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Impact of climate change on crop production and adaptation practices in coastal saline areas of Bangladesh

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Abstract
People living in different coastal areas of Bangladesh have been suffering from lower crop productivity and less cropping intensity due to different climatic vulnerabilities. The study was carried out in Satkhira sadar upazila of Satkhira district and Kalapara of Patuakhali district 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. To achieve the objectives, data were collected through intensive survey of randomly selected 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, adaptability, coastal area, Bangladesh.

1. Introduction
Bangladesh is a deltaic country situated between the Himalyan Mountains in the north and the Bay of Bengal in the South. Because of its geographical position, there is little doubt that Bangladesh is likely to be one of the worst affected nations in the face of climate change (Harmeling, 2014) [8]. The country annually and inter-annually experience floods, cyclones, droughts, river bank erosions, salinity intrusions, tornados and other natural calamities that have adverse effect on agriculture, fishery, infrastructure, water and health (ADPC & BCAS, 2008) [5, 6]. The country has been facing prolonged and repeated floods in the northern and central regions, severe cyclones, salinity increase in coastal areas, erratic rainfall and drought in northwest region (BCAS, 2008) [6]. The country has faced devastating *Sidr* in November 2007, *Aila* in April 2009, series of flood of 2004, 2007 and 2009, *Nargis* in 2010 and *Mahasen* in May 2013 (Ahmed, 2010; MOEF, 2009) [1, 12].
Bangladesh is predominantly an agricultural country. She is one of the densely populated countries having about 160.0 million of people in its 1, 47.570 square kilometer of area (BBS, 2010). The geographical location and geological setting of Bangladesh renders it one of the most disaster prone countries of the world (FAO, 2006) [7]. As a result of its natural set up, the country is highly vulnerable to almost all type of disasters i.e. floods, cyclones, droughts, tidal surges, tornadoes, earthquakes etc. (Ali, 1996) [2]. Changing climate is having its impact evident in different parts of Bangladesh, especially in eco- sensitive zones like coastal, drought and flood prone areas. Though the climate change is adversely affecting each and every sector, their impacts are going to be much higher on agriculture sector, worst

affecting the agriculture dependent livelihood resources (LACC, 2008) [10]. 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 CO_2 concentration (IPCC, 2001) [9]. 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. Considering the above circumstances, the present study entitled “Farmer’s Perception towards Impact of Climate Change on Crop Production and Their Adaptation Practices in Selected Coastal Saline Areas of Bangladesh” was undertaken with following objectives.

- To assess the long-term weather data and farmers perception towards magnitude and trends of climate change during past 10 years.
- To find out the different risk factors with severity of affecting crop production systems in the coastal region.
- To identify the adaptive technologies practicing by the farmers to combat the changed climatic effect.

2. Methodology

The present study is a descriptive and diagnostic type of research. In order to study the climate change patterns and effects in coastal saline regions, two upazila namely Kalapara upazila of Patuakhali district and Sadar Upazila of Satkhira District in the south-western region of Bangladesh were selected as the locale of the project. Two Union from each upazila were selected randomly. Lists 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. Primary data were collected through intensive household survey and 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 their adaptation measures. Both open and close-ended questions were included in the questionnaire. 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 and Discussion

3.1 Climate Change Scenario in the Studied Coastal Saline Areas

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 Evidences from database

The evidences 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.

3.1.1.1 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 01- 04). 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 Satkhira whereas 0.002 and 0.305 at Patuakhali 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.

