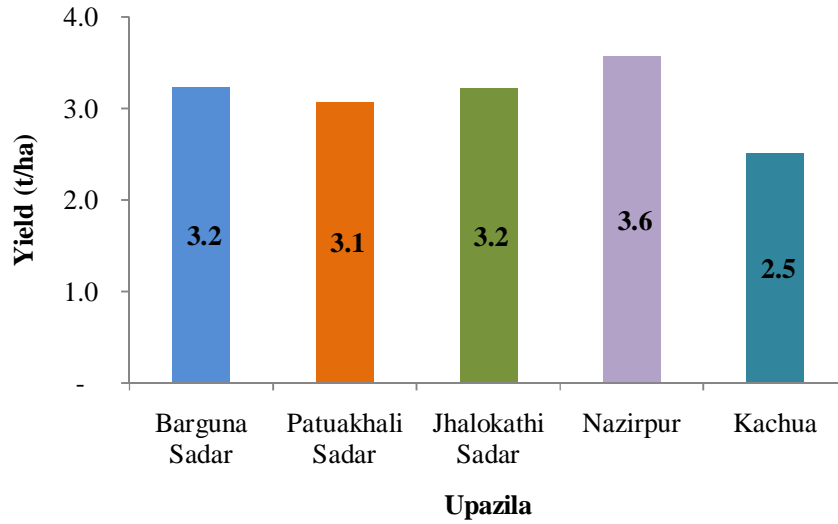


Figure 4.7: Yield of hybrid sunflower (Hi-Sun 33) in the coastal regions of Bangladesh in the Rabi season, 2010-11.



Photograph 4.5 Hybrid sunflower (variety: Hi-Sun 33) cultivation in Jhalokathi district in the rabi season, 2010-11 (BRAC Final Report of CIP, 2012).

Table 4.7 Yield and some plant characters of sunflower cultivated by the farmers in the coastal regions of Bangladesh in rabi season 2010-11 (average of 2 crop cuts per block).

Upazila	Yield and some plant character				
	Flower diameter (cm)	Seed per flower	% of filled seeds	1000 seed weight (gm)	Yield (t/ha)
Barguna Sadar	23.83	1,498.00	94.66	69.50	3.23
Patuakhali Sadar	19.23	1,233.79	97.65	67.83	3.07
Jhalokathi Sadar	18.50	1,271.35	99.53	66.50	3.22
Nazirpur	22.45	988.50	99.01	60.30	3.57
Kachua	26.47	1,485.83	98.61	58.83	2.50
Mean	22.10	1,295.49	97.72	64.59	3.12

Source: Crop cut data from BRAC block demonstration from rabi season 2010-11

Mungbean: Mungbean is not a new crop in the coastal regions of Bangladesh. A small section of the farmers in Barisal region cultivate this crop after the harvest of aman rice by ploughing lands when soil moisture reached to about field capacity. They cultivate mostly traditional varieties, the yield of which is very low (about 500 kg/ha). BRAC has introduced a modern high yielding variety developed by the Bangladesh Agricultural Research Institute, BARI Mung6, popularly grown in other parts of the country to cultivate it in the Rabi season of 2010-11. Like other rabi crops, most of the participatory farmers applied fertilizer at the recommended rate to grow mungbean.

Yield and a few plant characters of mungbean at the time of harvest are summarized in Table 10. The pod length of mungbean varied from 7.13 cm to 8.69 cm with an average value of 8.0 cm. Mean effective grains per pod was 10.01 that varied from 7.71 to 12.13, more than 84% of which was mature grain.

Yield of mungbean in different upazilas are presented in Figure 4.8 and Table 4.8. Average yield of mungbean was 1.10 t/ha, much higher than the traditional harvest (almost double). Mungbean produced the highest grain yield in Barguna sadar upazila (1.15 t/ha) followed by Kachua (1.14 t/ha), Nazirpur (1.13 t/ha), Jhalokathi Sadar

(1.08 t/ha) and Patuakhali sadar (1.02 t/ha). Although the variation in production was not significant, the lowest yield was obtained by the farmers of Patuakhali sadar upazila. Such yield difference was observed due to differences in management practices followed by the farmers and may be due to variation in residual soil moisture or water logging conditions occurred owing to tidal flooding. Both production cost (av is BDT 20,720 per ha) and gross income (av is BDT 61,487 per ha) of mungbean was about half of those of maize and sunflower and its cultivation seems profitable (BCR = 3.01) in the coastal regions of Bangladesh (Photograph 4.6).

