Climate Change and Rice Yield in Bangladesh: A Micro Regional Analysis of Time Series Data

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Abstract- The study examines the trend of three main climatic variables (eg. Temperature, Rainfall and Relative humidity) for Rajshahi, Bangladesh by using the time series data for the 1972-2010 period and assesses the relationship between the variables and the yield of three major rice crops (eg. *Aus*, *Aman* and *Boro*). The results of Ordinary Least Squares (OLS) reveal the significant effects of climatic variables on rice yields and these effects vary among the three rice crops. Increase in Temperature and Relative humidity and decrease in Rainfall have both positive and negative effects on the yield. The three climatic variables can explain 23, 91 and 89% of the variance in *Aus, Aman* and *Boro* production. The study also evaluates the local knowledge and resource based adaptation techniques adopted by the farmers. Different coping mechanisms like change in transplantation time, cropping pattern change, digging of ponds, selection of short duration species etc are being adopted to minimize the impacts of climatic variations on rice production. Necessity and development of temperature tolerant *Aman* and *Boro* rice varieties and farmer's adaptive strategies are prominent.

Index Terms: Climate change, Climatic variation, Rice yield, Adaption and Bangladesh.

I. INTRODUCTION

Climate is considered as the major controlling factor of life on earth which is continuously changing due to natural forces as well as anthropogenic activities like land use changes and emission of greenhouse gases and aerosols. Atmospheric temperature, rainfall, humidity, solar radiation etc. are dominant climatic factors closely linked with agricultural production that forms the economic base of underdeveloped Bangladesh which is considered as the most vulnerable country facing climate change (Basak, 2011). Agricultural production in Bangladesh is always vulnerable to unfavorable weather events and climatic conditions. Modern technological developments such as improved crop varieties and irrigation systems attempt to change the scenario but still weather and climate are important factors to play a significant role to agricultural productivity. The impacts of climate change on food production are major environmental concerns of this agriculture dominated economy. Earth's atmospheric temperature has been in an increasing trend since the 1980s and the average surface temperature has increased by about 0.15 to 0.2 °C in the last 100 years (Mendelshon, 2007). With the potential increase in temperature, rainfall has already become variable and unpredictable and the extreme climatic events (eg. Floods, droughts, heat waves and cyclones) are frequent. Bangladesh faces an increase in average day temperature for the last three decades and the number of days without rain is also increasing which results in an uneven distribution of rain and extreme events like flood and drought (Sarker et al., 2012). This climatic variability has adverse effects on paddy rice and it is the most important dietary component of Bangladeshi people.

Rice is the dominant agricultural product of Bangladesh which covers about 80% of the total cropped area and accounts for more than 90% of total grain production (Asaduzzaman et al., 2010). The agro economic contribution is 20% of the Gross Domestic Product (GDP) and almost 66% of the labour force depends on agriculture for employment (GOB, 2010). Agricultural sector of this country is already under pressure with the continuously changing climate, land and water resource depletion and faces challenges in providing food security to its increasing population. Dependency of livelihood on agriculture reveals the necessity of assessing the climate change effects on rice production to ensure food security and economic development. Therefore, the objective of this study is to assess the empirical relationship between three climatic variables and rice yields of three crops using time series data over the period from 1972-2010 for Rajshahi District of Bangladesh.