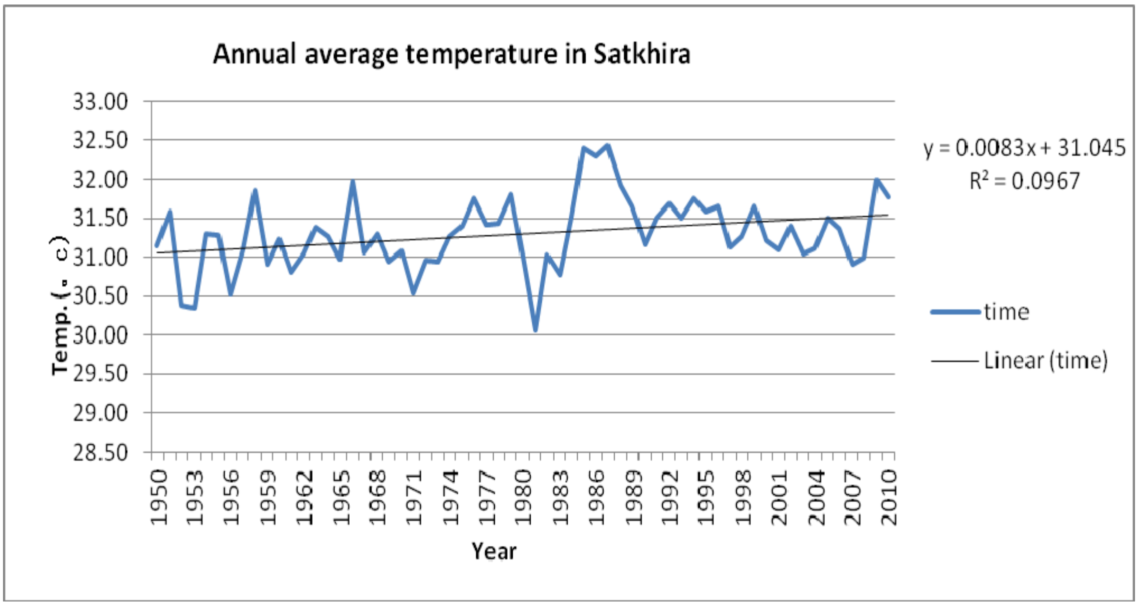

Fig 1: Long term (1950-2010) trend of annual average temperature in Satkhira.

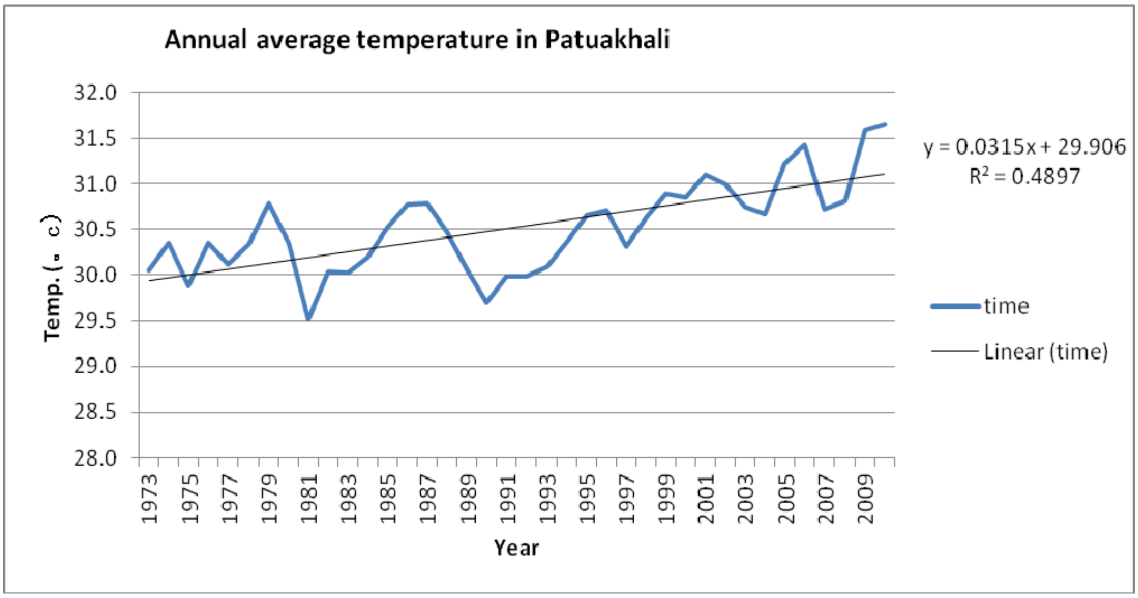

Fig 2: Long term (1950-2010) trend of annual average temperature in Patuakhali.

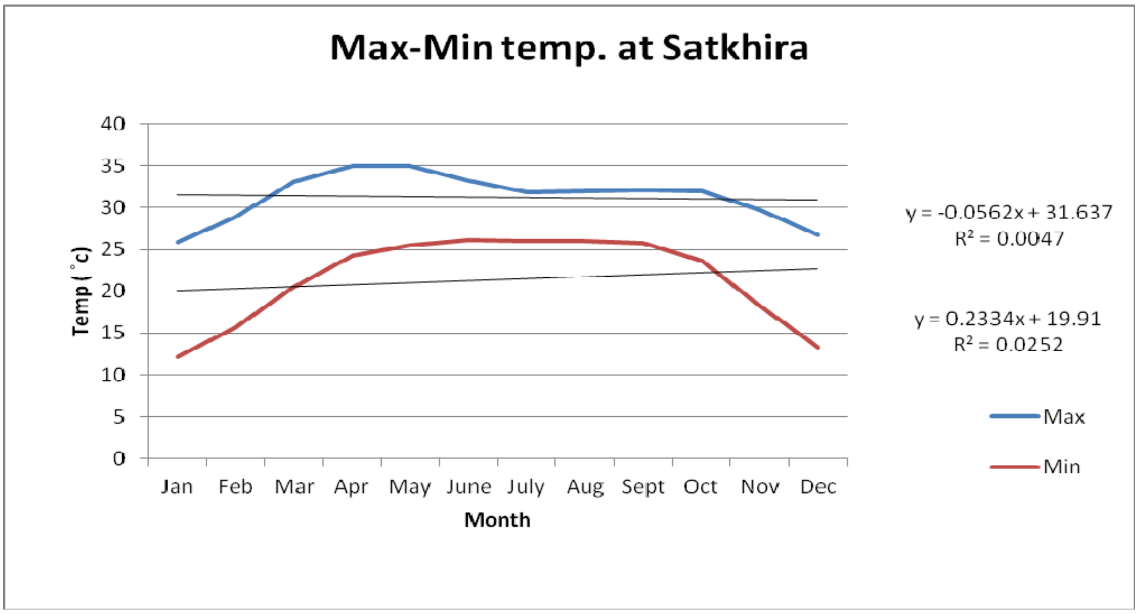

Fig 3: Long term (1950-2010) trend of maximum-minimum temperature in Satkhira.

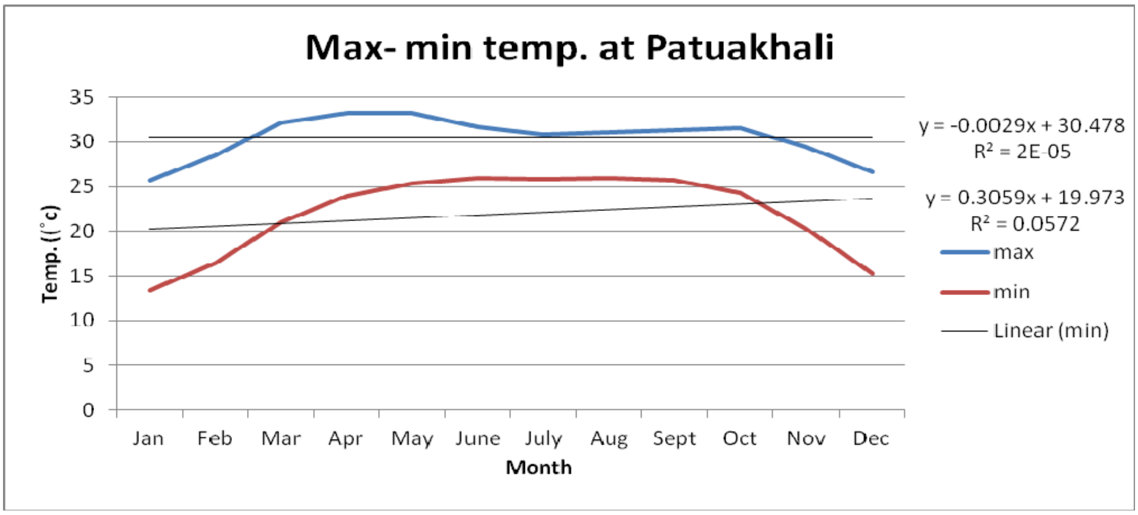

Fig 4: Long term (1950-2010) trend of maximum-minimum temperature in Patuakhali.

3.1.1.2 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 Satkhira (Figure 5) and 635 mm in Patuakhali (Figure 6) 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 (Wang *et al*. 2009) [14] that might have hampered the growth of the vegetation. Subash and Mohan (2011) [13] reported wide year-to-year variation in the monthly distribution of rainfall in Indo-Gangetic region.

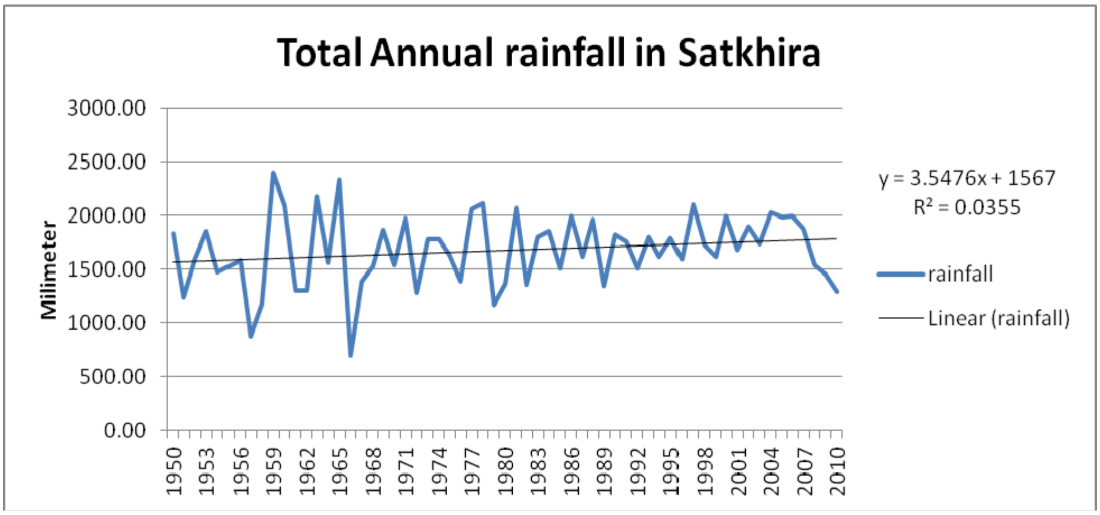

Fig 5: Long term (1950-2010) trend of annual total rainfall in Satkhira.

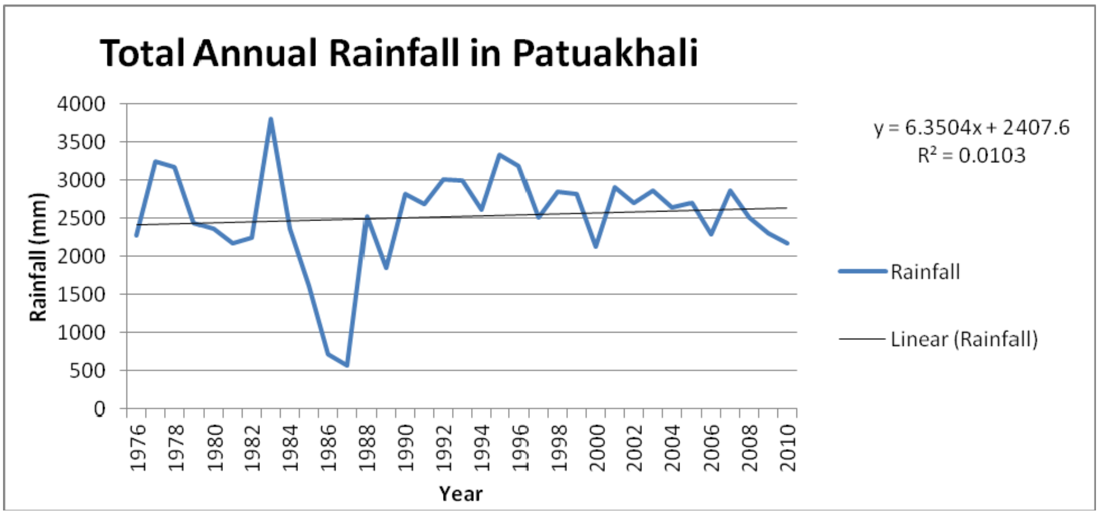

Fig 6: Long term (1950-2010) trend of annual total rainfall in Patuakhali.

3.1.2 Farmer's Perception on Changes in Climatic Variables and Natural Hazards

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 metereological 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) [12].

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

Climatic parameter	Respondents Perception (%)				
	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

3.2 Impact of Climatic Vulnerabilities on Crop Production

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 07 -16).

3.2.1 T. Aman Rice

Data presented in Figure 7 reveals that majority of the respondents in Satkhira districts opined pest and disease infestation, salt water and waterlogging were the major risk factors in T. aman crop. Whereas in Patuakhali tropical cyclone, pest and disease infestation and drought were the major risk factors in T. aman crop (Figure 8).

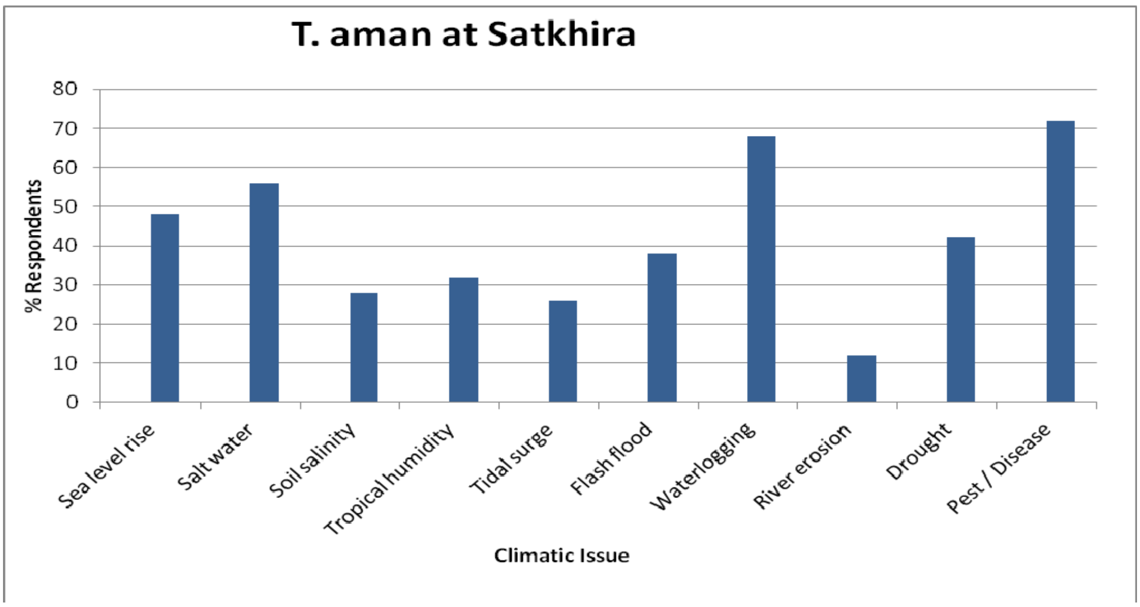

Fig 7: Farmers response on long term impacts of climate change affecting T. aman at Satkhira