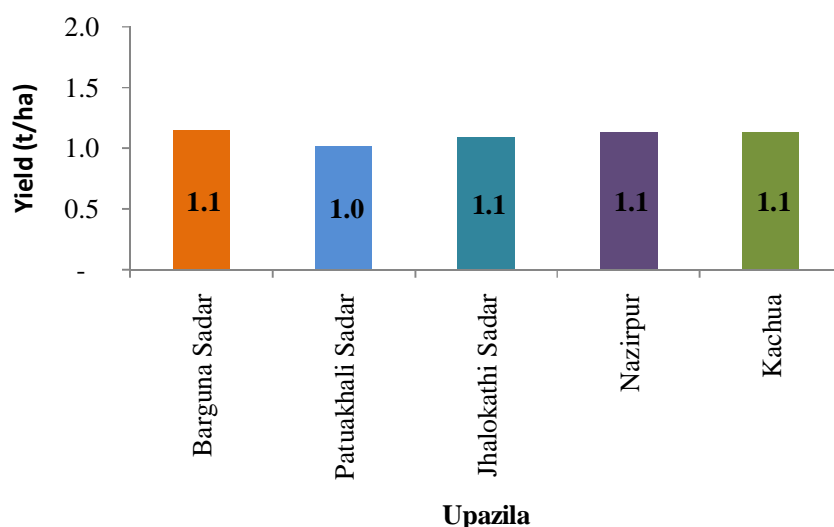


Figure 4.8 Yield of mungbean (BARI Mung6) in the coastal regions of Bangladesh in the Rabi season, 2010-11.

Table 4.8 Yield and some plant characters of mungbean cultivated by the farmers in the coastal regions of Bangladesh in rabi season 2010-11 (average of 2 crop cuts per block).

District	Yield and plant character				
	Pod length (cm)	% filled grains	Grains per pod	1000 grains weight (gm)	Yield (t/ha)
Barguna Sadar	8.34	70.97	11.98	47.60	1.15
Patuakhali Sadar	8.53	80.88	12.13	35.00	1.02
Jhalokathi Sadar	7.13	81.58	7.71	37.95	1.08
Nazirpur	7.33	100.00	7.88	40.83	1.13
Kachua	8.69	100.00	10.35	37.14	1.14
Mean	8.00	84.03	10.01	39.70	1.10

Source: Crop cut data from BRAC bloc demonstration from rabi season 2010-11



Photograph 4.6 BARI mung 6 cultivation in Jhalokathi district in rabi season 2010-11 (BRAC Final Report of CIP, 2012)

4.5 Productivity and profitability of different cropping patterns: The most common cropping practice of the farmers in the coastal regions of Bangladesh is to grow single aman rice under rainfed condition. Some farmers in Barisal region cultivate either aus rice before aman season or kheshari and/or mungbean after the aman season. But most of the farmers in Khulna region cultivate only aman rice in a year. In most cases, the farmers of both Barisal and Khulna region cultivate low-yielding traditional rice in the aman season. As a result they could not produce enough rice to meet up their food requirements. Moreover, frequent visit of natural disasters in the recent years has made their food security more vulnerable.

BRAC, with the financial assistance from the European Union has taken up the crop intensification project to equip the farmers of the vulnerable coastal regions of Bangladesh with the most appropriate and productive agricultural technologies to improve their food availability and income and to reduce their food insecurity and vulnerability through development of year-round cropping practices by utilizing available resources they have in and around their farms. Water is the key element in this endeavor. Therefore based on the availability of the water resources, BRAC has

identified four cropping patterns in participation with the farming communities and local agricultural extension providers of the Government of Bangladesh and has organized participatory demonstration of those patterns in block approach (block means a contiguous area of 10-20 ha of 50-60 farmers' land) in Kachua, Barguna sadar, Jhalokathi sadar, Patuakhali sadar and Nazirpur upazilas (Table 4.9). Although Kachua upazila (Bagerhat district) is in Khulna division, availability of water resources in this upazila almost match with the districts of Barisal division; and the demonstrated cropping patterns were the same in this upazila as in different upazilas of the Barisal division.

Table 4.9 Developed and demonstrated cropping patterns in the coastal regions of Bangladesh.

