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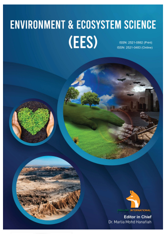

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RESEARCH ARTICLE

RESILIENCE OF AGRICULTURE FARMERS FOR CROP PRODUCTION IN RESPONSES TO CLIMATE CHANGE IMPACT ON SOUTH-EASTERN COAST OF BANGLADESH

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ABSTRACT

Coastal people of Bangladesh have been experiencing from lower crop productivity and fewer cropping intensity because of different climatic vulnerabilities. The research work was carried out in Banskhali upazila of Chattogram district and Teknaf of Cox's Bazar district to assess the impact of climate change on crop production process and to suggest suitable coping strategies and adaptation options for advancing the coastal agriculture for increased agricultural production. To attain the objectives of the research, the author were collected randomly 240 sampled respondents using pre-tested interview schedule. Long-term data/information on climate change showed that there is a trend of temperature rise and erratic rainfall. Participants stated that the current climate in the study area behaving differently than in the past on a number of climate risk factors like increased temperature, frequent drought, changes in seasonal rainfall pattern, long dry spells, increase of soil salinity, increase of tidal surges affecting crop production. The study showed that the main reasons of yield reduction (20-40 % yield loss) in *T. aman* crop are erratic rainfall, increased intensity and frequency of drought, salinity, floods, cyclone, use of local varieties, increased incidences of pests & diseases etc in the context of climate change. Average yield level of HYV Boro is being affected (20-40 % yield loss) by high temperature and salinity and that of *T.Aus*/Aus crop is being affected (20-40 % yield loss) by tidal surge. Vegetables, pulses and oilseed crops are being affected (40-60 % yield loss) by soil wetness, excessive rainfall and water-logging in the selected areas. Sorjan system of cropping, rice-fish dual culture, utilization of bunds as vegetables/spices production in gher areas, floating bed agriculture and homestead gardening with introduction of salt-tolerant & drought tolerant crop varieties have been identified as potential adaptation options for development of coastal agriculture for increased agricultural production in attaining food security.

KEYWORDS

Climate Change, Crop Production, Coastal Area, Adaptation, Coastal Agriculture

1. INTRODUCTION

Bangladesh still largely an agrarian country, 75% of its 161 million population lives in the village areas depending mainly on cultivation of field crops, vegetables, fruits, livestock, fisheries, labor selling, and small business. The total cultivable land of the country is only 7.9 million hectares. The south-central Barisal and south- western Khulna regions comprises of 21.6 % of Bangladesh mostly under the agro-ecological zone 14 called Ganges tidal floodplain. The population of these areas is more dependents on agriculture as industry is mostly absent, except a few numbers but the area is being recurrently battered by cyclone, tidal bore/surge and salinity due to its proximity to sea. Thus, poverty and food insecurity is a major concern in this region. The coastal zone covers 19 out of 64 districts facing or in proximity to, the Bay of Bengal, encompassing 153 upazilas.

A total of 48 upazilas/thanas of these districts are considered as "exposed" directly to vulnerabilities from natural disasters Bangladesh occupies a unique geographic location spanning a relatively short stretch of land between the mighty Himalayan mountain chain and the open ocean. It is virtually the only drainage outlet for a vast river basin complex made up of the Ganges, Brahmaputra and Meghna rivers and their network of tributaries. These rivers, which cause almost regular and serious floods over much of the country during the summer monsoons, are reduced seriously during the dry winter months. In Bangladesh, salinization is one of the major natural hazards hampering crop production. About 53% of coastal area is affected by different degrees of salinity. According to BARC, light 0.29, moderate 0.43 and high 0.12 million hectares land salinization was observed in Bangladesh which cost 586.75 million USD per year. According to the Global Climate Risk Index, Bangladesh is the most climate change vulnerable country in the world. Salinity affected soil increase 21% in last three decades in this region. Future changes of temperature and rainfall are estimated for Bangladesh and it was found from the observed data that the temperature is generally increasing in the monsoon season (June-August) (Ali and Hossain, 2019; Ahsan and Brandt, 2015; Barua et al., 2017; Barua et al., 2018; Barua et al., 2020).

Climate change is considered as the most critical global challenge of the

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century. It is predicted that global temperatures will increase further between 1.4 and 5.80 C by 2100. Sea level rise, polar ice melting, glacier melting, extreme weather events such as storms, floods, droughts and heat waves, changes in morphology, physiology, phenology, reproduction, species distribution, community structure, ecosystem and species evolutionary processes in marine, freshwater and terrestrial biological systems, change in crop production patterns, spread of infectious diseases and pests are some of the incidences likely to happen as a result of climate change (IPCC 2007; Barua et al., 2011; Barua and Rahman, 2017: Barua et al., 2017; Barua and Rahman, 2019: Barua et al., 2020).

Impacts of climate change on food production are global concerns, but it represent a particular threat for Bangladesh. Agriculture is already struggling mainly thanks to a rise in demand for food, also on depletion of land and water resources. The prospect of worldwide global climate change makes this problem a priority for Bangladesh. Climate change further threatens food security. Higher temperature and water stress thanks to heat would end in decline in vegetation and agricultural production.

The topography of the country, geographical position and climate changes over time cause natural disasters to be regular phenomena in Bangladesh. The social and economic activities of Delta communities are often affected by disasters, which are the most vulnerable regions of the country. The greatest devastation is often in the form of dynamic erosion and accretion in communities living in riverine island areas. These regions are known for their numerous natural and social hazards. They are known as cars. For example, carpenters lose significant amounts of usable land every year because of continuous erosion on the banks of the river. Apart from natural hazards, charity lives are hampered by poor communication structures that limit the equal access of care dwellers to the social and economic benefits of continental residents. The many charitable regions of Bangladesh, which forms around 5% of the total area of the Nation (7,200 km2) and of the population (6.5 million people), face these challenging conditions. The fact that in these regions people are often unable to migrate and find jobs on the mainland is just as challenging.

Climate change could result in the decline of agricultural production in many tropical and sub-tropical areas that already face food deficits, and could displace millions of people, decrease water availability and increase the spread of diseases such as Diarrhea, Malaria etc. More than 90% of all deaths caused by natural disasters were from droughts, floods and windstorms. In 1999, the US reported twice to thrice the number of disasters that happened in Bangladesh. Yet, in Bangladesh disasters caused 34 times more deaths than the US. Agrochemical use affects 25 million agricultural workers each year and kills hundreds of thousands. Global climate change is predicted to increase the risk of flooding in Bangladesh by 20% affecting especially poor people that currently live in flood plains. Developing countries in semi-arid zone are speculated to be particularly hard hit by reduced water availability resulting from global climate change. The average cost of natural disasters as a percentage of the GDP is 20% higher in low-income countries than in rich industrialized countries (Barua et al., 2017; Barua et al., 2018: Barua et al., 2020).