II. MATERIAL AND METHODS

Both primary and secondary data were collected to complete the study. Primary data were collected during May to June, 2014. The study area was Tanore Upazila of Rajshahi District of Bangladesh located between 24°29´ and 24°43´ north latitudes and between 88°24´ and 88°38´ east longitudes. It has an area of 295.39 square kilometers lies in Barind tract consists of high terrace and valleys free from seasonal flooding (banglapedia.org). The average annual temperature is 25.7°C and rainfall is about 1407 mm (en.climatic-data.org). River Shiba flows by the eastern side of this region. Four villages of Tanore upazila namely Badhair, Kalma, Kamargaon and Saranjai were selected. Multistage sampling was used to select the said four villages for this observational study. Rajshahi was selected for a handful of reasons. First and foremost, this district of Bangladesh is severely affected by extreme climate events viz., extreme heat waves and cold waves. Furthermore, it is one of the drought prone areas of Bangladesh. A semi-structured questionnaire, in-depth interview, and focus group discussion (FGD) were used to collect information according to the objectives of the research. On the basis of the Kothari, 2006 formula, 200 household (50 from each four villages) is drawn as sample size by random sampling technique from the total 1600 household which is 10% of the total household at 95% confidence level. The climatic data related to rainfall, average temperature and relative humidity were collected from the secondary sources of Bangladesh Meteorological Department, Dhaka for Rajshahi weather station which covers the period of 1972-2010. Rice yield data by variety for the same time period (1972-2010) were obtained from various issues of the Bangladesh Economic Review (GOB, 1991, 2001, 2010).Various climatic data were processed according to the seasonal variation to evaluate the climate variability accurately as much as possible. Average of month of respective data was calculated from the time series data. Then the data were processed for the following three growing seasons (Sarker et al., 2012).

- *Aus Growing Season (March-August):* This season is characterized by high temperature and evaporation of pre monsoon summer with occasional thunderstorms and the intensive rainfall of the early months of monsoon.
- *Aman Growing Season (June-November):* Production of this season is dominated by the regular intensive rainfall of monsoon, highly humid weather and cloudiness.
- *Boro Growing Season (December-may):* This season is depicted as the driest and sunniest period of the year consists of the months of winter and pre monsoon summer.
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According to BRRI (1991), *Aus* rice requires supplementary irrigation during the initial stage of its growing season while *Aman* is almost completely rain-fed rice that grows in the months of monsoon, although it necessitates for supplementary irrigation during planting and sometimes in the flowering stage depending on the availability of rainwater. On the other hand, since *Boro* rice grows in the dry winter and the hot summer, it is thus completely irrigated (Mahmood, 1997).

The trend pattern was evaluated from the equation y=mx+c. where, m implies the rate or trend value per year and least square value R^2 reveals the significance number to fit with the trend.