Pattern no	Cropping Patterns	Demonstrated Districts
1	Rice-Rice-Rice	Bagerhat (Kachua) Barguna (Barguna Sadar) Jhalokathi (Jhalokathi Sadar) Patuakhali (Patuakhali Sadar) Pirojpur (Nazirpur)
2	Rice-Rice-Maize	
3	Rice-Rice-Sunflower	
4	Rice-Rice-Mungbean	

Source: Crop cut data from BRAC block demonstration from rabi season 2010-11

Since water is the most critical factor for crop production and is very true for the coastal regions of Bangladesh. Soil salinity is also a determining factor for crop intensification, but its effects can be overcome when fresh or relatively non-saline water is available. For this reason all the developed and demonstrated cropping patterns cannot be adopted by the farmers for higher productivity across the coastal regions of the country despite of higher economic return of all the demonstrated cropping patterns. Benefit-cost ratio of the demonstrated cropping patterns varied from 2.61 to 2.79 (Table 4.10), which is quite acceptable for adoption of agricultural technologies.

The most appropriate cropping patterns that the farmers could adopt for improving their food security and livelihoods are shown in Table 12. The farmers of Kachua, Barguna sadar, Jhalokathi sadar, Patuakhali sadar and Nazirpur upazilas could get an

annual production of 12-18 t/ha by adopting (a) Rice-Rice-Maize, (b) Rice-Rice-Sunflower and (c) Rice-Rice-Mungbean patterns in Aus, Aman and Rabi seasons. Water resources in these districts are favourable for three crop cultivation (two rice and a rabi crop). By investing an amount of BDT 94,600-116,700 per ha in a year, the farmers could get an annual income of BDT 249,700-324,800 per ha (Table 4.10).

There are some areas in Barisal division where three rice crops can be cultivated by utilizing rainfall and river water. The farmers could get an annual production of about 18.0 t/ha by investing about BDT 120,000 per ha per year. With such investment they can earn about BDT 316,000 per ha annually (Table 4.10). Although, three rice crops need 14 months to grow from seed to seed, the farmers have developed techniques to grow three rice crops in a year. They used about 7% of their land for raising seedlings and kept reserved for raising seedlings only (that needed about 3 months per year). Field duration of three rice crops thus reduced to about 11 months leaving 1 month for land preparation (10 days turn around period between crop seasons). Thus the farmers were able to accommodate three rice crops in their land and able to harvest about 18.0 t/ha per year.

But the most promising rabi crop could be adopted in the coastal regions of Bangladesh is sunflower owing to its salt tolerant and drought resistance ability. The farmers of the coastal regions of the country have shown interest in cultivating sunflower to meet up their edible oil requirement. Those who cultivated this crop in the rabi season 2010-11, extracted oil from sunflower seed by using traditional mustard oil extracting mills available in the localities. It was reported that the farmers have used a portion of sunflower oil for their home consumption and have sold a portion in the local market at the prevailing market price of soybean oil. Seeing the success, BRAC has taken up a pilot study to popularize sunflower in the coastal regions of Bangladesh and to develop local enterprise (oil mill) for oil extraction from sunflower. The cropping pattern, Rice-Rice-Sunflower, produced a gross annual income of about BDT 303,000 per ha as against the annual production cost of about BDT 115,000 per ha. The benefit cost ratio of this pattern was 2.64.

Table 4.10 Profitability of different cropping patterns in the coastal regions of Bangladesh.

Cropping Pattern	Cash cost (BDT/ ha)				Gross Return (BDT/ha)				BCR
	Aus	Aman	Rabi/Boro	Total	Aus	Aman	Rabi/Boro	Total	
Rice-Rice-Rice	40,167	36,964	45,628	122,759	93,839	110,664	127,538	332,041	2.70
Rice-Rice-Maize	40,255	34,580	42,797	117,632	99,291	92,473	136,556	328,320	2.79
Rice-Rice-Sunflower	40,674	33,918	40,932	115,524	96,127	93,469	114,841	304,437	2.64
Rice-Rice-Mung bean	40,678	32,976	20,720	94,374	94,450	90,333	61,487	246,270	2.61

Source: Crop cut data from BRAC block demonstration from rabi season 2010-11

4.6 Livelihoods Improvement

The Eusuf and Associates (2012) has evaluated the activities of the BRAC project and submitted an evaluation report to BRAC. Based on the evaluation report of the consulting firm, the outcome level on the cropping intensity, varietal improvement, net income of the beneficiaries, availability and utilization of food etc are summarized as below.

