CLIMATE CHANGE INDUCED SEA LEVEL RISE IMPACT ON AGRICULTURE AND FOOD SECURITY IN SOUTH-WEST COASTAL REGION OF BANGLADESH

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ABSTRACT

Climate change is undeniable and unequivocal. The south-western coastal part of Bangladesh is to be identified as environmental handicap by climate change. The impacts of higher temperatures, more variable rainfall, more extreme weather events, and sea level rise are becoming huge threat in every sector of life and livelihood. The coastal zone of Bangladesh is naturally susceptible to disaster whereas climate change asserts a new depressing effect to the lives and agronomy. The aims of this study are to investigate the climate variability and to assess its impacts on agriculture and to correlate these by data analysis. Furthermore, to propose some adaptation programs to ensure food security. The whole study is based on long-term climatic data, regional climatic scenarios, crop productivity data and impact analysis of different aspects of climate change on agriculture and water. This study reveals that the crop yield is negatively impacted by rise in temperature, erratic rainfall, salinity, scarcity ofirrigationwater sources. It is roughly estimated that there will be a decrease of crop production of about 9% and 30 % and salinity affected areas will increased up-to 16% and 18% in 2050 & 2100 respectively .Theecological conditions are more vulnerable which is very likelyto be alerted though slowly but surely due to climate changeand sea level rise. However, adaptations to climate change like agronomic manipulations, sustainable climate resilient, shifting the planting dates, using short duration crop cultivars can reduce vulnerabilities, delay the process and increase food security.

Keywords:*Climate change, coastal zone, impact, agriculture, correlation.*

1. INTRODUCTION

There is unequivocal evidence that the global climate is warming because of an increased concentration of greenhouse gases (GHG) in the earth atmosphere. Global warming will lead to thermal expansion of sea water, together with melting of glaciers and sea-ice, the resultant effect of which is the rise in sealevel. A 0.1 to 0.5m rise in sea-level by the middle of this century (as predicted by most of the estimate) will pose a great threat to the livelihoods and agriculture in low-lying coastal areas of the world including about 1/5th of the total land area of Bangladesh. Climate variability refers to variations in the prevailing state of the climate on all temporal and spatial scales beyond that of individual weather events. Global climate change indicates a change in either the mean state of the climate or in its variability, persisting for several decades or longer. This includes changes in average weather conditions on Earth, such as a change in average global temperature, as well as changes in how frequently regions experience heat waves, droughts, floods, storms, and other extreme weather. It is important to note that changes in individual weather events will potentially contribute substantially to changes in climate variability. The threat of climate change has been observed differently by developed and developing nations due to their contextual difference. The severity of salinity problem in Bangladesh increases with the desiccation of the soil. 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. The south-western coastal zone of Bangladesh is worldwide recognized as an extremely vulnerable area (Agarwala *et al.*, 2003). Impacts of climate change and sea-level rise should have real consequences on the already existing vulnerable food securities. The present cropping patterns and livelihoods will make the people more vulnerable to cope with the negative impacts of global warming and sea-level rising consequences. As agriculture is highly vulnerable to climate change, food security, food prices and nutrition will be adversely affected (Mainuddin *et al.*, 2011). Therefore, collection of relevant information relating to the degree of global warming on sea-level rising and its consequences on the coastal land masses and population are essential in formulating policies for food security in the coastal regions of Bangladesh. Therefore the study is conducted to investigate the climatic variation and evaluate the food production status with the assessment of the impact on food due to predicted sea level rise by data analysis. Furthermore, exploration of the tactic regarding food security against predicted sea level is also piloted here.

2. STUDY AREA

The south-western coastal zone of Bangladesh that includes districts viz. Bagerhat, Jessore, Khulna, Narail and Satkhira under Khulna Division and Barguna, Barisal, Bhola, Jhalokati, Patuakhlai and Pirojpur under Barisal Division. Most of the coastal parts and associated islands of Khulna and Barisal Divisions lie within 1m from sea level where incursion of saline water is common. It is predicated that these areas will be inundated and unsuitable for crop production due to sea-level rise in the next 50 years. More than 20 million people, equivalent to about 15% of total country's population live in this coastal region of Bangladesh.