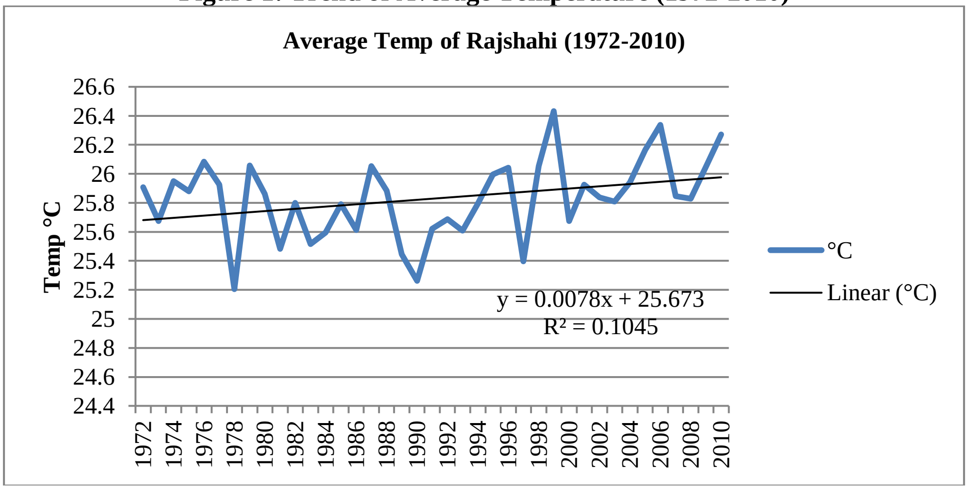
III. RESULT AND DISCUSSION

3.1 Trends of Climatic Variation

3.1.1 Trend of Temperature

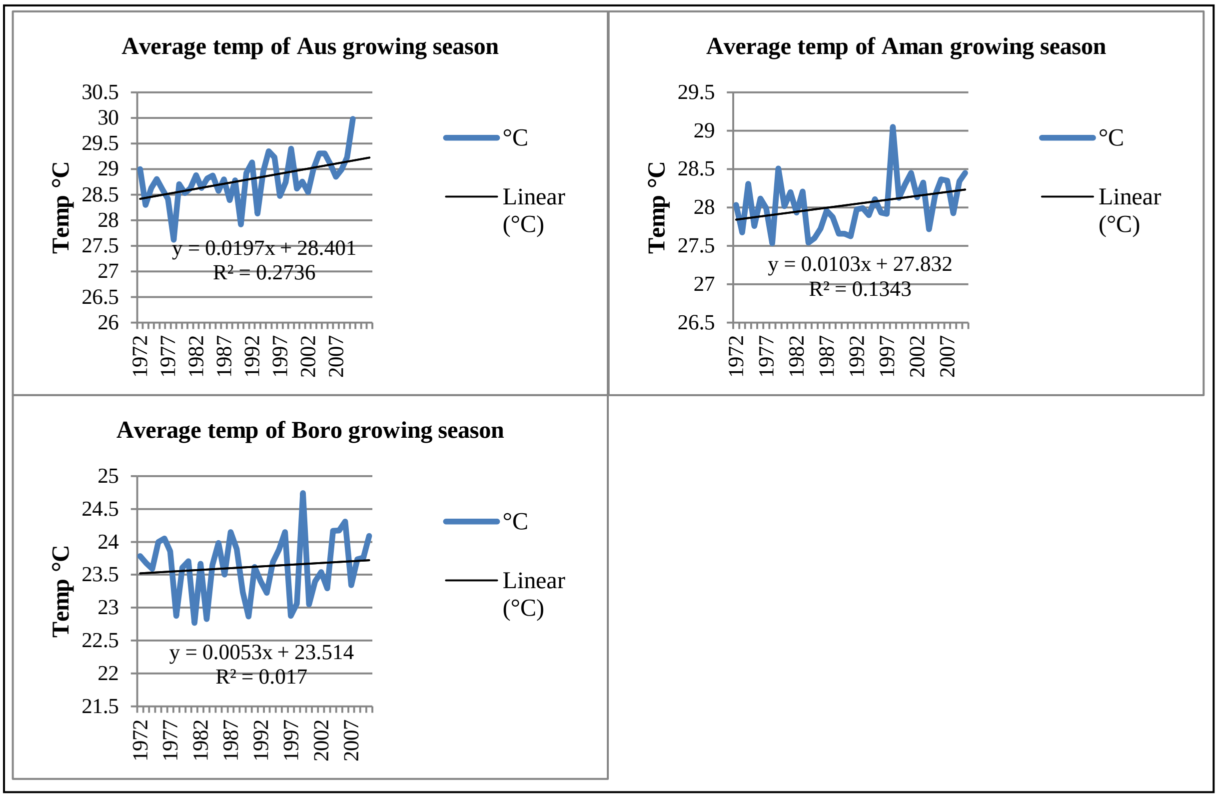
An overall increase in temperature is observed over the period of 1972-2010. The pattern of the temperature trend is irregular (Fig. 1) and the average temperature of this region is increasing at a rate of 0.007°C per year with an R^2 of 0.104.