Increasing the cropping intensity was the prime objective of the project as a means of improving the total productivity to ensure food security of the cyclone affected farm households. Evaluation study found that the cropping intensity considerably increased due to the project interventions. Before project intervention single, double, and triple crop lands were respectively 29%, 64%, and 7% in the blocks. During the project the farmers were motivated to cultivate the land 2-3 times a year. As a result, while evaluation was done, no land was found has single crop with the blocks, rather about 20% and 80% lands were used for double and triple crops, respectively. The cropping intensity was estimated to be about 178% before the project intervention and increased up to 280% during the project implementation.

The evaluation study noted a major shift of crop variety from local to improved varieties. Several new crops varieties have been introduced as part of the project interventions under the project. As a result, cultivation of the same land in three crop season in a year has been possible. For that total cropped area and the total yield has been increased resulted increased production, developed resilient agriculture and ensured food security. Some local varieties are extinct from the existing blocks. Production per unit area has been increased up to 250% in case of cultivation with hybrid rice variety Alloran compared to common local variety (Godaila, Moinamati etc.).

The project intervention not only brought back the farmers in proper cultivation practices and recovered the degraded lands but also ensured higher yields and production compared to the past. Farmers lost interest to cultivate local variety which has low yield and longer growth duration and also subjected to various risks. The same pieces of land are used for cultivation of high yielding variety(s) and hybrid

seeds again and again year round increasing cropping intensity, larger cropped area, higher yield and increased total production with higher income. Therefore, the production is increased several times compared to the farmers' traditional cropping practices in the past. The framers are cultivating a number of new high value and high yielding crops and are getting higher benefit per unit of area and per unit of time, proving sufficient resilient to climatic hazards. The farmers generally cultivated local variety of paddy once or at best twice in a year before project intervention. Before project intervention, it was hardly found any farmer cultivated vegetables and other high value rabi crops whose return might have been much higher than rice cultivation. But after the project implementation, many of the farmers became interested to grow non rice crops like oilseeds, pulses, vegetables and other high value crops and have been able to earn more income from the same pieces of land.

During the project evaluation it has also been observed that all respondents reported about their net income per bigha has been increased over their earlier income. Study estimated average gross income of the farmers of existing blocks and found that the gross income has increased from BDT 88,157 to BDT 216,226 per acre indicating an increase of 245% due to the project intervention.

The study assessed overall availability of different essential foods such as rice, edible oil, vegetables, pulses, egg, fish and milk in the beneficiary households. It is found that while only 35% beneficiary households reported availability of these foods round the year in their households before the project but after the project 87% beneficiary households have these foods available in their house year the round. This indicated increased access to essential food due to the project. The study noted slight improvements of food intake in the beneficiary households during the project due to increased income indicating better nutritional standards. Intake of different food items like rice, vegetables, pulse, milk, fish, meat, egg, fruit, sweets, tea, biscuits, curds, and cakes has increased due to better income of the households.

The key findings came out from the impact evaluation process are stated below:

- Agriculture rehabilitation through increasing cropping intensity and changing cropping pattern by introducing suitable crop varieties is an effective and

sustainable strategy for mitigating damages from cyclone and other natural calamities and disasters.

- Many hybrid and HYV varieties of crops grown in plain lands that are also suitable in the selected coastal area. However, introduction of special varieties that are saline tolerant and strong enough to stand to cyclone and tidal surge are needed in coastal areas.
- High value crops offer higher returns in short period and grow well in the coastal areas during rabi season and offer supplementary income.
- Block based cultivation of crops by well organized groups with similar categories of farmers may bring successes with minimum risks and failures.

Annual Income: Evaluation study survey data on income of beneficiary households indicated that all beneficiary households are poor. Average annual household income per year was BDT 55,504 before the project intervention with an average 4.93 members per household and BDT 31 per capita per day which is much less than \$1. Only 1% beneficiary households had income above poverty level income of \$1 per capita per day before the project which slightly increased to 11% households after the project. Therefore, the project targeting the beneficiary was proper and rightly focused on poverty. Household annual income is presented in Table 4.11 and Figure 4.9.

Table 4.11 Annual Income of Beneficiary Households

Annual Income (Taka)	Before Project		During Project		After Project	
	HH	%	HH	%	HH	%
1201-6,000	0	0	0	0	1	0.4
6,001-12,000	5	1.9	3	1.2	3	1.2
12,001-18,000	1	0.4	0	0	1	0.4
18,001-24,000	12	4.6	6	2.3	1	0.4
24,001-30,000	20	7.7	8	3.1	6	2.3
30,001-42,000	55	21.2	33	12.7	32	12.3
42,001-60,000	84	32.3	74	28.5	66	25.4
60,001-80,000	67	25.8	74	28.5	67	25.8
80,001-100,000	12	4.6	43	16.5	45	17.3
100,001-115,000	1	0.4	5	1.9	10	3.8
115,001-150,000	2	0.8	13	5	27	10.4
Above 150,000	1	0.4	1	0.4	1	0.4
Av. Annual Income	55,503		65,965		71,211	

Source: Eusuf and Associate (2012), Evaluation Report of CIP.

