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Analyzing the effect of Climate Change on Agriculture and Food Security: Evidence from Southern Coastal Region in Bangladesh

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Abstract
Bangladesh is one of the most vulnerable countries in the world for various types of natural disasters because of geographic location and its coastal areas are most vulnerable. The climate in Bangladesh is changing and it is becoming more unpredictable year by year. This research attempts to quantify the climate change impact on socio-economic parameters, agricultural production and food security in the coastal belt of Koyra Upuzila, Bangladesh. This research also assesses the impact of climate change on their livelihoods and recommends policy guidelines to ensure sustainable livelihood in the study area. The study area was conducted in the southern coastal belt of Bangladesh. In order to get a view of the nature of the study area, a reconnaissance survey was conducted. In five extreme disaster affected unions of koyra upuzila namely Dakshin Bedakashi Union, Uttar Bedakashi Union, Moharajpur Union, Maheshwaripur Union and Bagali Union and 30 respondents have been taken randomly as sample size at each union. After the union selection, respondents were then selected at the rate of following simple random method. The study followed three data collection tools for triangulation purposes. There were focus group discussion, in-depth interviews with key informants and observations. According to the view respondents from these three factors account for 26% responsibility, here most of the responsible for lowering down of food production are improper rain and delayed rain whose percentage is 42.7, which is the greatest percentage for this cause. In the field of genetically modified organism here 60.7 percentage people could not get and 39.3 percentage people got this strategy to ensure food security. Here maximum people in this area also did not get salt tolerant rice varieties where percentage is 84 to ensure this food security. The housing condition of the lower income declines people is vulnerable and they cannot save their assets during cyclone period and moreover there is not adequate cyclone center in the study area to save the lives and asset of the people.

Keywords: *Natural Disasters, Climate Change, Food Security, Socio-economic, Vulnerable People*

1.1 Introduction

The study area is situated in the coastal belt of Bangladesh and frequently faces different types of disaster. These disasters include cyclone and tidal surge, flood, heavy rainfall and water logging, draught, river bank erosion etc. Recently the area faced a devastating disaster Sidr in 2007 and Aila in 2009, which affected the upazila severely. Climate change is the worst impediment proved in the

recent periods to development and poverty reduction as it affects the poor most and pushed them into the class of the poorest and most vulnerable regions of the world. Climate change is real, and its first impacts are already being felt. It will first affect the people and food systems that are already vulnerable, but over time the geographic distribution of risk and vulnerability is likely to shift. Certain livelihood groups need immediate support, but everybody is at risk (IPCC, 2007). Climate change is emerging as a major threat to food security, and governments need to find *"creative solutions"* and *"alternative approaches"* in order to deal with the challenge, according to the Food and Agriculture Organization of the United Nations (FAO, 2007). Inter-Governmental Panel on Climate Change expressed the Fourth Assessment Report states that the intensity and frequency of both flood and cyclone will increase in future (IPCC, 2007). The coastal people of Bangladesh notice the disastrous impacts of climate change on agricultural production, livelihood patterns, and human system. Climate change is realized as the greatest threat to the living beings on the earth affecting widely from tropical to arctic regions and from sea to land and atmosphere, Unnayan Onneshan (2009). Food insecurity is more of a demand concern, affecting the poor's access to food, than a supply concern, affecting availability of food at the national level (Amartya Sen's, 1981). The devastating cyclone Aila and Sidr struck the south-western coastal region of Bangladesh and the worst affected upazilas of khulna district are Koyra, Dacope, Paikgacha and Batiaghta, (Unnayan Onneshan, 2009). The last few decades of scientific research and inquiry have revealed an increase in global temperatures and a shift in global precipitation patterns (Parry, 2010)**.**

2.1 Objectives

a) To quantify the vulnerability regarding socio- economic parameters, agricultural production and food security in the designated coastal areas of Bangladesh.
b) To assess the impact of climate change on their livelihoods, food consumption status, socio-economic inequalities and recommend policy guidelines to ensure sustainable livelihoods in the study area.

3.1 Literature Review

The vulnerability of Bangladesh to climate change is the result of a complex interrelationship among biophysical, social, economic and technological characteristics of the country (Ali 1999). Ahmed and Alam (1998) reports temperature will rise from 1.3^0C and 2.6^0C by the year 2030 and 2075 and rainfall will increase in dry seasons. Ali et al., (1996) reports that certainly that cyclone intensity (wind speed) and its frequent attacks increases to the coast due to sea surface temperature (SST) increase. World Bank (2000) reports the severe cyclonic storms, generating long wave tidal surges frequently hits coastal belts of Bangladesh as this country is located at the angle of northern Indian Ocean and at the coastline of the Bay of Bengal. In previous year, climate change was a non-representational occurrence, now it has turned into a tangible reality. Between 2000 and 2019, Bangladesh experienced 185 natural disasters, ranking 9th in the climate risk index in 2017 and advancing to the 7th position in the long-term climate risk index by 2019. (Eckstein et al. 2019, 2021). In Bangladesh, the most fatal natural disasters are cyclones and floods. During the period from 1965 to 2020, more than 12 major cyclones and hundreds of minor cyclones hit Bangladesh and caused around 500,000 deaths. (Hossain et al. 2020). Ahmed (2006) has identified rainfall floods, flash floods, river floods, and the tidal and surge flood and divided them in four major types of floods in this country among which river flood is of the greatest concern to the people. Nearly every year, some part of the country experiences flooding (Rahman et al. 2017). Among 162 counties of human exposure to flood hazard zones Bangladesh is at the top of those countries. (Hassan, 2016).

IPCC (2007) expressed the Fourth Assessment Report states that the intensity and frequency of both flood and cyclone will increase in future. So, these two climatic shocks are a major challenge for Bangladesh in implementing PRSP. Climate Change Cell (2008) reports that in the last ten years, the people of coastal belt experiences huge damages and losses due to climatic extremes like flood, cyclone and drought. Sea level rise because of rapid global warming in the coming decades will push over 25 million people to become climate refugees in Bangladesh alone. Previously in Bangladesh thunderstorms were not considered dangerous calamities but in recent years it is dangerous Bangladesh faces around one-fourth of worldwide deaths are caused by them (Farukh et al. 2017). Haque (2009) clearly shows the direct relationship between disaster and income inequality. Through income inequality index Gini and however, a significant change of income due to disaster is clear. Again, the difference between equity line and Lorenz Curve is increasing due to disaster which also tells that disaster increases the Income Inequality. Roy. K, Rahman. M and Kumar, u (2009) confirmed that in order to meet the growing demand of food grains in Bangladesh beyond 2015 there is an urgent need to expand area of irrigation and increase its efficiency. Hasan, S. J. Masum and Hasan, M.M (1999) demonstrated that climate change will have a massive impact on food production and may jeopardize food security in many regions. The adverse effect and impacts of climate change vary from person to person. For those who are affected, their perception, and adapting strategies change over time (Uddin 2022).

4.1 Methodology

The study area was conducted in the southern coastal belt of Bangladesh. One of the significant coastal cyclone prone areas of Bangladesh is Koyra Upzilla and it has been selected for this study. The data collection process started during the period from June 2023 to September 2023. In order to get a view of the nature of the study area, a reconnaissance survey was conducted. It helped to prepare a perfect questionnaire for the study and to finalize the sample size. A clear and structured questionnaire is prepared to collect the needed information. For this purpose, a questionnaire has also prepared for the present study. It is not possible to taking account all the population of the study area for this research. In this context, a part of the population has taken into consideration. In five extreme disaster affected unions of koyra upuzila namely Dakshin Bedakashi Union, Uttar Bedakashi Union, Moharajpur Union, Maheshwaripur Union and Bagali Union and 30 respondents have been taken randomly as sample size at each union. After the union selection, respondent were then selected at the rate of following simple random method. The study followed three data collection tools for triangulation purposes. These were focus group discussion, in-depth interviews with key informants and observations. The focus group discussion were constitute by ward members, Union Parishad Chairman, most affected persons of this are who include both men and women and religious leaders. The household questionnaire was designed in a manner to extract information about socio-economic characteristics of household, level of exposure to risks, the level of experience they had on the catastrophic impact of last disaster on their livelihoods and how they cope with the disaster. Systematic random sampling was used to select individual households. Questionnaires exploring how livelihoods had been impacted and how communities were adapting to climate change based on available information in the dataset, we used several indicators to assess the impact of climate change on their livelihoods.

5.1 Results and Analysis

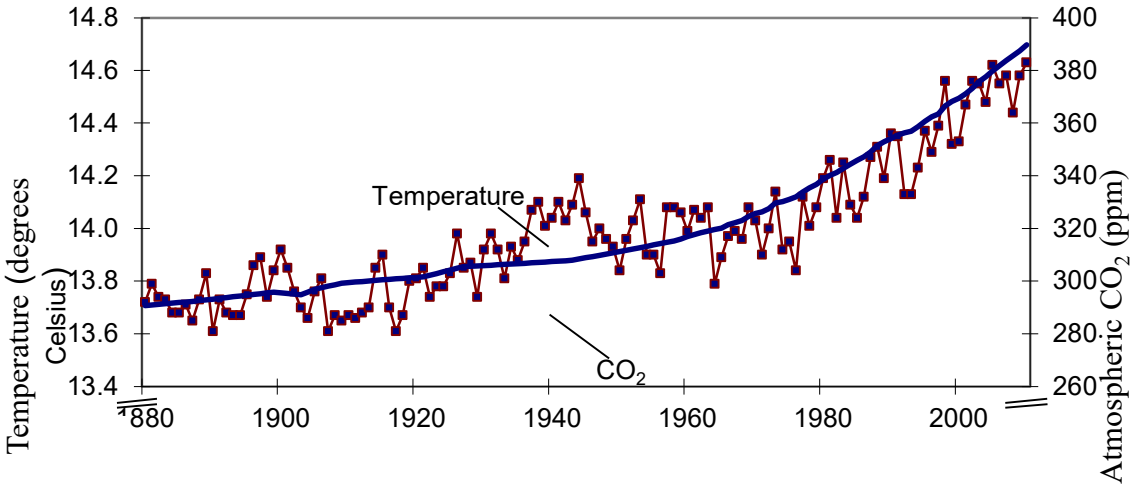
Table: 01: World Carbon Dioxide Emissions from Fossil Fuel Combustion in 2006 and 2008, with IEA Projection for 2020

Emissions	**Growth Rate, 2006-2015**	**Growth Rate, 2015-2020**	**CO_2 Emissions, 2006**	**CO_2 Emissions, 2008**	**CO_2 Emissions, 2020**
	Percent		Million Tons Carbon		
By Fuel:					
Coal	3.1	1.6	3,185	3,431	4,555
Oil	1.3	0.9	2,937	2,947	3,454
Gas	2.0	1.5	1,484	1,602	1,918
By Sector:					
Power Generation	2.9	1.6	3,119	3,250	4,365
Coal	3.2	1.7	2,273	2,365	3,300
Oil	-0.4	-1.9	241	236	211
Gas	2.8	2.0	605	650	853
Total Final Consumption	1.7	1.1	4,123	4,323	5,090
Coal	2.7	1.1	855	990	1,150
Oil	1.5	1.2	2,515	2,527	3,033
Transport Sector	1.7	1.3	1,708	1,746	2,126
Marine Bunkers Sector	1.0	1.0	159	158	326
International Aviation Sector	2.2	1.8	108	124	145
Gas	1.4	1.2	754	807	907
Other Energy Sector			364	406	472
Total CO_2 Emissions	2.2	1.4	7,606	7,980	9,927

Source: Earth Policy Institute, 2018

From a glance on the above table, it can be observed that the amount of generation of CO_2 around the world is increasing alarmingly due to enhanced activities of various sectors. This alarming increment of CO_2 in the past years is supposed to be increased at still higher rate in near future in the near future also.

Fig. 01: Average Global Temperature and Atmospheric Carbon Dioxide Concentration, 1880-2010



Source: Earth Policy Institute, 2018

It is evident from the graph that rate of emission of CO_2 and rise in temperature are almost concurrent. Moreover, they both have rising trend over the past several decades. If this trend persists, then, it is likely that people will find them in a much hotter world in the future. As the graph shows that when temperature changes from 13.7 to 14.7°C, atmospheric CO_2 emission changes from 290 to 390 ppm. At present both the rates of change are very first.

Table: 02: Projected Global Warming and Rainfall Scenarios in Bangladesh

Year	Sea Level Rise (CM)	Temperature Increase (°C)			Rainfall Fluctuation Compare to 1990 (%)	
		Monsoon	Winter	Annual	Monsoon	Winter
2030	14	+0.8	+1.1	+1.0	+6	-2
2050	32	+1.1	+1.6	+1.4	+8	-5
2100	88	+1.9	+2.7	+2.4	+12	-10

Source : Yusuf H.K.et. al, 2008

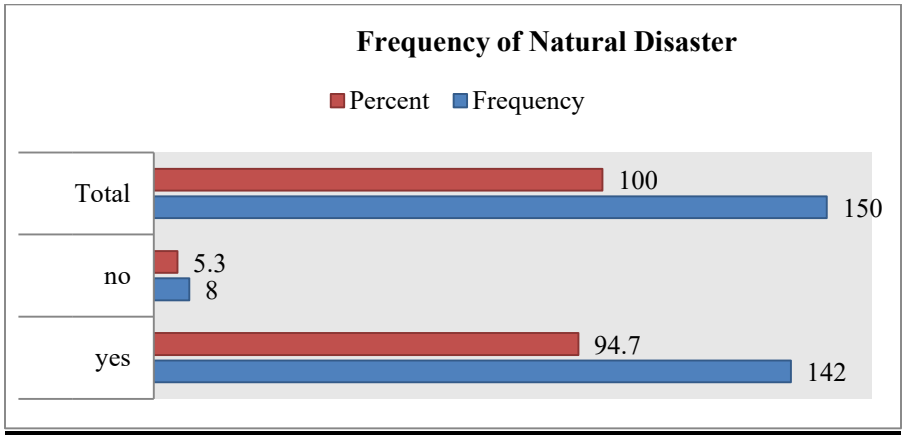
In the above table shows the variation of climate in near future where temperature rises, sea level rises, and fluctuation of seasonal rainfall. There is growing need to qualify the effects of rising temperature on yield of crops in different agro-ecologies and agro-production environments. Similarly, various climate change scenarios need to be evaluated for these regions and the specific adoption strategies be evolved.

Table: 03: Effects of 1 to 5 Meters Sea Level Rise on Population and Land Area around the World

Region	Sea Level Rise	Population Directly Affected		Area Inundated		Urban Area Inundated		Agricultural Area Inundated	
	Meters	Millions	Percent	Square Kilometers	Percent	Square Kilometers	Percent	Square Kilometers	Percent
Latin America & Caribbean	1	2.9	0.6	64,632	0.3	3,080	0.6	16,104	0.3
	2	4.7	0.9	101,76	0.5	5,212	1.0	29,514	0.6
	3	7.2	1.5	149,13	0.8	8,090	1.6	47,003	1.0
	4	10.3	2.1	193,76	1.0	11,614	2.3	66,330	1.4
	5	13.5	2.7	234,17	1.2	15,294	3.0	85,959	1.8
Middle East and North Africa	1	8.3	3.2	24,654	0.3	3,679	1.9	4,086	1.2
	2	10.9	4.2	33,864	0.3	5,037	2.7	6,031	1.7
	3	13.7	5.3	43,727	0.4	6,529	3.4	8,007	2.3
	4	16.5	6.3	53,615	0.5	7,951	4.2	9,819	2.8
	5	19.4	7.5	63,120	0.6	9,384	4.9	11,451	3.2
Sub-Saharan Africa	1	2.1	0.5	18,641	0.1	430	0.4	1,646	0.0
	2	3.7	0.8	28,083	0.2	742	0.7	3,404	0.1
	3	4.3	0.9	42,645	0.3	1,268	1.2	6,595	0.2
	4	8.5	1.8	59,661	0.4	1,853	1.7	11,231	0.3
	5	11.0	2.4	77,253	0.5	2,449	2.2	16,145	0.4
East Asia	1	37.2	2.0	74,020	0.5	6,648	1.7	45,393	0.8
	2	60.2	3.2	119,370	0.8	11,127	2.9	78,347	1.4
	3	90.0	4.8	178,177	1.3	17,596	4.5	121,728	2.2
	4	126.2	6.7	248,970	1.8	25,725	6.6	174,076	3.2
	5	162.4	8.6	325,089	2.3	34,896	9.0	229,185	4.2
South Asia	1	5.9	0.5	12,362	0.3	809	0.3	3,442	0.1
	2	10.2	0.8	21,983	0.5	1,379	0.6	6,951	0.2
	3	17.8	1.4	35,696	0.9	2,311	1.0	13,501	0.5
	4	22.1	1.7	52,207	1.2	3,599	1.5	23,716	0.8
	5	39.5	3.0	69,225	1.7	5,117	2.1	35,190	1.2
World	1	56.3	1.3	194,309	0.3	14,646	1.0	70,671	0.4
	2	89.6	2.0	305,036	0.5	23,497	1.6	124,247	0.7
	3	133.0	3.0	449,428	0.7	35,794	2.5	196,834	1.1
	4	183.5	4.2	608,239	1.0	50,742	3.5	285,172	1.6
	5	245.9	5.6	768,804	1.2	67,140	4.7	377,930	2.1

Source: Earth Policy Institute, 2018

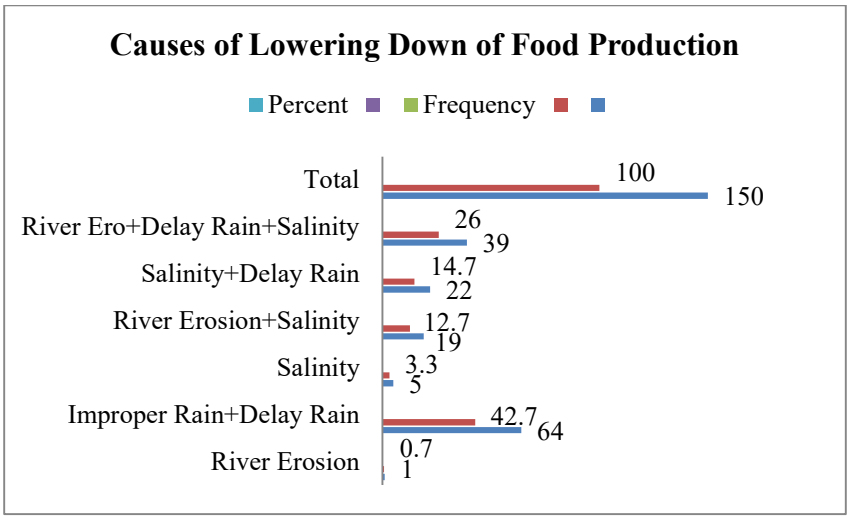
Fig.: 02: Knowledge about Frequency of Natural Disaster of the Respondents



Source: Authors' Compilation based on field survey, 2023

Above figure shows the percentage about having climate change and frequency of natural disaster. At present they are facing the consequence of climate change and frequency of natural disaster is increasing gradually. Figure shows among the respondents 94.7 reported that frequency of natural disaster has increased than before and only 5.3 percent think that there is no change in climate.

Fig.: 03: Lowering Down of Food Production by Causes

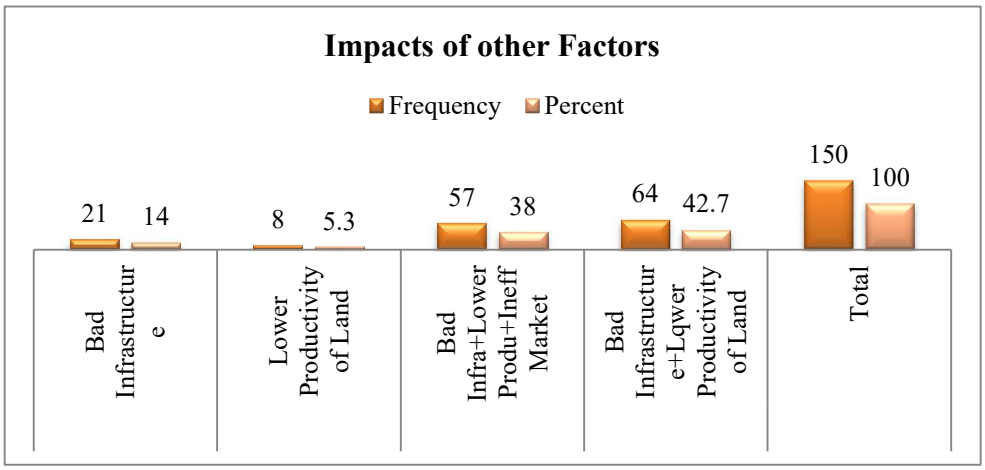


Source: Authors' Compilation based on field survey, 2023

Above figure shows factors which are responsible for lowering down of food production. Southern region climate suffers river erosion, delayed rain and salinity. According to the view respondents from these three factors account for 26% responsibility, here most of the responsible for lowering

down of food production are improper rain and delayed rain whose percentage is 42.7, which is the greatest percentage for this cause.

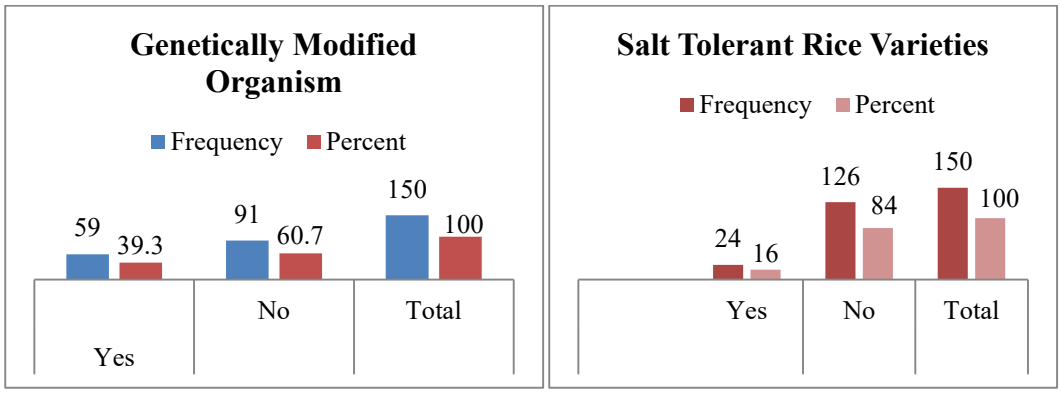
Fig.: 04: Impact of Other Factors to Hamper Food Security

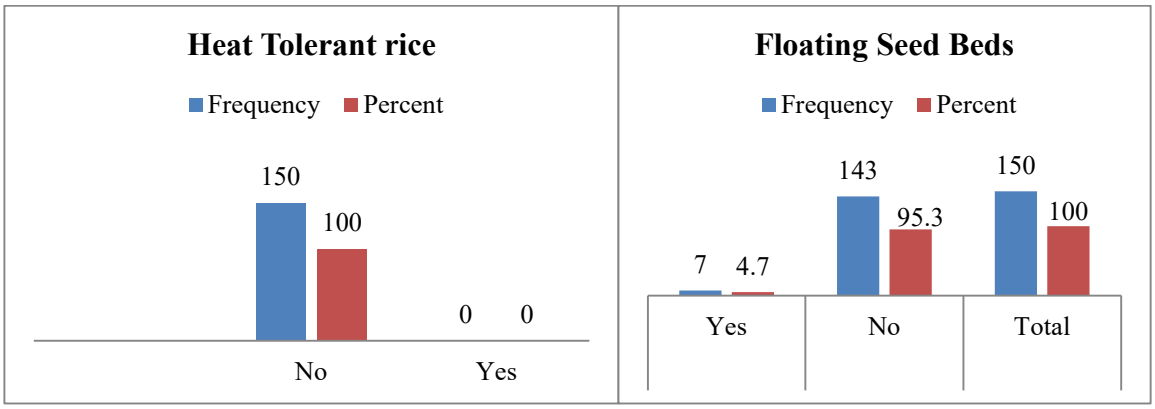


Source: Authors' Compilation based on field survey, 2023

This above figure shows that various reasons to hamper the food security, bad infrastructure is 14% responsible for this insecurity of food, also lower productivity of land is 5.3 % and both bad infrastructure and lower productivity of land is 38% responsible to hamper the food security.

Fig.: 05: Adaptation Strategy by Type





Source: Authors' Compilation based on field survey, 2023

The above four figures show various types of adaptation strategy aiming at ensuring food security. In the field of genetically modified organism here 60.7 percentage people could not get and 39.3 percentage people got this strategy to ensure food security. Here maximum people in this area also did not get salt tolerant rice varieties where percentage is 84 to ensure this food security. To ensure the food security the heat tolerant rice strategy did not got the people in the area. In this area 95 percent people did not get floating seed beds to ensure the food security and only 4.7 percentage people got this strategy.

5.1 Barrier Factors Obstacle in Rice Production

There are a variety of barrier factors that creates the obstacles to produce rice in the south west region of Bangladesh. These barrier factors are (a) Delayed rain, (b) cyclone, (c) floods, (d) excessive rainfall, (e) salinity (f) water logging, (g) river bank erosion and (h) others.

Table: 04: Descriptive Statistics

Name of Factors	Mean	Std. Deviation	Analysis N
Delayed rain	1.04	.197	150
Cyclone	1.53	.501	150
Floods	2.25	.463	150
Excessive rainfall	2.43	.523	150
Salinity	1.01	.115	150
Water logging	2.53	.631	150
River bank erosion	1.13	.482	150
Others	1.51	.865	150

Source: Author's Compilation based on field survey, 2023
Note: Mean and Standard deviation are based on a 4-point scale where 1= frequently , 2= occasionally, 3= rarely, 4= not at all

Descriptive statistics of 8 factors are given in the table no. 00. Salinity has got the lowest mean value of 1.01 and its S.D. is .115. This implies the fact that most of the respondents believe that this factor has high effects on lower production because it occurs frequently. On the other hand, water logging has got comparatively higher mean value of 2.53 and its S.D. is 0.631.

Table: 05: Correlation Matrix

	Delayed Rain	Cyclone	Floods	Excessive rainfall	Salinity	Water logging	River bank erosion	Others
Correlation coefficient	1.00	.191	-.035	.094	.273	.043	.017	-.082
	.191	1.00	.153	-.029	.109	-.099	-.115	-.141
	-.035	.153	1.00	.034	.064	.006	.009	-.151
	.094	-.029	.034	1.00	.016	.242	.104	.225
	.273	.109	.064	.016	1.00	.086	-.031	-.069
	.043	-.099	.006	.242	.086	1.00	.350	.048
	.017	-.115	.009	.104	-.031	.350	1.00	.181
	-.082	-.141	-.151	.225	-.069	.048	.181	1.00

Source: Authors' Compilation based on field survey, 2023
a. Determinant = 0.595
In the above table shows the correlation matrix analysis of the factors to identify the inter-correlation among the variables themselves. The table reveals that the chosen variables are highly correlated to each other.

Table: 06: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.523
Bartlett's Test of Sphericity	Approx. Chi-Square	75.424
	df	28
	Sig.	.000

Source: Authors' Compilation based on field survey, 2023
KMO is the sampling adequacy and Bartlett's test of sphericity. The KMO statistics varies between 0 and 1. Value close to 0 means factor analysis likely to be inappropriate and 1 means appropriate. A value close to 1 indicates that the patterns of correlations are relatively compact and so factor analysis should yield distinct and reliable factors. Value lies between 0.5 to 0.7 means mediocre, Value lies between 0 .7 to 0 .8 means good, Value lies between 0 .8 to 0.9 means great and Value lies above 0 .9 means superb. In this case it is 0.523 so it is mediocre.

5.2 Explain the Model and Shows the Relationship between Climate Change and Poverty
Results from OLS regression models to identify the magnitudes of the relationship between poverty and socio-economic parameters are shown in table:

Table 07: OLS Regression Model

Poverty gap index	**Co efficient**	**p> I t I**
Total house hold member	155.4355	0.105
Per head consumption	-0.480637*	0.000
Dependent on family head	353.102	0.588
Per head income	.0234839	0.436
constant	8812.992*	0.000

*Significant at 5% level

The tables shows that total house hold member, per head consumption expenditure, number poor house hold member living below the poverty line are significant independent variable of which per head consumption expenditure is the most significant independent variable. Per head consumption expenditure is inversely related with poverty gap index. Climate change affects mostly the livelihood option of the rural people and reduces house hold income level, thus it squeezes the house hold consumption expenditure. That means climate change influences to the consumption expenditure inversely. The model shows that 1 unit reduction in house hold consumption change in will significantly lead to increase in the 48 % poverty gap. Thus, it can be concluded that climate change will negatively impact on poverty.

6.1 Findings and Recommendations

Rural communities of koyra upuzila, whose livelihoods are intimately tied to the environment, are profoundly affected by the climate. Climate change will have a significant impact on rural poor especially in the coastal koyra upuzila of Bangladesh. The impacts will force thoughtful lifestyle changes and destroy livelihoods. Communities are not made aware of climate change and supported in finding ways to adjust. Most of the people of the study area depends on agriculture and for the climate change it hampers the agricultural activities and lost their interest to continue their occupation. The impact of climate change on agriculture is therefore likely to lead to a loss of stability in productivity and an overall decline in food production in southern region. Low purchasing power and production loss during disasters leads to the inequality of the food distribution in study area. The changes in livelihood patterns put pressure on non-agriculture sector and study finds that any changes in income earned from this sector inversely affect poverty in the study area. On the other hand, adaptive policies GO and NGO's help might to reduce the food consumption inequality. Policy makers from all sectors urgently need to focus attention on the implications of climate change. Support for adaptation to the impacts must start now. Many aspects of climate change and variability are already having a profound effect on the livelihoods of poor rural communities and enough is known about the future impacts of climate change for action to be taken now. Finally, the vulnerability of the poorest to climate change is a central challenge in the coastal upuzila of Koyra.

7.1 Conclusion

Vulnerability of Bangladesh to climate change is well recognized due to its higher level of exposure to both the gradual change phenomenon and extreme events, and due to lack of institutional and financial capacity to deal with climate change related problems as well. Changes in the climatic system and its associated adverse impacts are already visible. Changes in the duration of seasons, i.e. lengthening of the summer season and shortening of the winter season, shifting of season; increase in the frequency of hazards; changes in the rainfall pattern etc. are major indicators of climate change in Bangladesh. The relationship between climate change adverse impacts and poverty is multi-dimensional and complex. For better understanding the complex relationship needs longitudinal disaggregated poverty database along with different streams of income of a household and their assets. The relationship between adverse impacts of climate change and income inequality is complex as well. It has been revealed that during and immediately after a disaster. The damage of disasters is enormous as well as hard to estimate.

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