Figure 1: Trend of Average Temperature (1972-2010)



Positive trend is also observed in the temperature pattern of three rice growing seasons. The trend values of Aus, *Aman* and *Boro* growing seasons are 0.019°C, 0.01°C and 0.005°C per year with respective R^2 values of 0.27, 0.13 and 0.017 (Fig. 2)

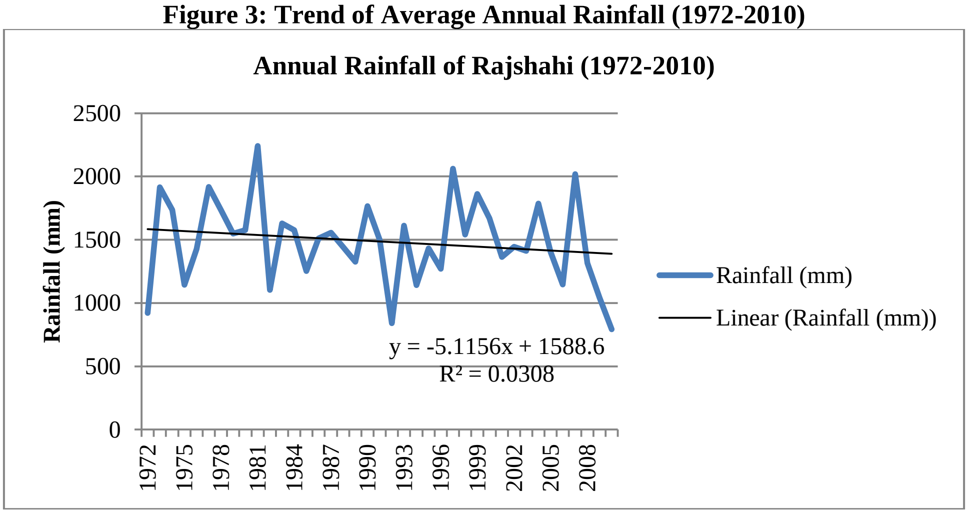
Figure 2: Trend of Average Temperature of the Growing Seasons



3.1.2 Trend of Rainfall

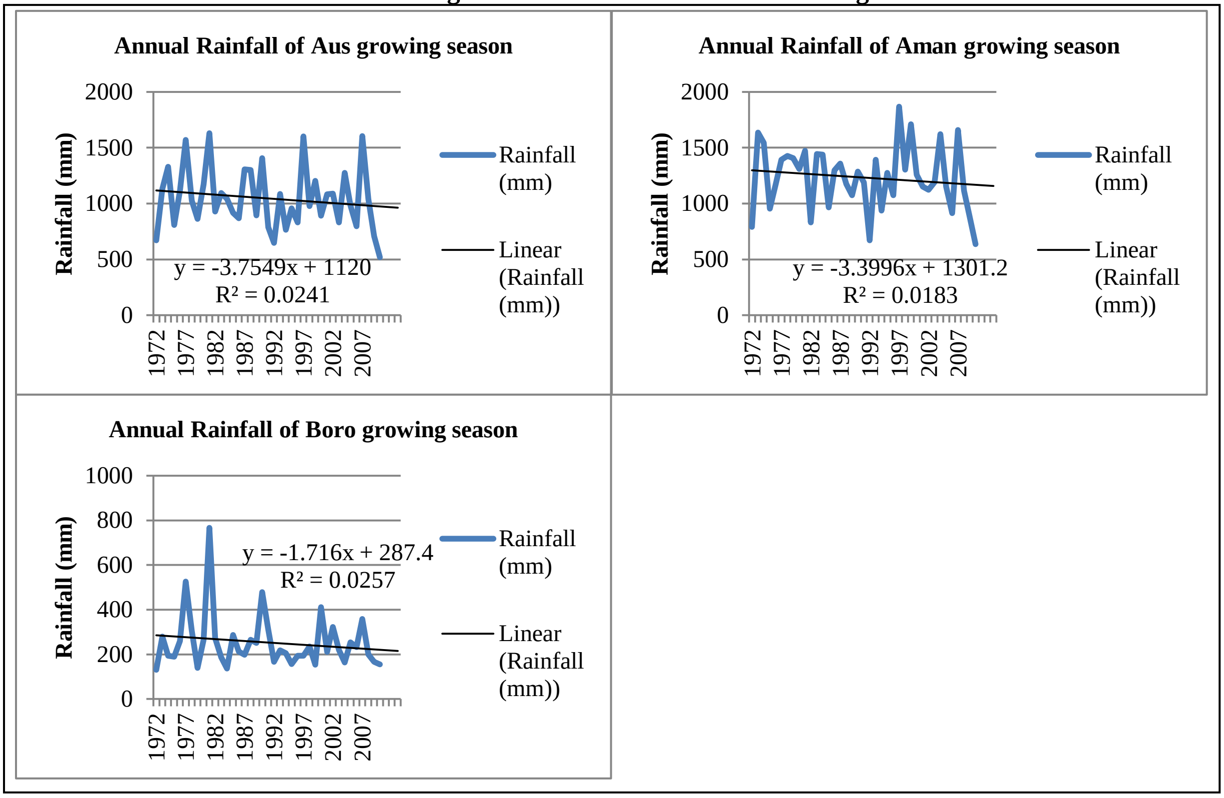
Rajshahi is one of the most drought prone areas of Bangladesh and the rainfall is comparatively lower than any other part of the country. The study finds that it shows a gradually decreasing trend over the period of 1972-2010 at a rate of 5.11 mm per year with an R^2 of 0.03.

Figure 3: Trend of Average Annual Rainfall (1972-2010)



Rainfall pattern of different rice growing seasons is also showing a negative trend. Aus growing season has a decreasing rate of 3.75 mm per year, *Aman* and *Boro* have 3.39 and 1.71 mm per year respectively. Major portion of annual monsoon rain occur in *Aman* growing season but still it is showing a decreasing trend significantly affecting the yield. *Boro* growing season consists of the months of winter and pre monsoon summer. In tropical climate rainfall is apparently low in these two seasons. Variability in rainfall may affect *Boro* production. The R^2 values for these three growing seasons are 0.024, 0.018 and 0.025 respectively.

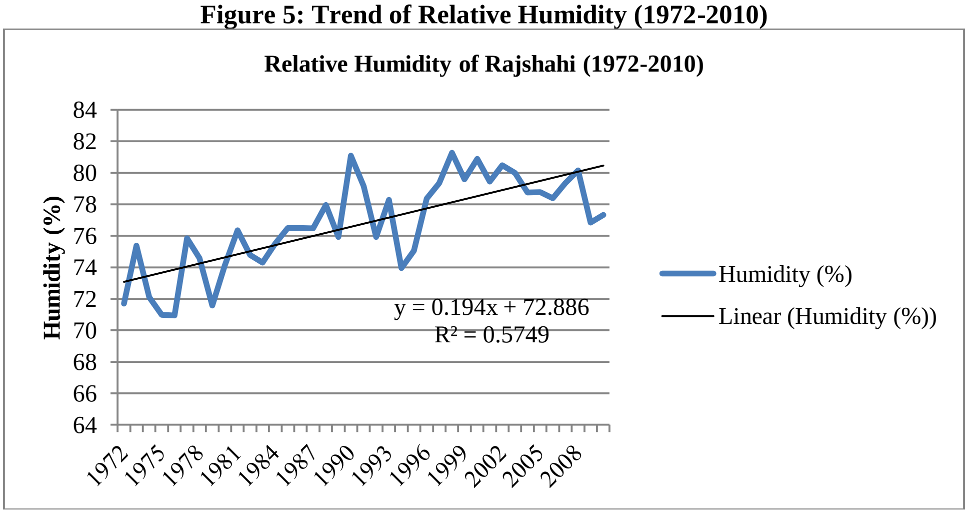
Figure 4: Trend of Rainfall of Growing Seasons



3.1.3 Trend of Relative Humidity

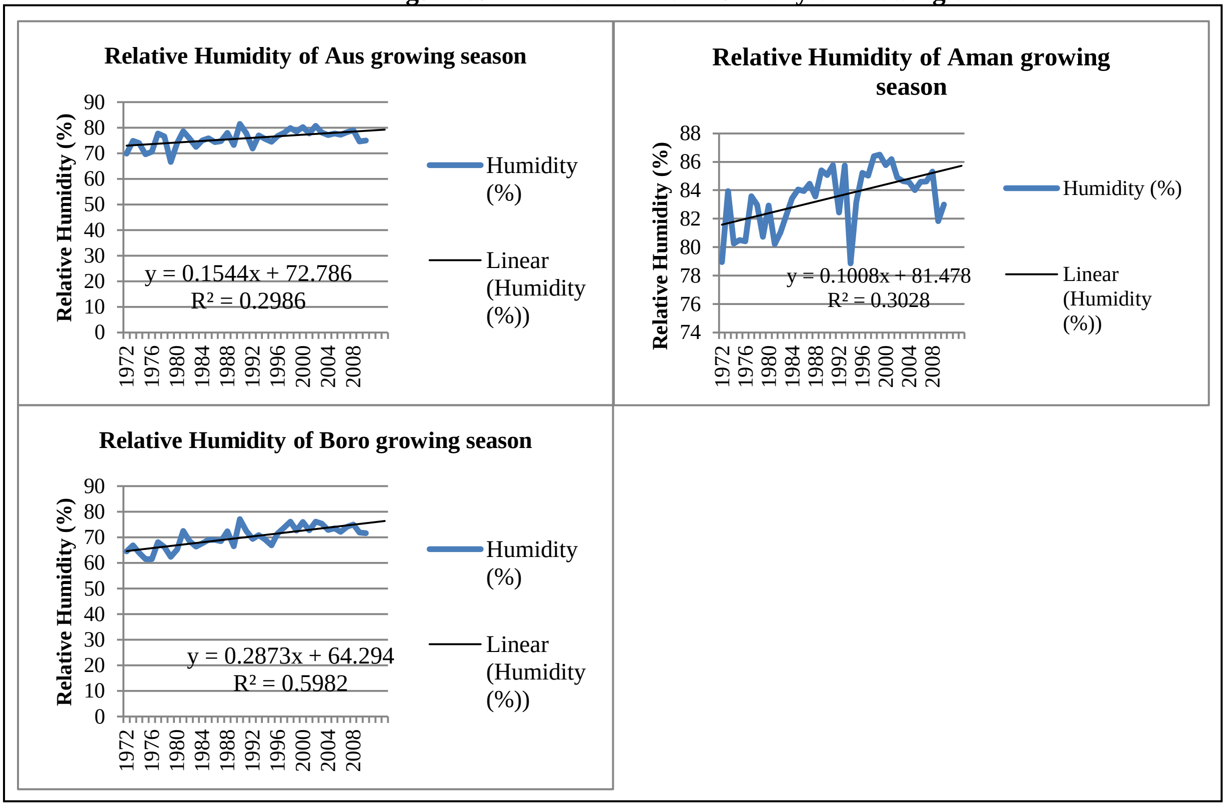
It is observed that the relative humidity of the study area is showing a comparatively higher increasing rate over the period of 1972-2010 with an increasing trend of 0.194% per year and an R^2 of 0.574.

Figure 5: Trend of Relative Humidity (1972-2010)



Three growing seasons show increasing rate of 0.154, 0.100 and 0.287% per year with R2 values of 0.29, 0.30 and 0.59 respectively.

Figure 6: Trend of Relative Humidity of Growing Seasons



3.2 Correlation and Regression Analysis of the Climatic Variable and Crop Yield

3.2.1 Correlation Analysis

The correlation analysis is performed among the climatic variables and crop yield. The results are shows in Table 1.

Table 1: The Correlation Analysis of Climatic Variables and Crop Yield

Crop	Rainfall (mm)	Average Temperature (ºC)	Relative Humidity
Aus	0.252	0.240	0.253
Aman	-0.081	0.313	0.534
Boro	-0.196	-0.204	0.488

Source: Authors' Own Calculation

The correlation analysis exposed the correlation between climatic variables i.e., rainfall, average temperature and relative humidity for the growing periods of crops under study [For *Aus* (March to August), for *Aman* (June to November), for *Boro* (December to May)]. From the table, rainfall is positively correlated with *Aus* (0.252), but negatively correlated with *Aman* (-0.081) and *Boro* (-0.196) which revealed that high rainfall is favorable for the *Aus* production. However, *Aman* is also depends on the monsoon rainfall but extensive rainfall is not required rather regular rainfall is important for the good production of *Aman*. Besides in the winter rainfall is almost not occurring in the selected study area and production is totally depends on supplementary irrigation.

Temperature has a positive weak correlation with *Aus* (0.240) and *Aman* (0.313) whereas a negative correlation with the *Boro* (-0.204). This result indicates that high temperature is negatively affected on the *Boro* production as high temperature increase the demand of water. The relative humidity has positive but weak correlation with the *Aus* (0.253), *Aman* (0.534) and *Boro* (0.488) which indicates that high relative humidity is helpful for the high production of crops as high relative humidity influence the plant development and photosynthesis of the leaves.

3.2.2 Regression Analysis

The regression analysis is also performed between the climatic variables and crop yield. List of variables used in regression model construction are as follows:

Dependent Variable	Independent Variable
Aus Paddy	Rainfall
Aman Paddy	Temperature
Boro Paddy	Relative Humidity

Table 2: Result of Multiple Regression Analysis between Climatic Variables and Crop Yield

Crops	R^2	R^2 (Adjusted)	F Value	P Value
Aus	0.231	0.163	3.409	0.028
Aman	0.912	0.617	8.863	0.000
Boro	0.897	0.752	7.529	0.001

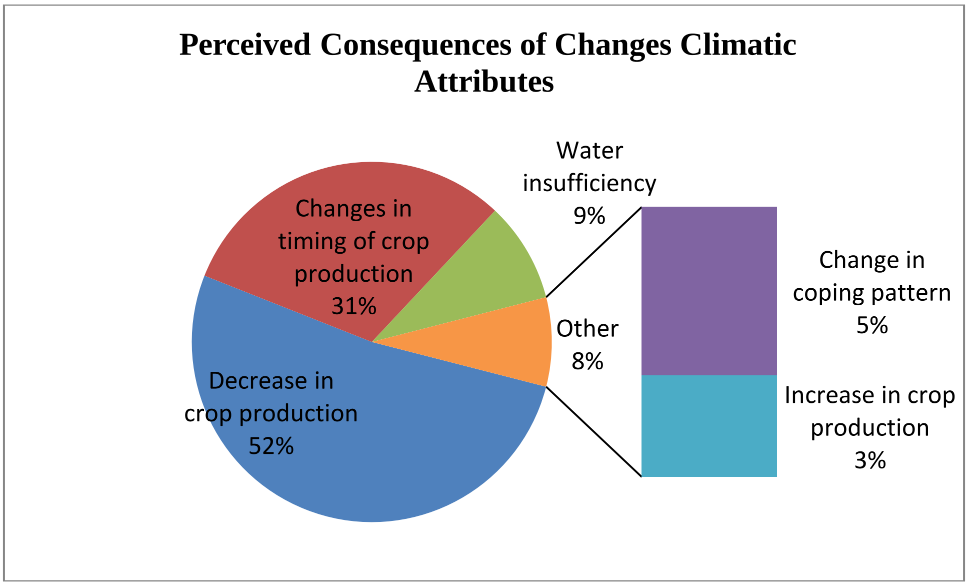
Source: Authors' Own Calculation

The regression analysis computed for the crops revealed that *Aus*, *Aman* and *Boro* have coefficient of determination of 0.23, 0.91 and 0.89 respectively. This indicates that 23, 91 and 89% of the variance in *Aus*, *Aman* and *Boro* can be explained by the independent parameters of the model. The implication is that 77, 9 and 11% of the variance in *Aus*, *Aman* and *Boro* explained by the other factors not included in the model. From the R^2 value it can be said that the crops yield values are lying closely in a straight line and showing a trend except *Aus* paddy, which scattered and lower fit in the trend. From the P value we can conclude that in *Aus, Aman* and *Boro* production there is a significant linear relationship between the dependent and independent variables as p valve is less than 0.05.

3.3 Implications of Climate Change on Crop Production

The respondents were asked about the consequences of climate change on crop production. In that case, 52% of the respondents perceived a decrease in crop production due to climatic variability whereas 31% observed changes in timing of crop planting and harvesting. The other major impacts were water insufficiency, change in cropping pattern however, very few respondents also perceived increase in crop production. The perceived consequences attributed to changes in different above mentioned attributes of climate change are shown in figure 7.

Figure 7: Perceived Consequences of Changes Climatic Attributes



The local people perceived that crop damage due to increased pest attacks had increased. The farmers also reported on the emergence of new pests in crops and felt, it was an impact of increasing temperature along with the disturbance in the natural pest predator system as a consequence of soil degradation due to unbalanced use of chemical fertilizers and pesticides. Consequently, the cost of production has been increasing while crop production is declining. Literature also showed that an increase in maximum temperature can enhance invasive weeds to enter the area (Dukes and Mooney, 1999). A decrease in the number of days with < 0°C also can cause an increase in insects and pests because of less winter kill (Ziska et al., 2011).

3.4 Farm Level Adaption Strategy

In order to cushion the effects of climatic variability, farmers take different sorts of measures to adjust with the climatic variability. Their practices vary based on degree of vulnerability, awareness, perception, localities and affordability of resources (Alam et al., 2011). However, these options are very few in compare to the problem. Local farmers responded that they have changed their plantation time due to the seasonal variability. They are now transplanted *Aman* and *Boro* rice before June and January to ensure the rainfall. Moreover, farmers changed their coping pattern and more interested to selected water scarcity tolerant species. Apart from this they are also converting their agricultural land into mango garden as its not required supplementary irrigation. In this study, farmers have adopted a variety of adaptation strategies including change in planting date, setup shallow tube well in pond, short duration species selection, move to a different side, interlink with little *khal*, improved irrigation facility and agro forestry product.

Table 3: Farmers Adaption Strategies

	Adaptive Measures	No. of Respondent (%)
1.	Change in planting date	62%
2.	Setup shallow tube well in pond	54%
3.	Short duration species selection	41%
4.	Move to a different side	28%
5.	Interlink with little *khal*	21%
6.	Improved irrigation facility	18%
7.	Agro forestry product	12%
		N=200

Source: Field Survey, 2014

IV. CONCLUSION

The objective of the study was to examine the relationship between climatic variables and rice yields using the time series data for the period of 1972 to 2010. The results of used OLS illustrate that three climatic variables have significant effects on the yield of three different rice varieties. Increase in temperature and humidity and the irregularity and gradually decreases in rainfall are statistically significant. Temperature maintains a negative correlation with *Boro* and the rainfall with *Aman* and *Boro*. The climatic variables explain 23, 91 and 89% of variance in *Aus*, *Aman* and *Boro* respectively. The P value indicates significant linear relationship between climatic variables and yield. To minimize the effects of the climatic variables farmers of the study area adopt some strategies like changing in planting date, digging of ponds and setting up shallow tube wells, selection of short duration species etc. based on indigenous knowledge and resources. The severe sensitivity of rice production to climatic variables reveals the necessity of further research and development of climate-resilient varieties and variety specific strategies to minimize the adverse effects of climate change. This study can be identified as an approach towards capturing regional climatic variations and obtaining a comprehensive picture of the issue of climate change and rice yield in Bangladesh.

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