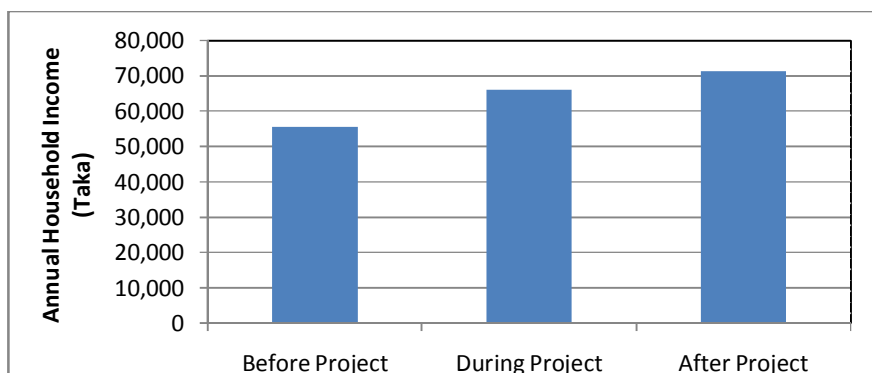


Figure 4.9 Annual Income of Beneficiary Households

Average Annual Household Expenditure and Savings: The evaluation study survey assessed annual expenditure and savings of the sample beneficiary households. Average annual expenditure of the sample beneficiary households increased from BDT 51,883 to BDT 68,408 between the period of before and after the project. Increase in the year of 2010 and 2011 was 16% per annum. The annual increase was little higher than the annual average inflation rate in Bangladesh during the same period. Therefore under the condition of income and expenditure it is unlikely that the beneficiaries have saved money during critical period. Household expenditure is in Table 4.12.

Table 4.12 Annual Family Expenditure of Beneficiary Households

Sl. no	Annual Expenditure (Taka)	Before Project		During Project		After Project	
		HH	%	HH	%	HH	%
1	6,001-12,000	3	1.2	4	1.5	3	1.2
2	12,001-18,000	1	0.4	0	0	0	0
3	18,001-24,000	8	3.1	3	1.2	2	0.8
4	24,001-30,000	14	5.4	9	3.5	6	2.3
5	30,001-42,000	69	26.5	45	17.3	35	13.5
6	42,001-60,000	86	33.1	83	31.9	88	33.8
7	60,001-80,000	71	27.3	72	27.7	56	21.5
8	80,001-100,000	7	2.7	33	12.7	51	19.6
9	100,001-115,000			3	1.2	7	2.7
10	115,001-150,000	1	0.4	8	3.1	11	4.2
11	Above 150,000	0	0	0	0	1	0.4
Average Annual Expenditure		51,882		61,333		68,407	

Source: Eusuf and Associate (2012), Evaluation Report of CIP.

Productive Assets in Beneficiary Households: During the survey two data sets on household assets were collected – productive asset and non-productive assets. The productive assets including low lift pump (LLP), power tiller, paddle thresher, harvester, weeder, hand sprayer, power sprayer, rickshaw/van, boat, bicycle, motorcycle, cow, buffalo, goat, sheep, ducks/poultry, mobile phone and others. Average value of productive assets has increased about 22%. Details of productive assets are in Table 4.13.

Table 4.13 Assets of Agricultural Production of the Project Beneficiaries

Sl. no	List of productive assets	Before Project		After Project	
		No. of assets	Average value	No. of assets	Average value
		owned	Per assets (BDT)	owned	Per assets (BDT)
1	Low lift (LLP)	23	10,469	38	13,173
2	Power tiller	13	41,353	24	47,041
3	Thresher	18	5,138	20	5,087
4	Harvester	493	88	622	106
5	Weeder	295	114	349	116
6	Hand sprayer	31	1,420	94	1,264
7	Mech. Sprayer	12	717	17	688
8	Rickshaw/Van	15	3,653	21	5,252
9	Boat	13	4,307	15	3,866
10	Bicycle	75	2,728	75	2,654
11	Motorcycle	2	53,500	3	113,333
12	Cow	501	10,442	553	11,884
13	Buffalo	19	12,052	17	7,735
14	Goat	162	1,638	204	1,721
15	Ducks/poultry	1902	153	2,466	199
16	Mobile phone	127	2,704	233	2,215
17	Others	2	28,500	61	1,434
	Average HH asset		178,976		217,768

Source: Eusuf and Associate (2012), Evaluation Report of CIP.