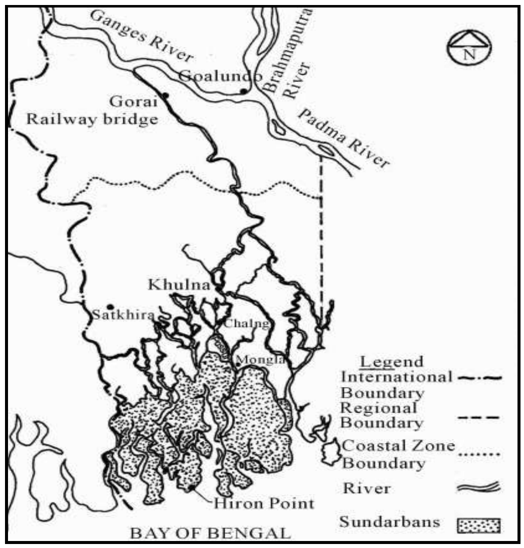

Figure 1: The South-west Coastal Region of Bangladesh

3. METHODOLOGY

3.1 Data Collection

Both primary and secondary data were collected for the research purpose.

3.1.1 Collection of Primary Data

At first, a primary survey was conducted in the study area in order to have a preliminary concept about climate change and food security. After that, a detail field survey was conducted to visually investigate the existing impacts of climate change on food security.

3.1.2 Collection of Secondary Data

To assess the impact of climate change on food security secondary data were collected from Bangladesh Bureau of statistics, Department of Agricultural Extension, Bangladesh Meteorological Department, Department of Food, Bangladesh Agricultural Research Institute, Soil Resource and from Bangladesh Agricultural Research counsel. Relevant information have been accumulated by journals, periodicals, browsing internets, personal communications and visiting various Non -Government Organization (NGO)s offices like Rupantor, Prodipon, World Food Program, etc.

4. RESULTS AND DISCUSSION

4.1 Variability of Climatic Conditions in the Study Area

Four climate parameters i.e. temperature, relative humidity, wind speed and precipitation records of long periods were investigated to examine climate change. In each case, noticeable changes were observed over times.

4.1.1 Temperature

Temperature is one of the major climatic parameters, to check change in temperature and its variability, data was rearranged from various perspectives. Here, a comparison was shown among year-wise monthly average maximum temperatures.

Year-wise monthly average maximum temperature from 1994 to 2013 was shown in figure and the variations in every year were inspected.

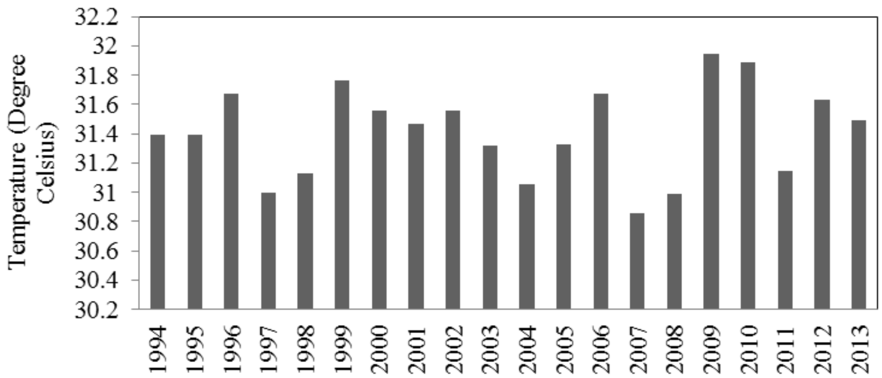

Figure 2: Average of year-wise monthly average maximum temperature

In these consecutive 20 years, maximum monthly average temperature was recorded in 2009 and the lowest in 2007 denoting 31.94 ^{o}C and 30.86 ^{o}C respectively. The difference between them is1.08 ^{o}C. From this graph, it is to be noted that temperature change is irregular and did not follow any well-defined trend while increasing or decreasing over the years.

Year-wise monthly average maximum temperature data from (1951-1960) to (2004-2013) are compared which is obtained by averaging them arithmetically.