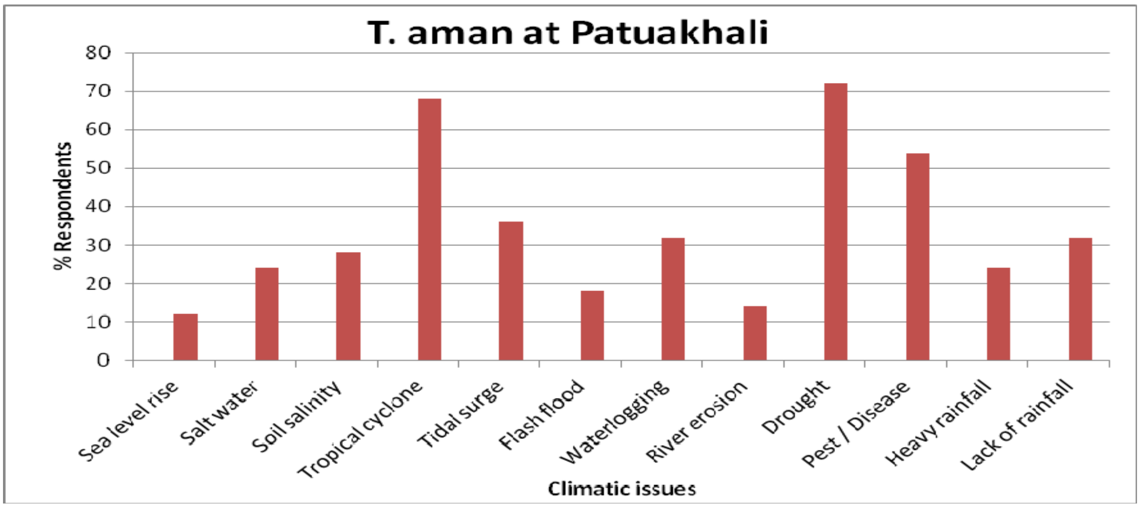

Fig 8: Farmers response on long term impacts of climate change affecting T. aman at Patuakhali

3.2.2 Boro rice

Data presented in Figure 9 reveales that more than half of the respondents in Satkhira 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 Patuakhali (Figure 10).

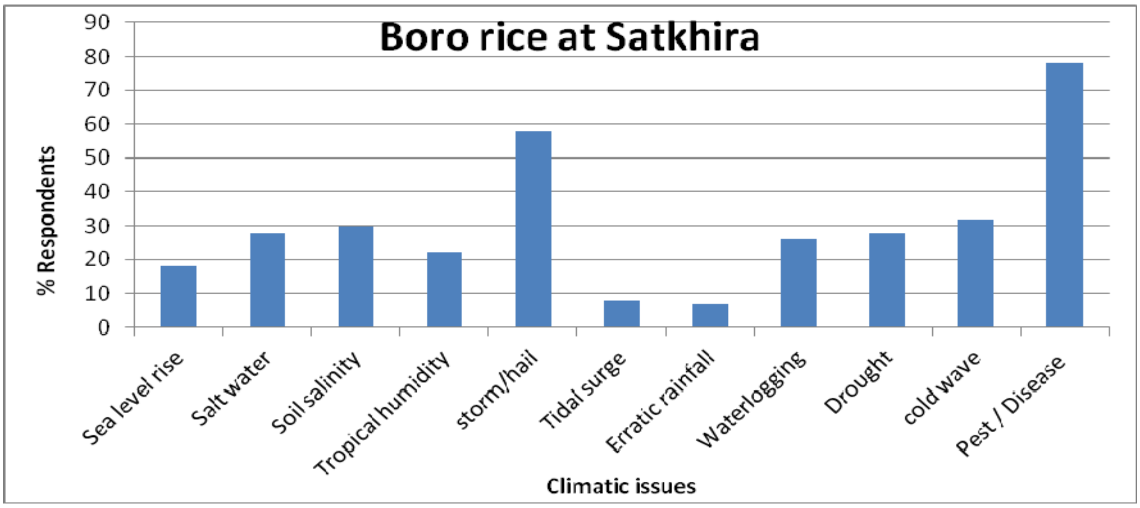

Fig 9: Farmers response on long term impacts of climate change affecting Boro rice at Satkhira

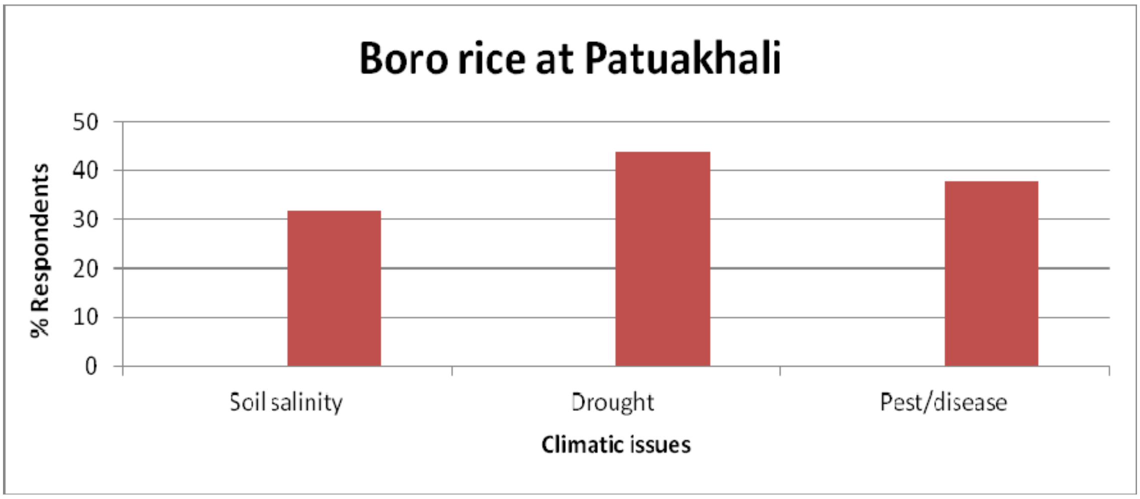

Fig 10: Farmers response on long term impacts of climate change affecting Boro rice at Patuakhali

3.2.3 Vegetable cultivation

Data presented in Figure 11 and Figure 12 reveals that pest and disease attack, soil salinity, salt water and water logging were the major problems in cultivation of vegetables in Satkhira districts. In Patuakhali districts major problems in vegetable cultivation were pest and disease attack, lack of rainfall, drought and waterlogging were the major risk vulnerabilities (Figure 13).

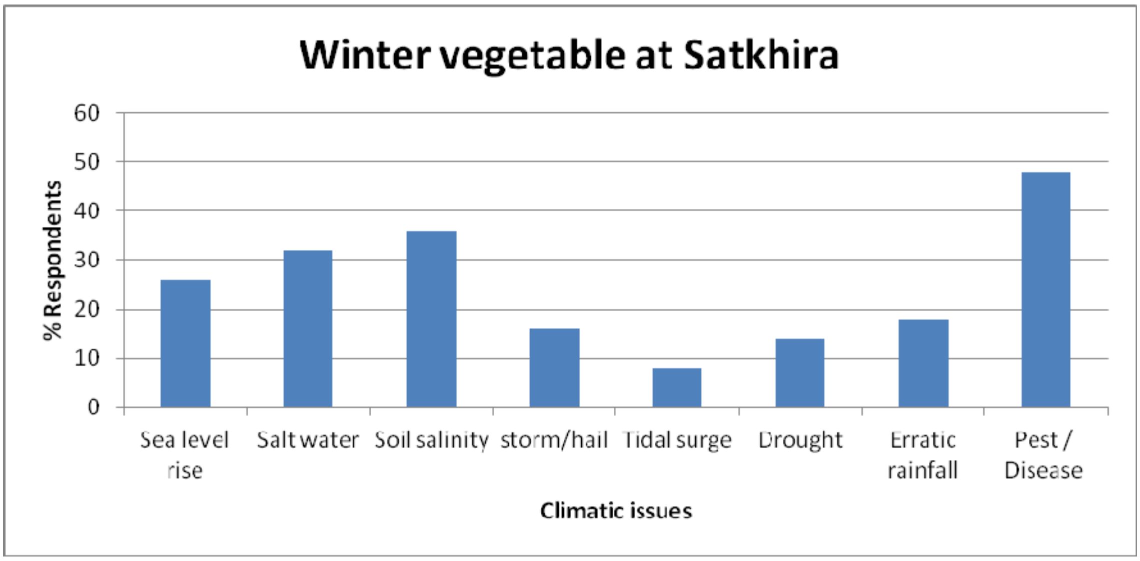

Fig 11: Farmers response on long term impacts of climate change affecting winter vegetables at Satkhira

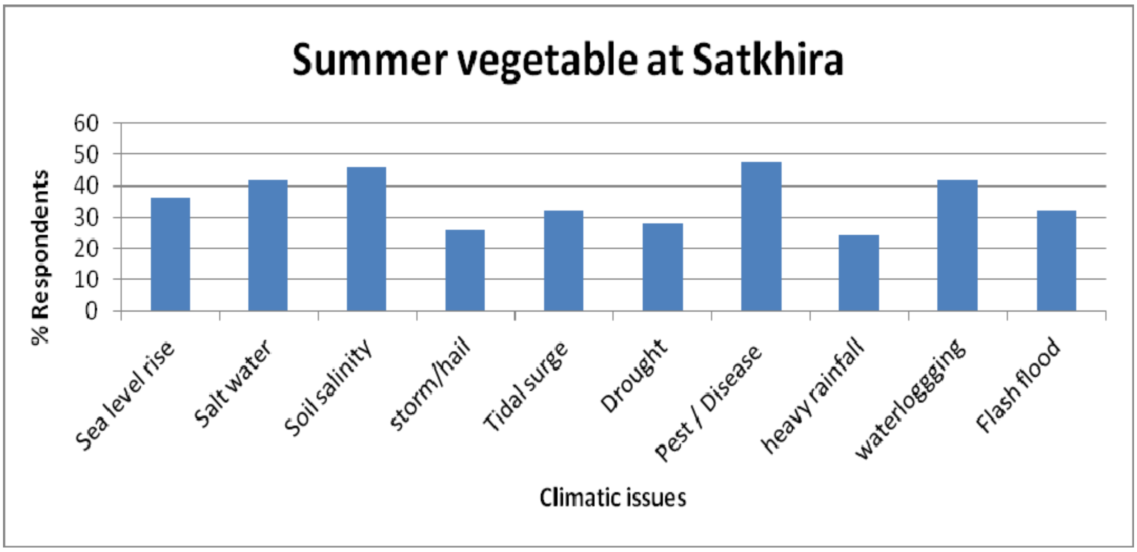

Fig 12: Farmers response on long term impacts of climate change affecting summer vegetables at Satkhira

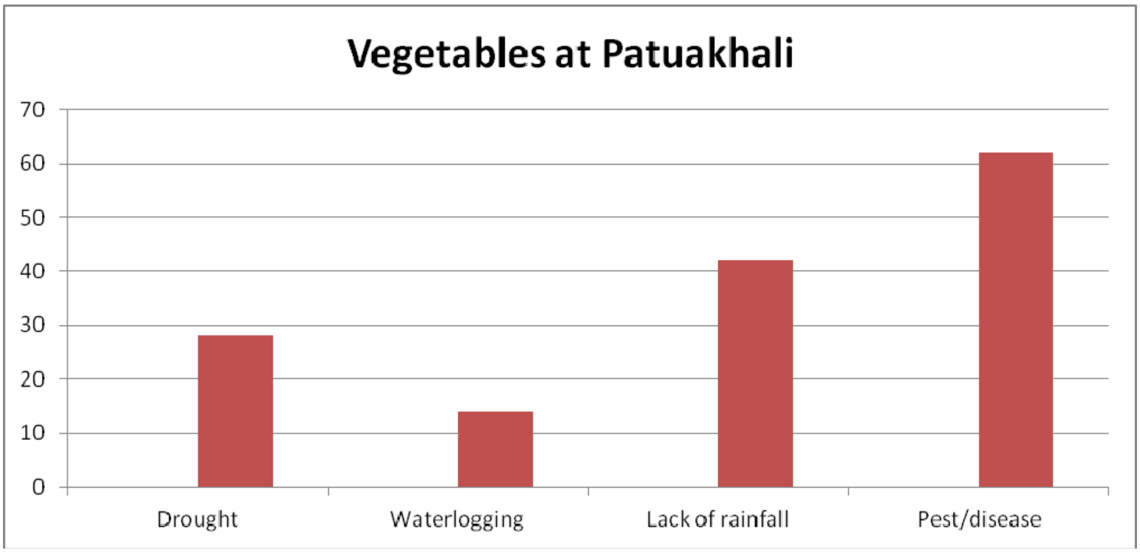

Fig 13: Farmers response on long term impacts of climate change affecting vegetable crops at Patuakhali

3.2.4 Pulse crops

Information in Figure 14 shows that water logging was the major risk vulnerabilities in pulse crops at Satkhira 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 Patuakhali.

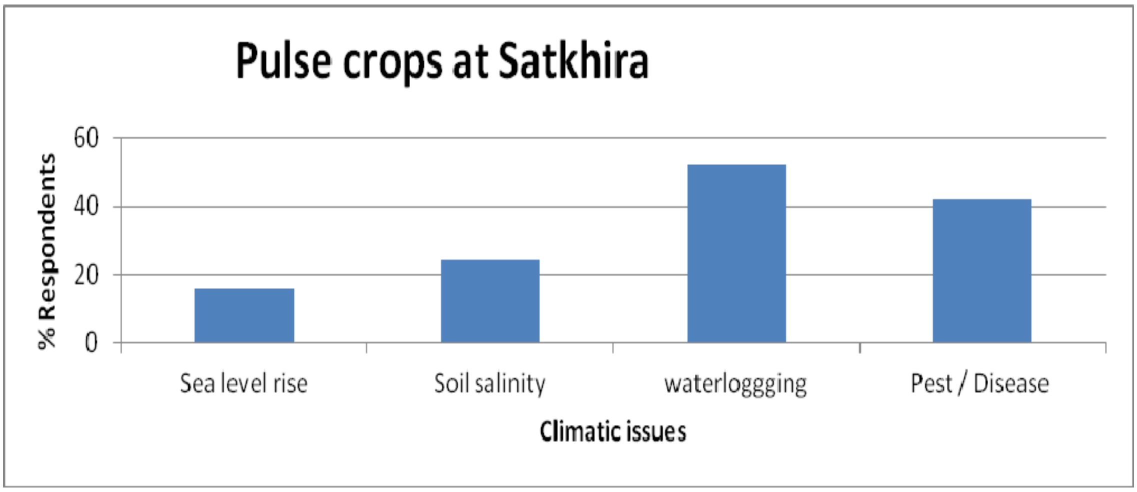

Fig 14: Farmers response on long term impacts of climate change affecting pulse crops at Satkhira

3.2.5 Oil seed crops

Data presented in Figure 15 reveals that majority of the respondents in Satkhira opined pest and disease outbreak is the most vulnerable factors in oil seed crop. Other risk vulnerabilities were erractic rainfall, soil salinity and cold wave. In Patuakhali, pest and disease attack, tropical cyclone and drought were the major risk vulnerabilities (Figure 16).

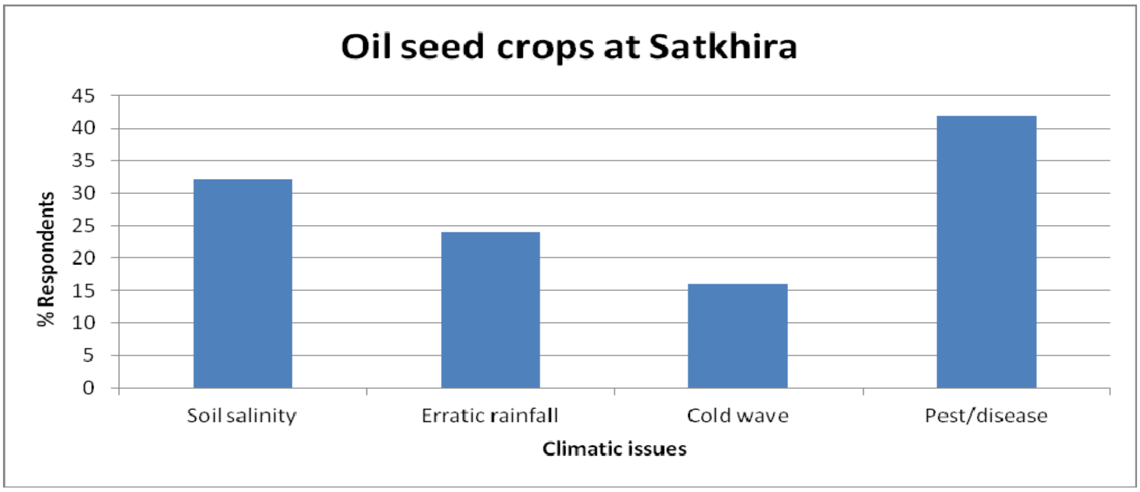

Fig 15: Farmers response on long term impacts of climate change affecting oil seed crops at Satkhira

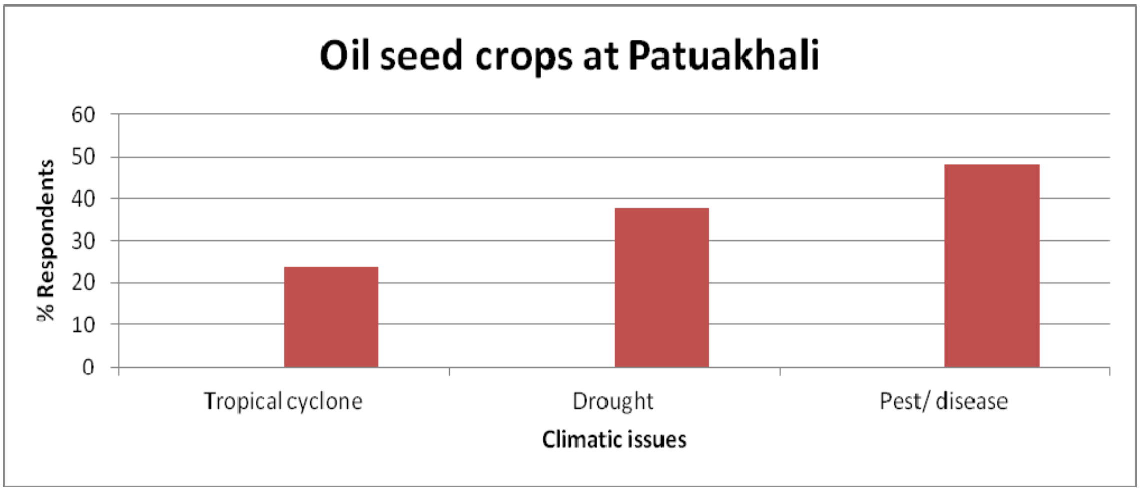

Fig 16: Farmers response on long term impacts of climate change affecting oil seed crops at Patuakhali

3.3 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 02 and Table 03.
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 2: Adaptation Practices for Sustainable Agricultural Production in the Context of Climate Change in Kalapara upazila of Patuakhali District

Sl	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 3: Adaptation Practices for Sustainable Agricultural Production in the Context of Climate Change in Satkhira Sadar Upazila

Sl.	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

3.4 Farmers' Suggestion

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 4).

Table 4: Farmers' suggestion on the needs of Govt. /NGO interventions to reduce the Impacts of Climate Change

Sl.	Initiatives	% Respondents Suggested	
		Satkhira Sadar	Kalapara
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 agro 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 agro net work	20.00	13.33

4. 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 aus (summer rice), boro (dry season rice) and other Rabi (dry season) crops are being partially restricted in study 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/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. Current climate in the study area 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 and 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.

5. Acknowledgement

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