4.7 Technology dissemination: BRAC has organized fields days synchronizing with the crop harvest in aus, aman, boro and rabi seasons; invited the neighbouring farmers (both husband and wife), government administrators and policy makers, GO-NGO extension providers, local leaders, social workers and mass media people for wider dissemination of the new and year-round farming technologies in order to achieve food security combating the adverse effects of climate change and also to highlight

EU's contribution in household food security for the cyclone victims of Bangladesh. The participants were selected in consultation with the Department of Agricultural Extension and local elites. BRAC has undertaken a unique technology dissemination approach in which they included both husband and wife with the aim of putting demonstrated year-round cropping technologies inside two heads in a family, storming of which may find ways to increase productivity and income, and may lead to ensure household's food security. The women participants have shown keen interest on higher food production in order to satisfy food requirements of their families. In total, 48,680 farmers (male and female) were invited to attend in different crop cutting sessions in the selected five upazilas (Table 4.14), some farmers were invited 2-3 times to show them the possibilities and profitability of year-round crop cultivation in their localities so that they can plan for to cope up with the adverse effects of climate change. Among them 36,680 farmers attended field days at least once and 12,000 farmers attended 2 to 3 times. The neighbouring farmers discussed crop production and protection related issues with the beneficiary farmers to learn more about the benefits of different crops and cropping patterns. Most of the neighbouring farmers showed their keen interest on rabi crops, as these were cultivated for the first time in their localities in the dry season, when most lands remain fallow. They had interactions with the beneficiary farmers and learned about the cultivation procedures, productivity and profitability of different rice and rabi crops grown in their locality. Besides, a total of 2,162 personnel from both GO, NGO and civil societies were attended in different crop cutting sessions, who are engaged in providing extension services and in policy formulation of the government. Thus, this approach is expected to help technology dissemination and sustainability of the outcome of BRAC's intervention in agricultural technology development and dissemination and development of climate resilient agriculture in the coastal regions of Bangladesh.

Table 4.14 Categories of participants attended different field days.

Upazila	Neighbouring Farmer	Policy Makers and Extension Providers						Total
		Govt. Official	Agriculture Extension	NGO	Mass Media	Elite	Total	
Barguna Sadar	10,430	36	134	280	20	129	599	11,029
Patuakhali Sadar	9,402	29	137	147	61	128	502	9,904
Nazirpur	9,890	15	130	60	76	35	316	10,206
Jalokathi Sadar	9,124	33	126	192	41	90	482	9,606
Kachua	9,834	25	111	108	-	19	263	10,097
Total	48,680	138	638	787	198	401	2,162	50,842

Source: BRAC Final Report of CIP, 2012

CHAPTER 5

CONCLUSION AND RECOMMENDATION FOR FURTHER STUDY

5.1 Conclusion

Climate change is not only an environmental concern but also a development concern for Bangladesh. This means that climate change as an issue must come out of the environmental problem to take centre stage as major development problems. Soil salinity is a worldwide problem; Bangladesh is no exception to it. In Bangladesh, salinization is one of the major natural hazards hampering crop production. Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degrees of salinity. Agricultural land use in these areas is very poor. Declining land productivity with shift towards negative nutrient balance is among the main concerns with food security problem in the country. Salinity problem received very little attention in the past. Increased pressure of growing population demand more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops. Thus combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy. Vulnerability within the coast is again spatially and temporally different. People at those vulnerable areas require adaptations to these consequences of climate change so that they do not have to move away from their homes. Necessarily adaptation tools are urgently needed for these vulnerable communities. One aspect of climate change is that though unstoppable, it is still likely to be slow in its manifestations. Improvement in the crop-based weather and flood forecasting systems, early warning system, improving drainage, cultivating adaptive crops, developing technology for floating bed agriculture, rice and fish culture and organized fisheries, etc. are some of the options for water logged areas. The impact of climate change on agriculture is undeniable and will most certainly worsen if governments and donors fail to take suitable steps right now. Bangladesh urgently needs support to develop climate-resilient agriculture for its people to survive and prosper in the long term.