Table 1: Year-wise monthly average maximum temperature

Year	Temperature (Degree Celsius)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
(1951-1960)	26.5	29.6	33.4	35.3	34.9	32.7	31.2	31.6	32.1	31.4	28.5	26.9
(2004-2013)	24.4	28.5	33.7	35.8	35.4	33.6	31.9	32.5	32.6	32.3	30.1	26.3

The monthly average maximum temperature has changed noticeably between these years. It decreases in December, in January and in February. Temperature in this perspective has grown in all the other months to a considerable extend. The highest monthly average maximum temperature ever recorded is in April i.e. 35.8℃ and the lowest was in January i.e. 24.4℃ respectively. Moreover, temperature is arriving at a steady state in two cycles, namely, one is April to May and another is July to October.

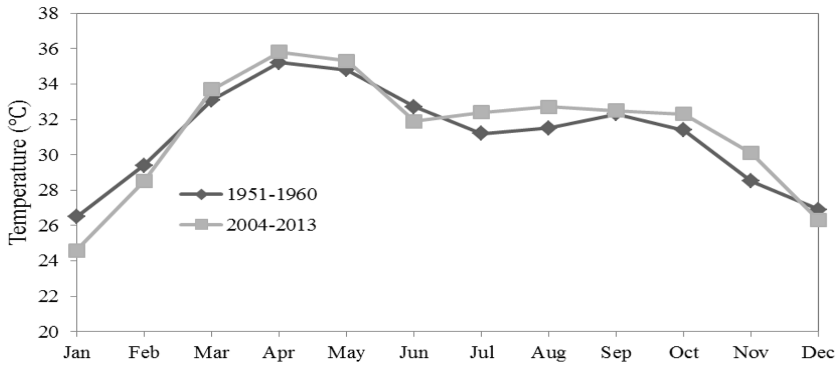

Figure 3 : Variation in monthly average maximum temperature (1950-2011)

4.1.2 Rainfall Intensity

Inadequate rainfall causes salinity intrusion, reducing crops yields and fresh water scarcity. On the other hand, excessive rainfall may cause flood and inundate croplands and pastures. So variability and changes in rainfall pattern was studied from different point of view.

Here, it can be seen that rainfall varies from year to year and no specific trend over the years exists i.e. the rainfall is erratic. From 2002 to 2005, rainfall was quite regular; their magnitudes were in the range of 121 mm to 135 mm. In 2006 rainfall decreased suddenly and then it raised and fell. Between these consecutive 20 years, the maximum rainfall was recorded in 1998 is 159 mm and minimum in 2011 which is 22 mm.

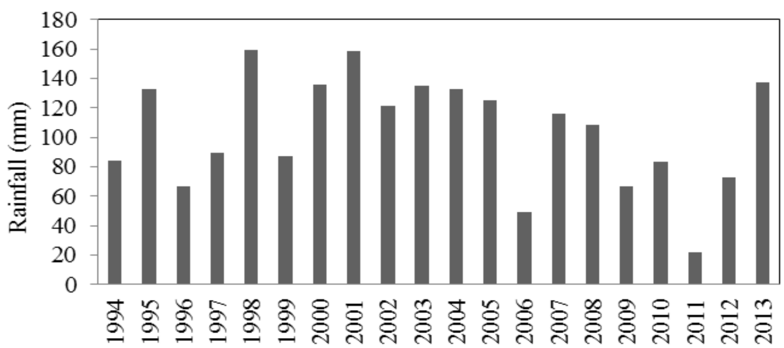

Figure 4: Median of monthly average rainfall

Now year-wise monthly average rainfall data from (1951-1960) to (2004-2013) are compared which is obtained by evaluating of their median value.

Table 2: Median of year-wise monthly average rainfall

Year	**Median of year-wise monthly average rainfall (mm)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
(1951-1960)	13	5	17	51	191	323	438	216	235	171	21	0
(2004-2013)	15	13	29	46	181	268	372	331	392	185	22	0

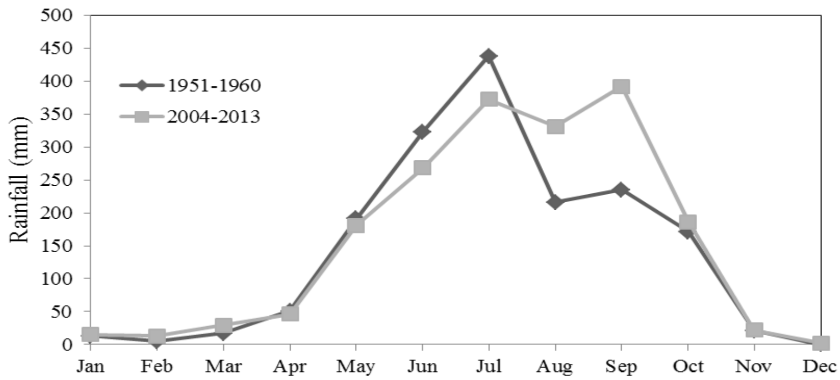

Figure 5: Variation in monthly average rainfall (1950-2011)

Rainfall decreases in May, June and July. It increases a little in February and May whereas the same raises a lot in August and in September. The maximum rainfall ever recorded is 438 mm which takes place in July. The months of August and September have also a large precipitation of 331 mm and 392 mm respectively. So it is noticed that rainfall is shifting and getting centralized in a small portion of the year.

4.1.3 Relative Humidity

Hereby year-wise monthly average relative humidity data from (1951-1960) to (2004-2013) are compared by plotting them in the following which is obtained by averaging them arithmetically.

Table 3: Average of year-wise monthly average relative humidity

Year	Relative humidity (%)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(1951-1960)	73.8	69.8	70.6	73	78	86	89	87.6	86.8	83.5	77	76.8
(2004-2013)	80	74.2	73	74.5	78	84	87.4	89.4	88.6	85.4	80.5	82.8

The magnitude remains virtually alike after first four months extending to next three months. Value of relative humidity goes up in almost all the months except Jun and July. The maximum relative humidity measured over these periods is found to be 89.8% in August.

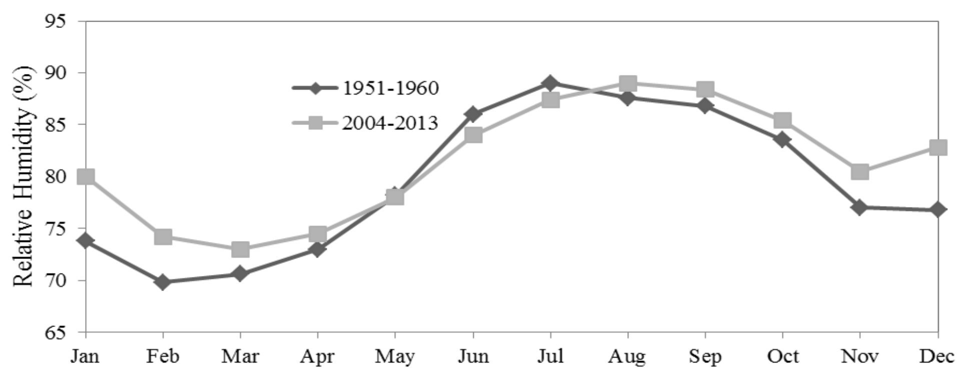

Figure 6: Variation in monthly average relative humidity (1950-2011)

4.1.4 Wind Speed

Year-wise monthly average wind speed in m/s data from (1961-1970) to (2004-2013) are compared by plotting them in the following graph.

Table **Error! No text of specified style in document.**: Average of year-wise monthly average wind speed

Year	Wind speed (m/s)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(1961-1970)	0.34	0.43	1.13	1.9	2.1	1.11	1.23	0.8	0.53	0.37	0.29	0.34
(2004-2013)	0.77	1.17	1.64	2.23	1.83	1.66	1.82	1.93	1.5	.8	0.57	0.93

We can see that it rises in all the months except May. From February towards March and from August towards November wind speed fluctuates suddenly whereas it rises and falls gradually in the other months of the year.

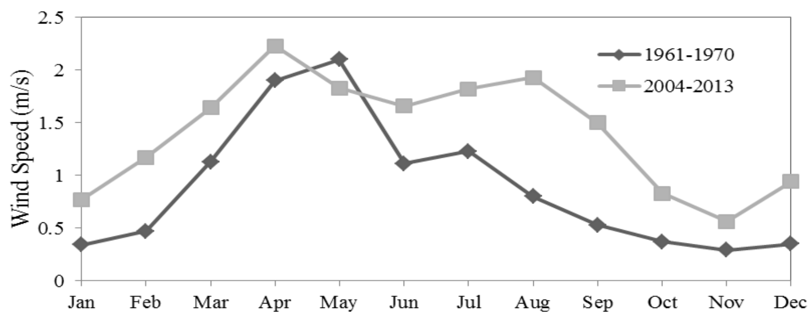

Figure 7: Variability in monthly average wind speed (1961-2012)

4.2 Agricultural Information:

The features of South-western coastal zone are shown below in table 5 in Terms of Salinity, tidal surge and Cyclones.

Table 5: Features of vulnerable districts in the south-western coastal zone

Sl No.	Name Of District	Area(km2)	Total population	% of total country population	Nature of vulnerability		
					Salinity	Tidal surge	Cyclones
1	Khulna	4,395	2,357,940	1.904	√	√	√
2	Bagerhat	3,959	1,516,820	1.225	√	√	√
3	Satkhira	3,858	1,845,120	1.490	√	√	√
4	Jessore	2,567	2,469,680	1.994	√		
5	Narail	990	694,900	0.561	√	√	√
6	Barguna	1,832	845,060	0.682	√	√	√
7	Barisal	2,791	2,348,440	1.896	√	√	√
8	Bhola	3,403	1,703,200	1.375	√	√	√
9	Jhalokati	758	692,680	0.559	√	√	√
10	Patuakhali	3,205	1,464,800	1.183	√	√	√
11	Pirojpur	1,308	1,099,780	0.888	√	√	√
	Total	29,100	17,038,430	13.8			

The total owner, operated, homestead, net cultivated and temporary cropped areas in the coastal districts are shown in Table 6.

Table 6: Operated, homestead, cultivated and cropped area (area in hectares)

Sl No.	Name Of District	Owner Area	Operated Area	Homestead Area	Net cultivated area	Temporary cropped area
1	Khulna	178399	143396	11285	108159	97075
2	Bagerhat	163333	166260	7787	137003	111378
3	Satkhira	175687	180676	9502	99540	84899
4	Jessore	196056	198783	12357	152744	128049
5	Narail	81005	79768	4143	65784	58636
6	Barguna	110546	108168	5236	91370	80587
7	Barisal	194757	190727	38716	151953	128047
8	Bhola	130854	138280	8196	116433	93935
9	Jhalokati	68283	58481	2575	49024	38516
10	Patuakhali	183767	175776	8294	149674	139073
11	Pirojpur	109558	105437	4890	88896	66074
	Total	1592245	1545752	112981	1210580	1026269

The land utilization categories as forest, not cultivable, cultivable waste, current fallow land, and single, double, triple, net and total cropped land for the 6 greater coastal districts is shown in figure 8 . The greater Khulna district is characterized by poor cropping intensity of 136% where the country average figure is 177%. Such lower cropping intensity in Khulna regions as compared to other coastal districts is attributed mainly to shrimp cultivation. Cropping intensity in Barsisal and Barguna is also lower than the country average whereas Jessore is ranked above the national figure of cropping intensity.

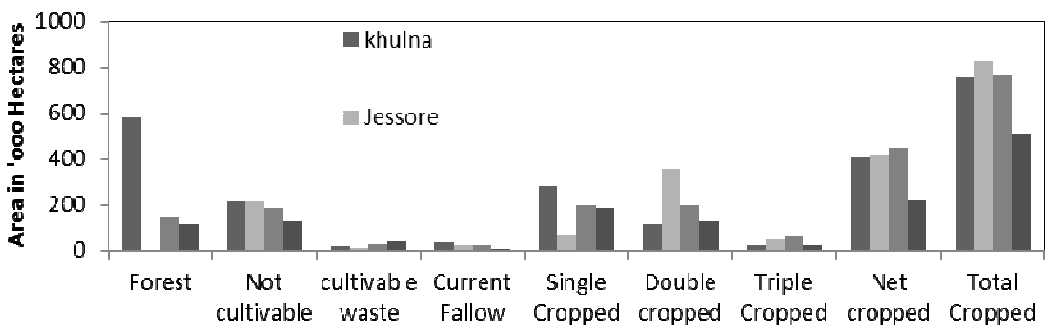

Figure 8: land utilization categories'

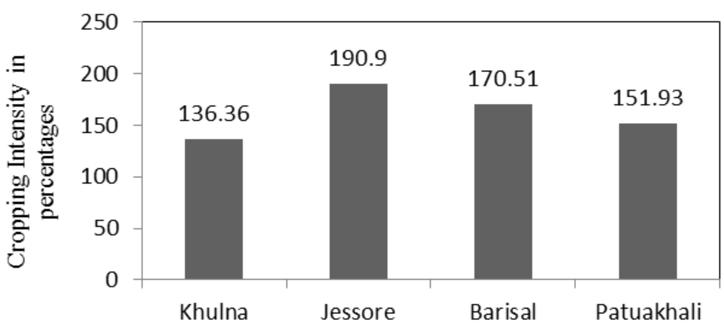

Figure 9: Cropping Intensity

The people of this zone cultivate grossly about 1.7 million hectares of land out of which 0.194 million ha for local Aus, 0.07 million ha for HYV Aus, 0.64 million ha for local Aman, 0.18 million ha for HYV Aman, 0.32 million ha for Boro and 0.018 ha for wheat crops (Table 7).

Table 7: Distribution of major cropped areas in costal districts

Sl No.	Name Of District	Gross cropped area (ha)	Cropped area (ha)					
			Aus (local)	Aus (HYV)	Aman (local)	Aman (HYV)	Boro	Wheat
1	Khulna	131051	7536	1623	56254	20772	27267	346
2	Bagerhat	143155	4989	1493	75981	11882	33446	122
3	Satkhira	139567	838	5573	15029	44623	43005	1867
4	Jessore	246472	6851	15449	25919	54991	88801	6584
5	Narail	93949	10532	1390	24459	7386	29402	2920
6	Barguna	142324	20934	14235	69777	9445	2716	90
7	Barisal	230038	34323	6215	84964	7967	49487	2200
8	Bhola	198375	36668	3172	81560	7212	19285	4371
9	Jhalokati	67484	15218	2707	32511	1694	4549	15
10	Patuakhali	244015	44484	5685	127243	8166	4857	112
11	Pirojpur	97626	13187	3152	45291	4213	14242	79
Total		1734066	194960	60694	638988	178351	317057	18716

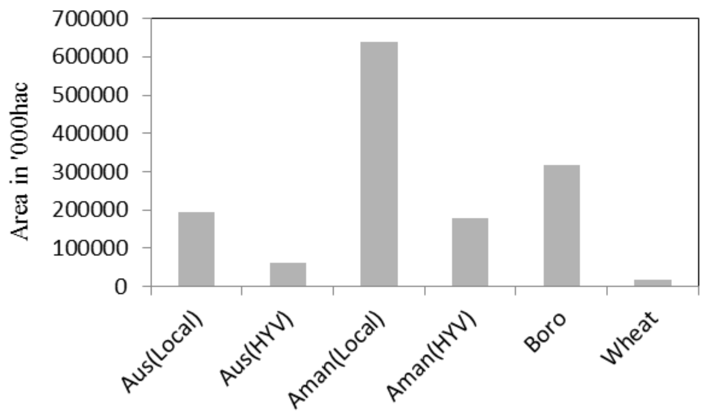

Figure 10: Distribution of major cropped areas

Farmers of Barisal and Patuakhali use traditional methods of irrigation from local channels and canals. Beside the traditional methods, irrigation by tube wells is not common in the remaining coastal zones. Only 2% of total cropped area remains under irrigation in Patuakhali whereas that figures are about 13 and 18 for Barisal and Khulna respectively. Percentage of irrigated land in Jessore (42%) is higher than the country average figure (33%).

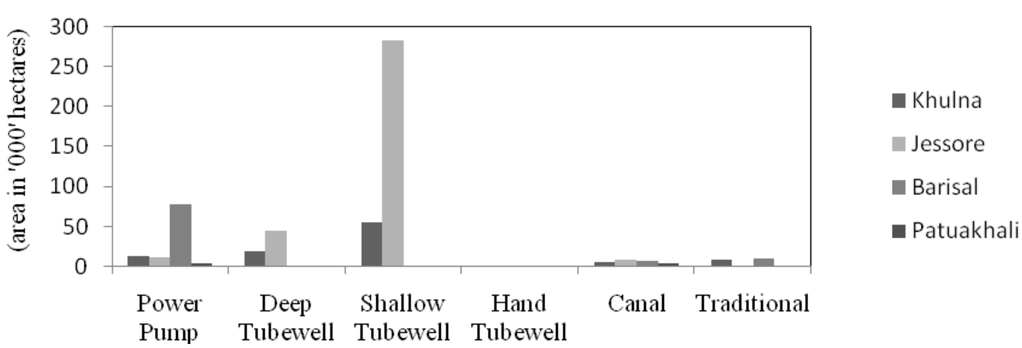

Figure 11: Irrigated area under different means

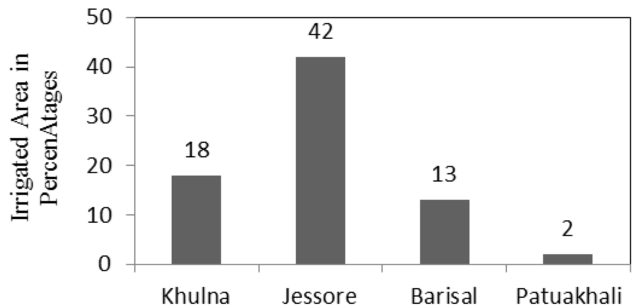

Figure 12: Percentages of Irrigated Area

4.3 Cropping Pattern

The cropping patterns as collected from Thana Agricultural Officers of some selected coastal regions and the same collected by case studies been collected directly through site visits which are presented in Table X. . The unique feature is that the cropping patterns are totally Aman dependent especially transplanted (T) Aman (Plate 5), whereas the Boro and Aus rice are of sporadic in occurrence. Some farmers cultivate only T Aman extended from August to November using upstream water flow due to monsoon flush when the salinity effects are moderate to mild, whereas the land remains fallow for rest of the year. Some farmers grow vegetables, potato, sweet potato, soybean, water melon, groundnut and pulses as Khesari, Mungbean or Cowpea after harvest of T Aman (i.e., in Boro season). In Boro season (December-May), the land-use pattern in Barisal Division is characterized by bare/fallow condition, Khulna with shrimp cultivation. Most of the coastal people grow crops especially rice with local cultivars .However, some progressive farmers use HYV but the use of salt-tolerant cultivars is scantly. People also use local varieties to produce other crops like wheat, potato, pulses, chilli, oil seeds, vegetables etc.

Table 8: Present land-use patterns in the south-western coastal zone

Division	**Major Cropping Patterns**		
	Aman (Jul-Nov)	**Boro/Rabi (Dec-May)**	**Aus/Kharif (May-Aug)**
Khulna	Shrimp, scattered T Aman, mixed shrimp + T Aman	Shrimp/fallow/ mixed Shrimp + Boro	Shrimp/Aus
Barisal	T Aman, broadcast Aman	Mostly fallow, scattered winter vegetables & pulses	Mostly fallow, scattered Aus

4.4 Crop Production Scenario

The dominant crop grown in the saline areas is local transplanted Aman rice with low yields. Despite of increasing soil salinity rice cultivation is in a satisfactory state at present as a result of some technological adaptation by BARI, DAE etc. Transformation of uncultivable land into cultivable land by reducing salinity, providing fresh irrigation water and stopping entrance of sea water into crop lands for shrimp farming can uplift several tons of rice production per year. But the overall situation may worsen when an extreme climate event arrives as we can see from the following figure. SIDR and Aila reduced rice yield in 2007-2008 and 2009-2010 crop years respectively. Since the intensity and probability of such extreme events are increasing, net agricultural yield might be diminished and even ruined in the coming decades.