Bangladesh is a South Asian low-lying deltaic country which is highly vulnerable to climate change. Its agriculture sector contributes to around 11.7% of GDP and provides about 42.7% of labour force. Employment generation, poverty alleviation and food security are greatly impacted by the performance of this sector (BBS 2017). Over the last few decades, temperature has increased and rainfall has become erratic (pre-monsoon rainfall has decreased). If these trends of temperature and rainfall persist, wheat, boro (winter season) rice and other crops that are cultivated in the pre-monsoon season would be adversely affected (Hossain et al., 2017; Rahman et al., 2018b). The Ricardian analysis and simulation models also confirmed the negative impacts of increased temperature and erratic rainfall on crop productivity in Bangladesh (Abidoye et al., 2017; Mishra et al., 2015; Ruane et al., 2013). In addition to isolation and remoteness of rural coastal regions, several added calamities, such as salinity, floods, waterlogging, cyclonic storms and tidal surges, intensify their vulnerabilities (Bhattachan et al., 2018). Therefore, existing agricultural productivity is more climate-vulnerable in coastal areas (Chen et al., 2012; Dasgupta et al., 2018; Gopalakrishnan et al., 2019; Nahar et al., 2018).

In the midst of declining farm productivity, the best option for farmers is the adaptation to climate change because mitigation efforts can be beyond their capacity (Gopalakrishnan et al., 2019). Climate change will reduce the existing adaptive capacity, transform agriculture and worsen livelihood assets (Hossain et al., 2018; Huq et al., 2015; Rakib et al., 2019). Any transformations in farming activities require active participation of farmers. They are the first and most fundamental starting point of adaptations (Bozzola and Swanson, 2014). Adaptation behaviour (output) depends on how people perceive (input) the situation (Schlüter et al., 2017). Perception is a psychological process that yields a meaning and complete image of a phenomenon by subjective interpretation of gathered information (Kalat, 2016). Adverse climatic events (e.g. heatwaves, heavy rainfall and tropical cyclones) hamper farming activities that generate an impression among the local people. Observation and experience of such events in a repeated manner shape their perception of climatic impacts (Shameem et al., 2015). Farmers who experience climatic impacts through their daily activities would better perceive climate change and adaptations (Ahsan and Brandt, 2015). Thus, tacit and explicit local ecological and traditional knowledge plays a fundamental role in understanding the necessity of adaptations and improving the participation in adaptive actions taken by farmers, government and external agencies (Leonard et al., 2013; Nyong et al., 2007).

The IPCC estimates that by 2050 rice production in Bangladesh could decline by 8% and wheat by 32% (against a base year of 1990) due to higher temperature and higher CO2 concentration (IPCC, 2001). As Climate change is going to have worst impact on livelihood, mainly in agriculture sector of Bangladesh (accounting for about 35% of the GDP and engaging more than 63% country population), it is needed that special and immediate attention be paid to the sector to ensure food security and livelihood to a major portion of national population, which obviously is more vulnerable to adverse impacts of climate change (BBS, 2005). 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 Aus (summer rice), Boro (dry season rice and other rabi (dry season) crops are being restricted. There is dearth of research in the field to get the actual scenario of the problems. So, the researcher made an attempt to identify the real consequences of climate change in the coastal saline areas.

Farmers in the coastal areas of Bangladesh perceive that climate is changing (Hasan and Kumar, 2019a,b; Shameem et al., 2015). It is now important to understand how they perceive climatic impacts on farm productivity. On one hand, different climate-induced stresses (e.g. floods, droughts, coastal inundation and cyclones) can have seasonally differentiated effects on different farm practices. On the other hand, farmer perceptions can vary across their geographical locations, previous experience, availability heuristic and social locations (Foguesatto et al., 2018; Hasan and Kumar, 2019b; Kais and Islam, 2019). The social location of an individual farmer depends on a broad range of characteristics, such as personal, social, demographic and economic attributes (Henslin, 2017). It is difficult to model all necessary parameters that influence climate change impacts on farm productivity because of location specificity of impacts (Morton, 2007). Therefore, it is necessary to take account of affected communities' perception as a substitute to scientific knowledge. The local farmers can be considered as important sources of information to understand such impacts, since they have a recursive interaction with climatic stresses to form a basis of adaptive and social learning (Ensor and Harvey, 2015; Garai, 2017). Against the aforementioned background, this research aims to explore farmer perceptions of climate change impacts on farm productivity in the coastal areas of Bangladesh. This paper attempts to answer several questions using farmers' own opinions: what is the present status of farm productivity in different cropping seasons and locations? How has the farm productivity changed over the past decade? Is the decreased farm productivity (if any) caused by climate change? What are the factors that influence farmer perceptions of farm productivity change and perceptions of causes that decrease farm productivity? Answers to these questions are sparse and inadequate in the existing literature. Thus, this research would provide information necessary to identify gaps between farmer knowledge and scientific estimation of climate change impacts on farm productivity. Findings of this study would help planners, academicians and policy makers to recognize the group of farmers who need to be targeted to implement climate change adaptation strategies in the south-eastern coast of Bangladesh

2. Methodology

2.1 Study Area

In order to study the climate change patterns and effects in coastal saline regions, two upazila namely Teknaf upazila of Cox's Bazar district and Banskhali Upazila of Chattogram district in the south-eastern coastal region of Bangladesh were selected as the locale of the study (Figure 1).

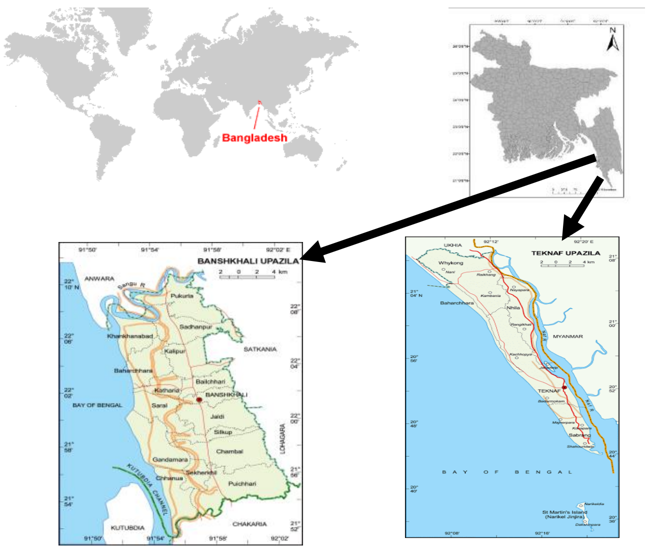

Figure 1: Geographical Location of the study areas

2.2 Sample size and sampling technique

Two Union from each upazila were selected randomly. A list of all farm households of the selected unions were collected from the concerned Upazila Agricultural Extension office with the help of Sub Assistant Agriculture Officers (SAAOs). From the list 240 farmers were selected (60 from each union) as a sample of the project following simple random sampling technique.

2.3 Data collection

Primary data were collected through an intensive household survey and through the application of different RRA (Rapid Rural Appraisal) tools such as focus group discussion, key informants' interview, crop calendar and direct field observation. Focus group discussions was conducted to crosscheck and generate information on farmers' experiences of climate change, problems in farming practices, their indigenous knowledge systems and the different adaptation measures adopted. Household surveys were conducted with structured interview schedule to gather detailed information on farmers' perception of climate change and on their adaptation measures.

2.4 Analysis of the data

Data collected from both meteorological stations and household survey was analyzed by using the Statistical Package for Social Science (SPSS) and Microsoft excel. Qualitative information such as farmers' experiences regarding climate change and adaptation measures taken on their farmland collected from key informants interviews and local level institution were analyzed manually, both by the researcher and in conjunction with the villagers, and interpreted in relevant chapters to complement and supplement the quantitative information collected from household interviews and the meteorological stations.

3. Results

3.1 Climate Change Scenario

Change of climate particularly temperature and rainfall of the study area was examined through analysis of long-term meteorological data base and perception of the local community respondents.

3.1.1 Evidence from database

The evidence of climate change over time were documented through analysis of long-term (1950-2010) climatic data of monthly temperature and rainfall to find out the trend of changes.

3.1.2 Trend of temperature

The findings of the long-term temperature data showed a steady increasing trend of both maximum and minimum temperatures over time (Figure 2-5). The study revealed that the increase in maximum temperature was more distinct than minimum temperature, while increment rate per year of maximum and minimum temperatures was 0.056 and 0.233°C at Chattogram whereas 0.002 and 0.305 at Cox's Bazar respectively. It was observed that the minimum temperature during winter season had been slightly decreasing (December-January), while it exhibited increasing trend in rest of the months of the years in both locations. These changes of temperature trend indicated that the study location gradually became warmer regardless of seasons. These changes might have influenced the pest and disease infestation as well as productivity of the vegetation both trees and crops of the locality.

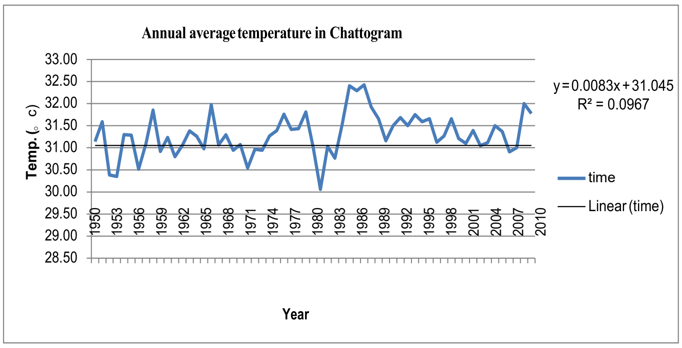

Figure 2: Long term (1950-2010) trend of annual average temperature in Chattogram

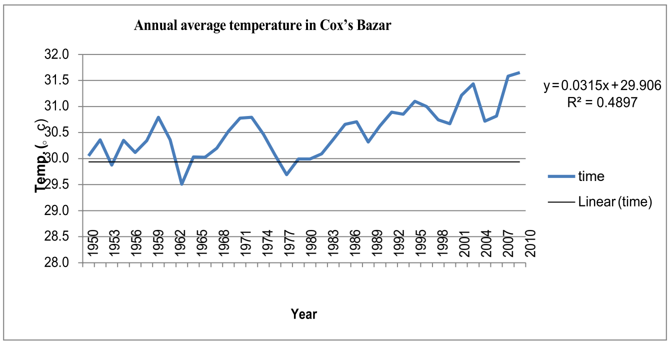

Figure 3: Long term (1950-2010) trend of annual average temperature in Cox's Bazar

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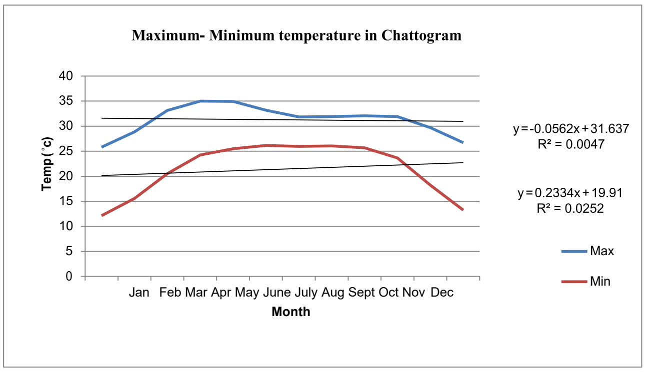

Figure 4: Long term (1950-2010) trend of maximum-minimum temperature in Chattogram.

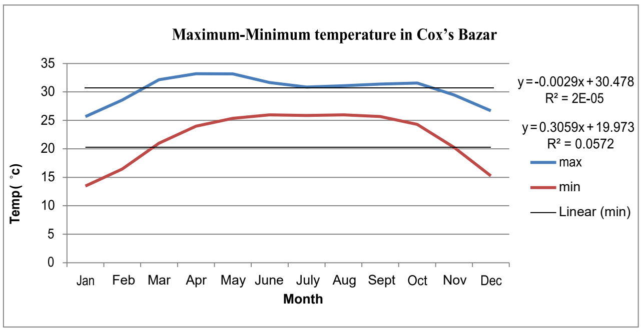

Figure 5: Long term (1950-2010) trend of maximum-minimum temperature in Cox's Bazar

3.2 Trend of rainfall and frequency of SPI

The analysis of long-term rainfall database reflected that change of rainfall pattern was not definite over seasons. The trend of annual rainfall indicated an increasing pattern in the study area and the increment rate was 354.7 mm in Chattogram (Figure 6) and 635 mm in Cox's Bazar (Figure 7) per three years. But there was sharp decreasing trend of annual rainfall has been recorded in both locations from 2007 to 2010 indicates that annual rainfall is decreasing in the recent year. This decreasing trend of annual rainfall hampered overall crop production in the selected study areas. Decreasing trend of winter season rainfall is associated with higher rate of increase in minimum temperature that might had hampered the growth of the vegetation (Wang et al., 2009). Subash and Mohan reported wide year-to-year variation in the monthly distribution of rainfall in Indo-Gangetic region (Subash and Mohan, 2011).

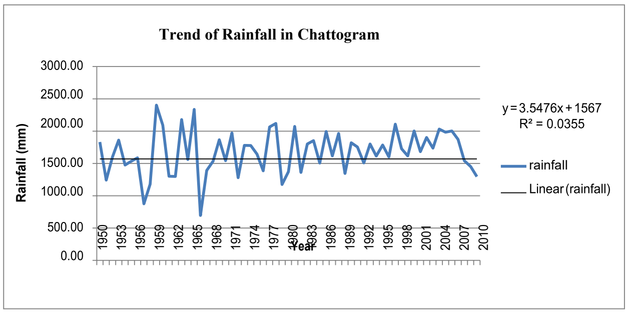

Figure 6: Long term (1950-2010) trend of annual total rainfall in Chattogram

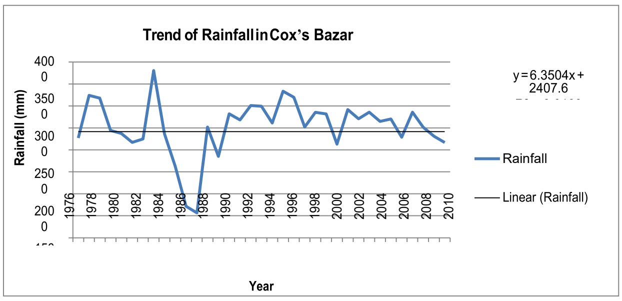

Figure 7: Long term (1950-2010) trend of annual total rainfall in Cox's Bazar

3.3 Farmer's Perception on Changes in Climatic Variables and Natural Hazard

The perception of the respondents on change of local climate and their important impacts over time (10 years ago) revealed that respondent's perceptions (Table 1) were almost similar to the evidences of climate change recorded from the meteorological database. Regarding the change of temperature over time, almost cent percent respondents opined that temperature had increased which was very consistent with the change of maximum temperature of meteorological database. Regarding rainfall intensity (precipitation), ground water availability and surface water availability almost cent percent respondents opined that the rainfall intensity had decreased over time which was very much consistent with the meteorological evidences. Regarding hotness, coldness, drought, fog and salinity, majority of the respondents opined that the intensity of these climatic variables had increased. Regarding flood and cyclone, majority of the respondents opined that the intensity of these two events became irregular. Though there was no evidence from database on frequency of above mentioned climatic components (hotness, coldness, ground water availability, surface water availability drought, fog, salinity, flood and cyclone) but this was confirmed by the respondents during FGD. However both meteorological database and respondents perception strongly support the change of climate over time and increasing trend of impacts of climate change. This location specific information is also in good agreement with national database (MoEF, 2010).

Table 1: Farmer's perception on changes in climatic variables and natural hazards in studied coastal areas

Climatic parameter	**Respondents perception (respondents opinion expressed as percent)**				
	Increased	**Decreased**	**Unchanged**	**Irregular**	**Total**
Temperature	93.33		-	6.67	100
Rainfall	-	100.00	-	-	100
Hotness	58.33	8.33	10.00	23.33	100
Coldness	43.33	8.33	16.67	31.67	100
Ground water Availability	-	91.67	-	8.33	100
Surface water availability	-	90.00	10.00	-	100
Flood	-	10.00	8.33	81.67	100
Drought	61.67	5.00	23.33	6.67	100
Salinity	81.67	-	18.33	6.67	100
Cyclone	16.67	8.33	13.33	61.67	100
Fog	68.33	8.33	11.67	15.00	100

3.4 Impact of Climatic Vulnerabilities on Crop Production

In order to identify vulnerable climatic variables affecting overall crop production, FGD was conducted with farmers, village leaders and schoolteacher of the study areas. Results of FGD has been presented in Table 2 and Table 3.

Table 2: Impacts of different climatic risk factors on crop production at Teknaf upazila of Cox's Bazar districts

Crop	**Climatic risk/ vulnerable factors**	**Severity of vulnerable factors**	**Crop yield loss/yield reduction (%)**
T. aman	Drought, salinity, flood	Moderate	20-40
Wheat	Temperature variation Late winter/short cold period	Severe	40-60 ,,
Maize	Drought Rainfall variation High wind	Severe Severe Severe	40-60 ,,
Potato	Temperature variation Late winter/short cold period Clayey soils Salinity	Severe Moderate Severe	40-60 ,, 20-40

Oilseed crops (mustard, ground nut)	Temperature variation Late winter/short cold period Clayey soils Salinity	Severe Severe Moderate Moderate	40-60 ,, ,, 20-40 ,,
Spice crops (chilli, onion, garlic)	Salinity Pests and diseases Soil wetness	Severe Moderate Moderate	40-60 20-40 ,,
Jute Sugarcane	Temperature variation High rainfall High wind	Severe Severe Severe	40-60 ,, ,,

Results of FGD showed that the main reasons of yield reduction (20-40 % yield loss) in *T. aus* crop are erratic rainfall, increased intensity and frequency of drought, increased salinity, tidal surges, floods, cyclone, use of local varieties, increased incidences of pests & diseases etc in the context of climate change. Similarly, average yield level of HYV Boro is being affected (20-40 % yield loss) by high temperature (causing sterility) and increased salinity and that of *T. aus* crop is being affected (20-40 % yield loss) by tidal surges. Vegetables, pulses, oilseed crops 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. But the people are to live with these climatic vulnerabilities and risks in the coastal region.

Table 3: Impacts of different climatic risk factors on crop production at Banskhali upazila of Chattogram district

Crop	**Climatic risk/ vulnerable Factors**	**Severity of vulnerable factors**	**Crop yield loss/yield reduction (%)**
Irrigated crops HYV boro	Saline ground water Unavailability of surface water Salinity, Pests and diseases	Severe Severe Moderate	40-60 ,, 20-40
T. aus	Water stagnancy/floods	Moderate	20-40
	Salinity	Moderate	,,
	Submergence	Moderate	,,
	Pests and diseases	Moderate	,,
T. aman	Floods/water stagnancy	Moderate	20-40
	Drought	Moderate	,,
	Changed timing of rainfall	Moderate	,,
	Pests and diseases	Moderate	,,
Wheat	Temperature variation	Severe	40-60
	Late winter/short cold period	Severe	,,
Maize	Drought	Severe	40-60
	Rainfall variation	Severe	,,
	High wind	Severe	,,
Potato	Temperature variation	Severe	40-60
	Late winter/short cold	Severe	,,
	period		,,
	Clayey soils	Moderate	,,
	Pests and diseases	Moderate	,,
Pulse crops	Heavy rain/excess moisture	Moderate	20-40
(khesari,	Soil wetness	Moderate	,,
mung bean,	Drought	Moderate	,,
soybean,	Salinity, tidal surges	Moderate	,,
cowpea)	Pests and diseases	Moderate	,,

Oilseed crops (mustard, sesame, ground nut)	Temperature variation Late winter/short cold period Clayey soils Salinity	Severe Severe Severe Moderate	40-60 ,, ,, ,,
Spice crops (chilli, onion, garlic)	Early rainfall Temperature variation Pests and diseases	Moderate Moderate Moderate	20-40 ,, ,,
Jute	Temperature variation	Severe	>60
Sugarcane	High rainfall	Severe	,,
	High wind	Severe	,,
Fruit crops	Salinity	Severe	.40-60
(papaya,	High wind	Moderate	,,
banana, water	Excessive rainfall	Moderate	,,
melon)	Pests and diseases	Moderate	,,

From household survey most vulnerable climatic factors were identified. Respondents perceived that temperature has increased over the years facilitates more pest/ disease infestation in different crops and duration of winter has been shortened affecting the potential growing period of winter crops. Increased intensity of soil salinity was perceived by the farmers as white crust of salts on soil surface and crop burning during drier months in the coastal areas. Presently, farmers are very concerned about climate change issues viz. erratic rainfall, temperature rise, short winter, intensity of drought, salinity, tidal surges, submergences, cyclone, tornadoes, flash floods, erratic rainfall etc. in crop production systems. Based on farmers' perception and farmers' response about climate change, most vulnerable crop specific climatic factors has been identified (Figure 8 -17).

3.5 Problem of T. aman rice production

Data presented in Figure 8 reveals that majority of the respondents in Chattogram districts opined pest and disease infestation, salt water and waterlogging were the major risk factors in T. aman crop. Whereas in Cox's Bazar tropical cyclone, pest and disease infestation and drought were the major risk factors in *T.aman* crop (Figure 9).

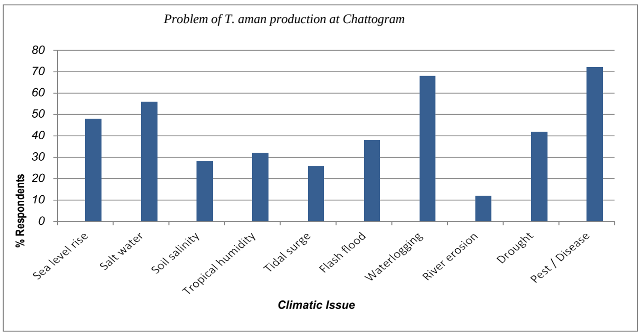

Figure 8: Farmers response on impacts of climate change impact of *T. aman* at Chattogram

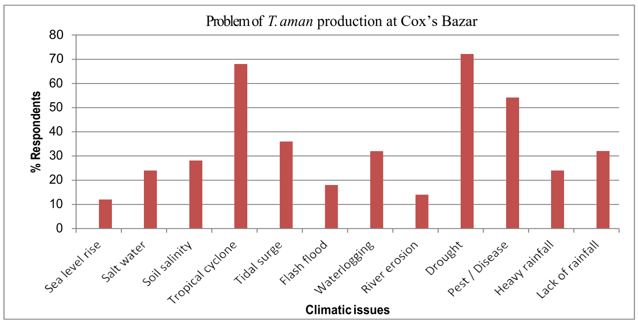

Figure 9: Farmers response on impacts of climate change affecting *T. aman* at Cox's Bazar

3.6 Problem of Boro rice production

Data presented in Figure 10 reveals that more than half of the respondents in Chattogram opined that disease and pest infestation and storm/hail were the major risk vulnerabilities in boro rice whereas soil salinity, pest and disease attack and drought were the major risk factors in boro rice at Cox's Bazar (Figure 11).

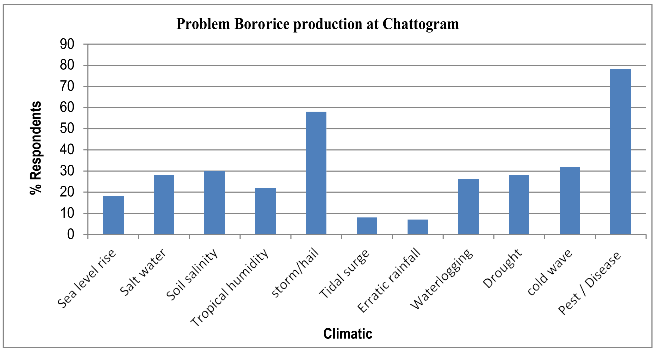

Figure 10: Farmers response on impacts of climate change on Boro rice at Chattogram

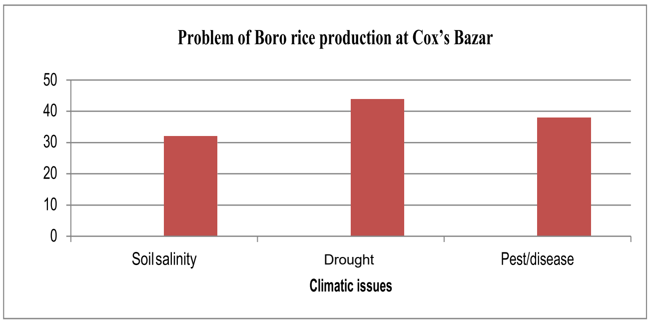

Figure 11: Farmers response on impacts of climate change on Boro rice at Cox's Bazar

3.7 Problem of Vegetable cultivation

Data presented in Figure 12 and Figure 13 reveals that pest and disease attack, soil salinity, salt water and water logging were the major problems in cultivation of vegetables in Chattogram districts. In Cox's Bazar districts major problems in vegetable cultivation were pest and disease attack, lack of rainfall, drought and waterlogging were the major risk vulnerabilities (Figure 13).

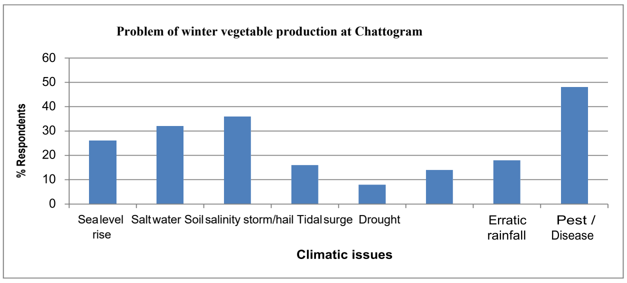

Figure 12: Farmers response on impacts of climate change on winter vegetables at Chattogram

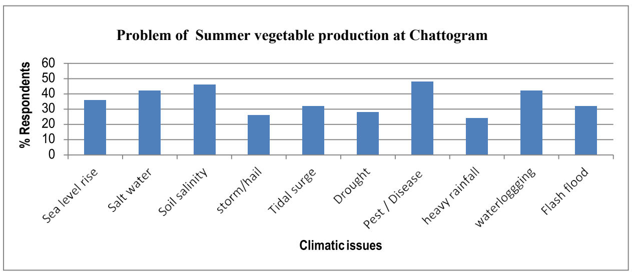

Figure 13: Farmers response on impacts of climate change on summer vegetables at Chattogram

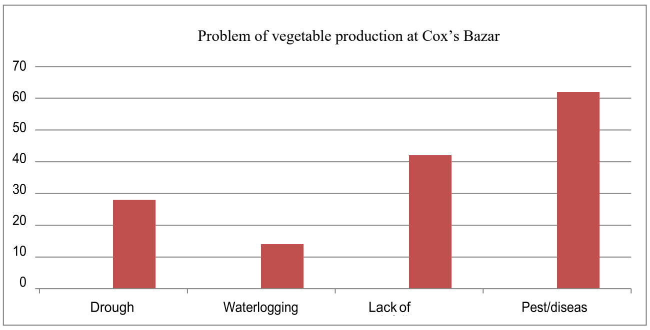

Figure 14: Farmers response on impacts of climate change on vegetable crops at Cox's Bazar

3.8 Problem of Pulse crops production

Information in Figure 15 shows that water logging was the major risk vulnerabilities in pulse crops at Chattogram as majority of the respondents opined. Other factors were pest and disease attack, soil salinity and sea level rising. None of the selected respondents were found to cultivate pulse crops at Cox's Bazar.

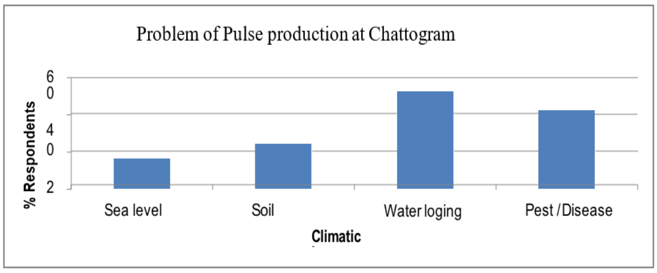

Figure 15: Farmers response on impacts of climate change on pulse crops at Chattogram

3.9 Problem of Oil seed crops production

Data presented in Figure 16 reveals that majority of the respondents in Chattogram opined pest and disease outbreak is the most vulnerable factors in oil seed crop. Other risk vulnerabilities were erratic rainfall, soil salinity and cold wave. In Cox's Bazar, pest and disease attack, tropical cyclone and drought were the major risk vulnerabilities (Figure 17).

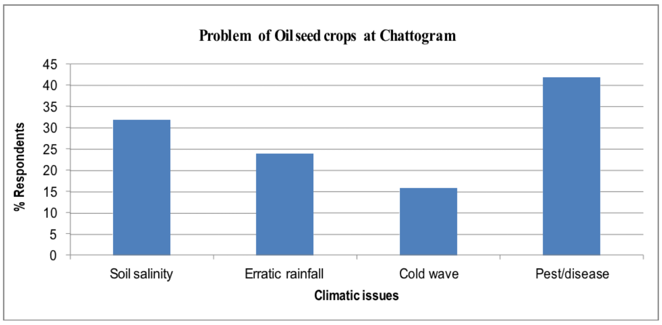

Figure 16: Farmers response on long term impacts of climate change affecting oil seed crops at Chattogram

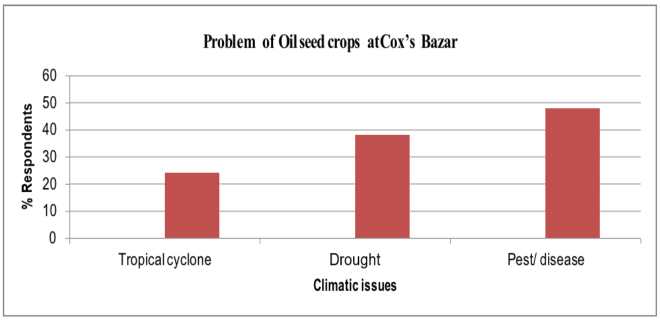

Figure 17: Farmers response on long term impacts of climate change affecting oil seed crops at Cox's Bazar

3.10 Adaptation Practices for Sustainable Agricultural Production

There were distinct changes of local climate specially temperature, rainfall, salinity, drought, flood, hotness, coldness and fog. which might have combined effect on productivity of crop production in the study area. Against the impacts of those changes, government as well as local community has undertaken some sort of adaptation measures. Based on the findings of the FGDs, field visits and discussion with farmers and review of the available literatures, some adaptation/innovative farming practices have been identified and documented. Identification of the innovative practices was considered based on i) analysis of the vulnerability, ii) suitability of the crops and practices to meet household needs, iii) possibilities of adoption by members of vulnerable communities, iv) targeted extrapolation area and above all v) possibilities of adaptation to the impact of climate change. Some promising adaptation practices have been summarized in Table 4 and Table 5.

A number of adaptation options/practices were being used by the respondents. Promising and viable adaptation options/practices were selected by the farmers. Among the different adaptation practices against climatic vulnerabilities, farmers were mostly habituated with "Sorjan system of cultivating year round vegetables, spices and fruits on raised beds and creeper vegetables on bed edges making trellis on ditches and cultivation of fish in ditches during wet months in the water-logged/tidal surge areas", "Floating bed agriculture", "Introduction of some salt-tolerant crop varieties (viz.wheat, maize, millet, mungbean, soybean, chickpea and rice)", "Utilization of bunds in gher areas in cultivating seasonal vegetables, fruits and spices and promoting science based rice-fish dual culture", "compost making and use of composts in homestead gardening" and " shrimp culture". With the changing climate, coastal people have been undertaken by the community to sustain their production system owing to their livelihood. Among those, coastal people changes their seed sowing/ seedling transplanting time accordingly. The respondent opined that due to having irrigation facilities and experience from erratic behavior of climatic variables the planting time have been shifted.

Table 4: Adaptation Practices for Sustainable Agricultural Production in the Context of Climate Change in Teknaf upazila of Cox's Bazar District

No	Adaptation Practices	% Respondents adopted
1.	Introduction of salt-tolerant crops (rice, mungbean, cowpea, soybean, ground nut) and sorjan system of year round cropping.	68.33
2.	Sorjan system of cultivating year round vegetables, spices & fruits on raised beds and creeper vegetables on bed edges and cultivation of fish in ditches during wet months.	55.00
3.	Using pond water in seed bed to escape salinity	45.00
4.	Promote compost making and use of compost in homestead Gardening	28.33
5.	Utilization of canal water by digging canals for cultivating boro crops in large fallow lands	23.33
6.	Floating bed agriculture (vegetable and vegetable seedlings) using water hyacinth bed	20.00
7.	Utilization of bunds in gher areas in cultivating seasonal vegetables, fruits and spices.	18.33

Table 5: Adaptation Practices for Sustainable Agricultural Production in the Context of Climate Change in Banskhali Upazila

No	Adaptation practices	% Respondents adopted
1.	Introduction of salt tolerant crop varieties (rice, wheat, maize, potato, strawberry, mungbean, cowpea, soybean, ground nut) in salt affected areas	71.67
2.	Sorjan system of cultivating year round vegetables, spices & fruits on raised beds and creeper vegetables on bed edges and cultivation of fish in ditches during wet months.	61.67
3.	Cultural practices (mulching, changes in planting time)	43.33
4.	Promote compost making and use of compost in homestead Gardening	40.00
5.	Floating bed agriculture in water logged areas	28.33
6.	Shrimp culture	15.00
7.	Boro rice-fish (bagda) dual culture	11.67

3.11 Farmers' Opinion/Suggestions on Adaptation Practices

Long-term impacts of climate change on crop production systems of the study areas were evaluated through household survey. There is a great scope of bringing the coastal area under intensive farming practices. In this context the respondents provided different suggestions to overcome the problems. Farmers' opinion/suggestions were evaluated through household survey in identifying the needs of GO/NGO interventions to reduce the long-term impacts of climate change for increasing crop production in the vulnerable coastal districts (Table 6).

Table 6: Farmers' opinion/suggestion on the needs of Govt./NGO interventions to reduce the Impacts of Climate Change

No	Initiatives	% Respondents suggested	
		Banskhali	Tekanf
1.	Training of farmers for increased sustainable agricultural production	23.33	15.00
2.	To use fallow land through local innovations/adaptation practices	20.00	23.33
3.	To produce and use of drought/salinity/flood adapted crop varieties	28.33	35.00
4.	To increase awareness among vulnerable farmers	21.67	20.00
5.	To increase agro production through farmers' community/groups	13.33	28.33
6.	To increase agriculture based production by maximum utilization of production inputs	15.00	23.33
7.	To give appropriate value of crops production/ marketing facilities of crops and promote agrobusiness	35.00	31.67
8.	To develop marketing system and make agriculture based network	20.00	13.33

4. Discussion

This study attempted to explore farmer perceptions of causes of decreased farm productivity in the coastal areas of Bangladesh. Firstly, we assessed the existing farm productivity and whether there were any decreases in the farm productivity compared with the past. Secondly, we identified whether the assessed decreases were due to climatic or non-climatic disturbances. Traditional impact modelling studies can fail to include complex factors, such as adaptation actions, technological advances and ambiguous links between climate change and droughts, cyclones, floods and salinity (Gornall et al., 2010; Morton, 2007). We assumed that farmers are the users of improved technologies in a changing climate. They continuously struggle to cope with natural hazards throughout the years (Garai, 2017). Therefore, their experiences, stored cues and associated knowledge (availability heuristics) could help them approximate the influences of climate change on farm productivity even without conscious analysis (Foguesatto et al., 2018; Simon, 1990).

From the finding of the study, it was found that wet and dry season temperatures showed an upward and downward trend respectively which is somewhat surprising. But as long as these two temperatures (wet and dry) are a part of the summer cropping season (Kharif) and winter cropping season (Rabi), respectively. The summer cropping season of Bangladesh is a combination of the significant part of the spring, summer and fall, while the winter cropping season is a mixture of the winter and earlier part of the spring. Higher temperature in the earlier part of wet season may be helpful because it helps in primary crop growth and development, while a warmer climate in the later stages can have negative impact, e.g. decreasing trend of crop growth. This might be cause that the wet temperature designated an inverted U-shaped trend of crop.

The dry summer or pre-monsoon season always had the lowest farm productivity. These seasonal differences in the productivity were mainly caused by different crop choices dependent on monsoon cycle (Hofer and Messerli, 2006). The monsoon season receives 80% of the total annual rainfall (Karmalkar et al., 2010). Farmers practise rainwater harvesting during monsoon using their ponds and canals. They use this water for agriculture in winter when river water becomes saline and unsuitable for irrigation (Hasan et al., 2018). Although the pre-monsoon occasionally receives rainfall, winter crops are on the other hand, the relatively coldness within the early phases of the season could also be damaging to crop growth, but because it gets warmer within the later stages, it becomes beneficial for ripening and maturity of crops. Thus, dry temperature indicated a U-shape trend.

However, in case of rainfall, the trends for wet and dry seasons were found hill-shaped which indicates that early stage rainfall in both seasons is favorable for crop farming in Bangladesh. Among the households' socio-demographic variables, the farming experience was positively associated with net crop income ($p < 0.05$) which suggests that experienced farmers are a much better custodian of their land and may have good knowledge and information on the changes in local climatic conditions. Farmers widely use irrigation especially groundwater irrigation to hedge against drought and heat stress, which also plays an important role to increase the productivity and hence net crop incomes in Bangladesh. However, groundwater level in many regions of Bangladesh is declining due to higher abstraction, which may cause an increase in salinity and irrigation cost and eventually may affect farmers' income in the long run (Barua et al., 2017). The positive and significant influence of farm size on net crop income ($p < 0.01$) indicates the economies of scale that large farms are associated with higher productivity compared to small ones.

This climatic situation in the coastal areas gives rise to a rice-based cropping pattern. Farmers cultivate mainly rainfed rice in the monsoon, irrigated rice and non-rice crops (e.g. several types of legumes, potato, groundnut and vegetables) in the winter, and small extent of rice and other crops (e.g. several types of gourds, beans, cucumber, watermelon, litchi and amaranths) in the pre-monsoon. However, the pre-monsoon season has the highest fallow lands in the coastal area due to a lack of irrigation water and higher soil salinity. Water availability for irrigation in the coastal areas is a key factor of crop productivity (Bhattacharya et al., 2019). Consequently, this pre-monsoon season had the lowest farm productivity in all the study areas. According to farmers' opinion, rice has become less profitable than other non-rice crops due to the lower farmgate prices at the time of harvesting.

5. Conclusions

Coastal agriculture is highly vulnerable to climate change and natural disasters. The intensity of disasters like sea level rise, tidal surge, soil salinity, salt water intrusion and cyclone in coastal belt are being increased. Consequently, the crop area is reducing and the cultivation of *T. aus, T. aman* , Boro crops are being restricted in some areas. A vast area of agricultural land that remains fallow or seasonal fallow (30-50 % of NCA of concerned districts) in drought prone, flood prone and coastal areas due to vulnerabilities which will be aggravated further in future due to climate change. The main reasons of fallowing are: soil wetness/water stagnancy, late harvest of T. Aman, drought and increased salinity and expansion of shrimp culture.

Long-term data/information on climate change showed that there is a trend of temperature rise, erratic rainfall, drought spell, increased tidal surges, increase of soil salinity and water salinity, increase of sea level and intrusion of salt water into crop lands, submergence, cyclones etc affecting crop production systems in the coastal region. The study showed that the main reasons of yield reduction (20-40 % yield loss) in T. Aman crop are erratic rainfall, increased intensity and frequency of drought, salinity, floods, cyclone, use of local varieties, increased incidences of pests & diseases etc in the context of climate change. Average yield level of HYV Boro is being affected (20-40 % yield loss) by high temperature and salinity and that of T.Aus crop is being affected (20-40 % yield loss) by tidal surge. Vegetables, pulses and oilseed crops are being affected (40-60 % yield loss) by soil wetness, excessive rainfall and water-logging in the selected areas.

Local perception of the impacts of climate hazards in coastal areas was assessed during FGDs and household survey. Participants stated that the current climate in this region is behaving differently than in the past on a number of climate risk factors affecting crop production. These are: frequent drought, changes in seasonal rainfall pattern, in-seasonal rainfall, long dry spells, increase of soil salinity, increase of tidal surges. In addition, participants perceived that temperature has increased over the years and duration of winter has been shortened affecting the potential growing period of winter crops. Cultivation of wheat is being affected at grain filling stage due to high temperature and increased incidences of pests and diseases. Increased intensity of soil salinity was perceived by the farmers as a result of white crust of salts on soil surface and crop burning during drier months in the coastal areas.

Sorjan system of cropping, rice-fish dual culture, utilization of bunds as vegetables/spices production in gher areas, floating bed agriculture and homestead gardening with introduction of salt-tolerant & drought tolerant crop varieties have been identified as potential adaptation options for development of coastal agriculture for increased agricultural production in attaining food security.

6. Recommendations

The results of our study may guide the government policy makers and rural development practitioners in designing the appropriate adaption strategies in the country. Adaptation policies should target different climatic zones based on the constraints and potentials of each zone in liew of recommending uniform interventions. To increase the resilience of crop farming sector of Bangladesh, immediate actions are required taking the current and anticipated climate change impacts into consideration. Based on the findings, our study suggests some essential climate adaptation policy recommendations which the government and policy makers may consider to address the challenges that farmers are likely to face as a result of climate change: (i) Developing Climate Change Scenarios based on GCMs: There is need for building upon existing adaptation option menus if available, based on GCMs and innovative field practices that are locally viable.

Assessment of past and current climate impacts; and understanding of local perceptions of climate impacts and local coping capacities and existing adaptation strategies is required. Capacity building in climate forecasting of DAE extension staff and community representatives should be an on- going part of such initiatives; (ii) Women's Involvement in Agriculture: Capacity building of women farmers and agriculturists is key for interventions to support and strengthen household coping strategies in agriculture and for managing climate variability. Given that women are increasingly engaged in homestead gardening, seed production and preservation, processing and compost making in the context of drought occurrences, it would empower women with technologies related short duration and drought-tolerant crop varieties, cropping systems and homestead gardening; (iii) Capacity building and training for strengthening local institutions, including self-help programmes and awareness raising for local institutions are required. Strengthening/ carrying out awareness raising campaigns and advocacy on climate change and adaptation issues among vulnerable communities should be undertaken involving the community in participatory dialogue; (iv) There is need for conducting, strengthening and expanding crop demonstrations and block farming based on adaptation practices.

Introduction of risk resistant crop varieties in agriculture with emphasis on crop diversification should be an integral part of the TOT, farmers training and demonstrations; (v) Road network, agro-processing and marketing infrastructure, canals and irrigation facilities need to be improved for mitigating impacts of crop production related vulnerabilities and climate change; (vi) There is need for improving the management of coastal saline soils through protective embankment, proper sluice gate, land leveling and improved drainage systems; vii) More study is required for making location specific production plan for better coastal agriculture based on soil-crop-climate suitability through proper assessment of soil related constraints, climate risks and socio-economic problems presently affecting crop production systems of systems of the vulnerable people of the coastal region and ix) climate change scenarios based on GCMs need to be done considering several climate change prediction models as available in South Asia.

Such recommendations include strengthening research capacity for the development of new cultivars and farming techniques with the changes in climate, enhancement of various enterprise diversification activities, making provision of crop insurance program and strengthening agricultural extension systems for disseminating up-to-date agricultural adaptation technologies to the farmers. Diversifying and generating off-farm employment opportunities in rural Bangladesh may also be crucial measures for the sustenance of rural masses. The present study was focused only on climate change impacts on net crop incomes. Future studies may consider analyzing the climate change impacts on other agricultural sectors, e.g. fisheries and livestock to assess the economic benefits or losses. We also suggest more research efforts in future for in-depth analyses of the economic impacts of climate change on farm income at the rural household level using a more holistic approach.

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