BRAC's crop intensification report submitted to the European Union revealed that the cropping intensity increased from 178% to 280% due to the project intervention (Evaluation Report, Eusuf and Associate, 2012). Major varieties shift from local to improved high yielding crop varieties. Several new crops were introduced. Average yield has increased due to varietal improvements. Crop yield increased up to 250% in case of hybrid paddy (Alloran) in comparison with other local (Godaila, Moinamati) varieties. We found in the report that agriculture rehabilitation through increasing cropping intensity and changing cropping pattern by introducing suitable crop varieties can be one of the most effective and sustainable strategy for mitigating risks of crop failure in cyclone and other natural calamities and disasters. It is proved that cultivation of land in blocks by a group of farmers may bring success with minimum risk and chances of failures.

Large scale block demonstration with active participation of the farmers is one of the effective approaches in disseminating the agricultural technologies in the farmers' field. From the meticulous demonstration it has been evidenced that year-round high yielding and hybrid rice cultivation through the very unique 'BLOCK' approach will be an effective means to assure food security, productivity and to disseminate effective technical knowledge of crop cultivation. The agriculture extension officers stated that BRAC's crop intensification project had been an effective means to teach local farmers about the proven ways to obtain optimal return from their land through cultivating HYV and hybrid varieties of rice and rabi crops. They asserted that block approach had been the key behind the colossal success of the project. They added that they would try to suggest the government to adopt block-based demonstration model and the strong monitoring and evaluation system of the project to improve food security under the threat of climate change. Through this approach BRAC has successfully disseminated improved crop cultivation in the coastal area.

Increasing the cropping intensity was the prime objective of the project as a means of improving the total productivity to ensure food security of the cyclone affected farm households. Evaluation study found that the cropping intensity considerably increased due to the project interventions. Before project intervention single, double, and triple crop lands were respectively 29%, 64%, and 7% in the existing old block areas.

During the project the farmers were motivated to cultivate the land 2-3 times a year. As a result, while evaluation was done, no land was found has single crop under the existing old blocks, where 20% and 80% lands were used for double and triple crops respectively.

The project intervention not only brought back the farmers in proper cultivation practices and recovered the degraded lands but also ensured higher yields and production compared to the past. Farmers lost interest to cultivate local variety which has low yield and longer growth duration and also subjected to various risks. The same pieces of land are used for cultivation of high yielding varieties year-round for higher yield and increased cropping intensity, and increased total production with higher income. Adoption of year-round cropping reduces the risks and food vulnerabilities of the farming communities in the coastal regions of Bangladesh.

The study assessed overall availability of different essential foods and noted improvements of food intake in the beneficiary households during the project due to increased production and income indicating better nutritional standards. The measures should be taken to increase crop intensity and productivity of crops is summarized below:

5.2 Recommendation for further study

Some Policy Recommendations are given below based on research findings:

- **Dissemination and Extension of Climate Resilient Agricultural Adaptation Options:** Block farming year-round crop adaptation practices should be demonstrated to develop climate resilient agricultural systems and to reduce risks of food security. The viable adaptation options need to be tested and disseminated at pilot villages for their acceptance. More study is needed for making location-specific production plan for developing climate resilient coastal agriculture based on soil-crop-climate suitability through proper assessment of soil and water related constraints, climate risks and socio-economic problems presently affecting crop production systems and livelihood of the vulnerable people of the coastal region.

- **Water management infrastructures development and management:** Water resources management infrastructures such as protective embankment, proper sluice gate, canal excavation and re-excavation inside coastal polders for improved drainage systems and for conservation of rainfall and fresh river water for irrigation in the dry season is necessary for adopting climate resilient agriculture and in turn food security of the coastal community. Therefore, water management infrastructures should be developed and maintained the existing structures focusing on the consequences of climate change and agricultural requirements.
- **Adoption of stress-tolerant crops:** Salinity, submergence and drought tolerant crops should be introduced to develop climate resilient agriculture and also to reduce the risk of crop damage and improve food security and livelihoods of the coastal communities of the country.
- **Capacity building:** The farmers and the agricultural extension personnel should be trained on improved, innovative and climate resilient adaptation practices for wider dissemination of the technologies for food security of the expanding population.
- **Encourage Women Involvement in Agriculture:** The participation of women in homestead farming, seed production & preservation, compost making, agro-processing, fish and livestock production in the homestead areas should be encouraged to further improve the climate resilience of the coastal communities of Bangladesh.
- **Marketing infrastructures development:** Road network, marketing infrastructures and agro-processing facilities should be developed for ensuring price of the farm produce and also for fare access of the agricultural input.
- **Coordinated Actions for Continuous Adaptation** –Adaptation to reduce the vulnerability of agriculture and allied sectors to the impacts of climate change requires coordinated actions, proper planning, financial resources for implementation and community involvement for improving coastal agriculture.