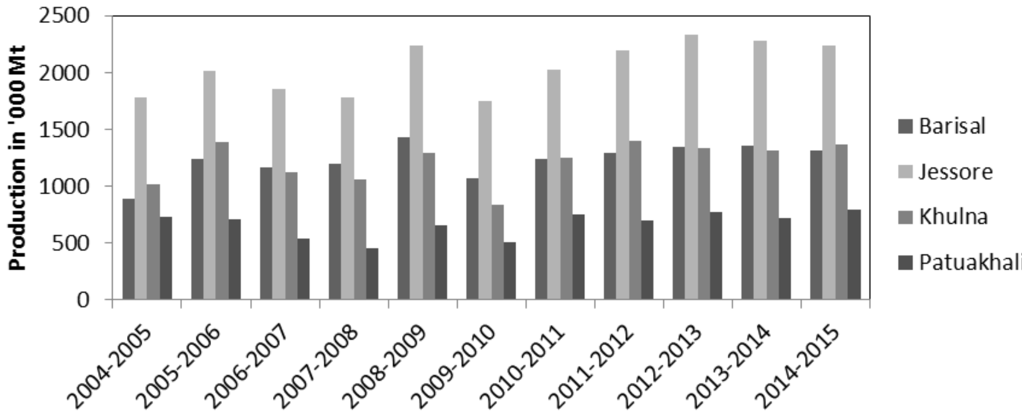

Figure 13: Season wise Rice Production

5. CORRELATIONS OF CROP PRODUCTION AND CLIMATIC PARAMETERS(SPSS ANALYSIS):

		Crop	Temperature	Rainfall	Wind	Humidity
Crop	Pearson Correlation	1	.252	.469	.183	-.045
	Sig. (2-tailed)		.454	.146	.590	.895
	N	11	11	11	11	11
Temperature	Pearson Correlation	.252	1	-.231	.409	.592
	Sig. (2-tailed)	.454		.495	.212	.055
	N	11	11	11	11	11
Rainfall	Pearson Correlation	.469	-.231	1	-.268	-.414
	Sig. (2-tailed)	.146	.495		.426	.206
	N	11	11	11	11	11
Wind	Pearson Correlation	.183	.409	-.268	1	.901**
	Sig. (2-tailed)	.590	.212	.426		.000
	N	11	11	11	11	11
Humidity	Pearson Correlation	-.045	.592	-.414	.901**	1
	Sig. (2-tailed)	.895	.055	.206	.000	
	N	11	11	11	11	11

The correlation between crop production and climatic parameters is entirely done by SPSS. From the tabular value, it can be seen that crop production is mostly influenced by rainfall variation. Temperature rise in last several years is also correlated to crop production scenarios. Further change in wind speed from last few decades also influence the production of crop. It also can be noticed that Relative Humiditywhich has increased significantly does not influence crop production mostly, in table it's correlation between crop production is found negative.

6. KEY FINDINGS

The predominant crop in coastal belt is Aman rice especially transplanted Aman with sporadic occurrences of Aus, and some pulses, vegetables, groundnut etc. in Boroseason and there remains vast scope for expansion and boosting production of new crops. Crop cultivation is seriously hampered in dry season due to either lack of water or presence of salinity either in surface water or in soil. Therefore, vast areas of land remain fallow in Boro season. But the research and extension approaches to bring this vast land area under alternate cropping patterns/crops are inadequate.

7. POLICY IMPLICATIONS AND RECOMMENDATIONS

1) Advancing the present cropping patterns in both Boro and Aman seasons by a fortnight should go a long way in avoiding the coastal cyclones and will mean a good harvest of rice, the main cereal of the country;
2) Introduction of salt-tolerant crops of Boro, wheat and maize will contribute to additional production of food grains and boost food security;
3) Development of submergence tolerant rice varieties capable of thriving tidal surges/floods should be an alternative option for food security;
4) Construction of embankment with extended mild slopes along the coastal land masses will slowed down the fury of tidal waves and surges; thus saving the crops, lives and properties of coastal inhabitants.

8. CONCLUSIONS

Evidences are indicative that the global warming has already set in as a result of increased concentration of greenhouses gases in the atmosphere. In addition to formation of cyclones and other potential changes global warming will lead to about 32 cm rise in sea-level by the middle of the current century? The inequitable, varied and unpredictable effects of global warming and sea-level rising should have devastating consequences on coastal agriculture. The coastal zone at present is a mono-cropped area predominantly occupied by Aman in the Wet season, mostly fallow or sporadic Boro, pulses, vegetables and other crops in the rest of the year. Tropical cyclones that form in the Bay of Bengal lashes Bangladesh coast twice in a year, the most severe ones occurring in late October to mid-November and late April to May. Both periods coincide with the harvesting (maturity) time of major cereals i.e. Aman and Boro, respectively. Therefore, to mitigate ill effects of global warming and ensuring additional crop production for food security the policy makers, researchers, extension workers, GOs and NGOs should set urgent priority to advance the harvesting of the Aman and Boro crops by a fortnight, introduce Boro and other cereals and vegetables in the dry season. If succeeded, the above practices not only ensure the food security but will turn the entire area into a food surplus zone.

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