5.3 Limitations of agricultural development of coastal region

The agricultural development in the coastal saline belt is constrained by various physical, chemical, economic, social and natural factors. In general, the major constraints identified that impede agricultural development in the coastal belt are as follow:

- The main constraint is the scarcity of quality irrigation water especially during dry season limits cultivation of boro rice and rabi (winter) crops.
- Soil salinity is the most dominant limiting factor in the region, especially during the dry season. It affects certain crops at different levels of soil salinity and at critical stages of growth, which reduces yield and in severe cases total yield is lost. A substantial area of land is tidally affected by saline water. Appropriate management practice for crop production in this area is not available.
- Fertility status of most saline soils range from low to very low in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper. The crop yields obtained in these soils are also low.
- Variability of rainfall, uncertain dates of onset and recession of seasonal floods and risk of drought restrict cultivation of aus and aman rice. Uncertain rainfall delays sowing/transplanting and flood damages aus and aman crops. Heavy monsoon rainfall causes delay in transplanting of aman and sometimes it completely submerged the standing crop.
- Narrow technological and germplasm bases for salt tolerant crops limit crop choices. On the other hand, due to extensive cultivation of a particular cultivar of crop year after year makes the crop susceptible to pests and diseases attack. Pests and diseases like leaf-hopper and tungro virus are prevalent in the region that may cause extensive damage.
- In the coastal saline belt with short winter season timely sowing/planting of rabi (winter) crops is essential but this is restricted by late harvest of aman rice and consequently higher soil moisture. Presence of saline groundwater

throughout the year within 1.0 meter depth is another factor affecting crop production in the saline belt.

- The texture of most of the saline soils varies silt clay to clay. Land preparation becomes very difficult as the soil dries out. Deep and wide cracks develop and surface soil becomes very hard. These also necessitate deep and rapid tillage operations.
- Perennial water-logging due to inadequate drainage and faulty operation of sluice gate facilities restricts potential land use of the low lands within the polder areas.
- Lack of appropriate extension programs for diffusion of modern technologies. Extension personal trained in saline soil management in also inadequate. This lacking retarded adoption of HYV technologies.
- Large land ownership and unfavorable land tenure systems and dominance of absentee farmers hindered adoption of climate resilient modern technologies and cropping practices.
- Difficult communication and remote marketing facilities also retard agricultural development of the region.

The above factors are more or less common to most of the saline prone areas in the south of the country along the seacoast. Therefore, the above issues should be taken into consideration for wider adaptation of the resilient agricultural systems highlighted in this study.

5.4 Limitation of the study

I have used mostly secondary data from only 5 upazilas of the 5 coastal districts of Bangladesh, may not be sufficient for appropriate policy recommendation for overall development of the coastal regions of Bangladesh. More information from both primary and secondary sources and from more areas and more number of farmers might improve the contents of this thesis.

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APENDIX-1: Interview Guideline

Name of the Respondent:

1. Village: Union: Upazilla: Zilla:
2. Is there any deficiency of Vitamin?
3. What are the major diseases mostly affect in your family members?
4. In which season/time your family members mostly suffer from illness?
5. What are the major diseases that mostly affected in your family members last five members?
6. Who was mostly suffered /affected from illness among your family members (Male/ Female,Children)?
7. What are your comments about these diseases (high/ low than previous?)
8. What are the possible reasons of these diseases?
9. What are the hazards that affect your family members during last five years?
10. Which kind of health problem you faced/ suffered during Hazard period?
11. What was the source of drinking water during Hazard period?
12. What was the source of domestic (Cleaning, cooking, sanitary etc.) Water during Hazard (Flood, Drought, Cyclone) period?
13. Is water is available for safe drinking, cooking, sanitary purposes (sufficient/ in-sufficient)
14. Is there any health problem due to insufficient water for drinking and domestic purposes?
15. Which kind of measures you undertake/ whom you meet for treatment in case of such kind of illness?
16. Is doctor/ health worker mentioned the name of the diseases of your family members after met with them for treatment?
17. What is meant by “Climate Change”?
18. What kind of problems/ calamity created from Climate Change?
19. What kind of diseases affects mostly / may be affected in future during disaster?
20. Do you think that due to climate change people facing health problem in your area?

Name of the Interviewer:

Date: