J. Sylhet Agril. Univ. 1(1):15-21, 2014 **ISSN: 2308-1597**

TREND ANALYSIS OF CLIMATE VARIABLES (AIR TEMPERATURE AND RAINFALL) AND ITS INFLUENCES ON RICE YIELD: A CASE STUDY FROM MYMENSINGH DISTRICT OF BANGLADESH

S K Kuri*[1], M J Hossain[2] and M Saha[3]

[1]*Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh, Bangladesh*
[2]*Department of Agricultural Statistics, Bangladesh Agricultural University, Mymensingh, Bangladesh*
[3]*Department of Agricultural Chemistry, Sylhet Agricultural University, Sylhet-3100, Bangladesh*

Abstract

The objectives of the study was to find out the changing trend of major climatic variable (temperature and rainfall) over the period and forecast for succeeding five years (up to 2017) as well as to explore its influences on rice yield in Mymensingh district of Bangladesh. The study was carried out on gathering data from Weather Yard, Bangladesh Agricultural University (BAU) and 8 annual issues of Bangladesh Bureau of Statistics (BBS) from 1975 to 2012. Different statistical methods were employed to attain the results by gathered data. Firstly, from the descriptive statistics it was found that climate variables and rice yield is changing over period and from trend analysis it was found that trend of average annual maximum temperature and average annual rainfall are decreasing. Whereas, average minimum temperature and average mean temperature trend are increasing overtime. From the forecasted value its rate of change was also calculated. It was found from the linear regression analysis that average annual maximum temperature and average annual rainfall had significant negative influences on rice yield while, average annual mean temperature had significant positive influence on rice yield of the study area. The changing trend of climatic variables was highly fluctuating and not favorable for better crop production as well as shows some indication of desertification for the study area.

Key words: Trend analysis, climate variables, rice yield

Introduction

The earth is only known as living green planet in our cosmic world. Its climate is completely favorable for life generation. The human is a dominating species in this planet. We manipulate the entire environment for our own needs and desires without thinking the affordable capacity of it. So the climatic system and its subsequent concerning factors are starting to show its significant effect towards the human community as a whole. So the major concern of human being now-a-days is changes of climate and its adverse consequences (Kuri, 2013).

Climate change constitutes a very serious threat to sustainable agricultural production and food security in many parts of the world. Climate change affects on agriculture through biological effect on crop yield which in terms effect on prices, production, consumption and the ultimate effect is on per capita calorie consumption and malnutrition. Recent research findings have shown that climate change had already affected agriculture in developing countries.

Bangladesh is an agrobased delta island situated at the shore of the Bay of Bengal. So multi type climatic phenomena are frequently visiting along with the whole country and dregs a significant effect on Bangladesh environment (Kuri, 2013).

Temperature greatly influences not only the growth duration, but also the growth pattern and the productivity of rice crops. During the growing season, the mean temperature, and total temperature range, distribution pattern and diurnal changes, or a combination of all these may be have high correlation with grain yield. Yield reductions due to these factors are forecasted 20% and 50% within the year 2050 and 2070, respectively (Basak *et al.* 2009).

Among the plant physiological factors, respiration and translocation are mainly affected by temperature. Plant respiration rate increased with increased temperature. The optimum temperature for the ripening of rice is 21-22 ^{0}C. Temperature below 21^{0}C retarted translocation is shortened, while temperature above 22^{0}C the accelerated

***Corresponding author: S K Kuri,** Department of Agricultural Extension Education, Bangladesh Agricultural University, Mymensingh, Bangladesh, email: s_kuri@bau.edu.bd.*

respiration rate and the grain-filling period is being shortened (Amin *et al.* 2004). Soil temperature has also bearing grain yield and it varied soil to soil. An increase in annual temperature up to 3^0C had a positive effect on the clay soil (up to 15%), and slightly negative effect on sandy soil. Van *et al.* (2003) reported that increase in the above rate of temperature could decrease the yield substantially on clay and sandy soil types (up to 40-45% over control) .

In Bangladesh low temperature i.e. cold problem occurs in winter season usually during November to February when minimum temperature remains often below 20^0C. Sometimes minimum temperature occurs below 20^0C even in March and April in some parts of the country (BRRI, 2002).

Islam *et al.* (2002) mentioned that rice production mainly depend on rainfall. Deficit rainfall in Bangladesh caused drought in rain fed ecosystem and consequently loss of crop yield occur and sometimes it become higher than the damage from flood.

Khan (2008) conducted a study at the coastal areas viz. Chittagong, Barisal and Khulna of Bangladesh to investigate probable effect of climate change on rice productivity. From the study during 1976-2005, annual rainfall showed decreasing trend over the year in Chittagong while increasing trend in Khulna. On the other hand, slightly decreasing trend was found in Barisal.

Bangladesh is rice based agricultural country and it is our staple food. Rice production is very much affected by the changing of major climatic factors. If the rice yield is affected severely, then the food security must fall in danger. So it is the urge of time to find out the impact of major climatic variables on rice yield.

Mymensingh is one of the most rice producing areas of Bangladesh. Kuri (2013) has found that major climatic factors in this district shown the indication of desertification. From the above discussion it was found that climatic variables like air temperature and rainfall has shown significant influence on rice yield. So, the present study has been undertaken to find the influence of air temperature and rainfall as variables on rice yield in Mymensingh district of Bangladesh over a long period of time. Keep this facts on mind, the present study had been undertaken to fulfill the objectives:

- To find out the changing trend of air temperature and rainfall over the period and forecast for succeeding five years (up to 2017).
- To explore the influences of air temperature and rainfall on rice yield.

Materials and Methods

Three statistical methods are employed to examine the variability of climate and its influence of rice yield. First, descriptive statistics such as mean, standard deviation (SD), range and coefficient of variation (CV) are used. CV is calculated by using the following formula:

CV= (SD ÷ mean) × 100.

Second, a simple trend model is used to examine the time trend of variability. In measuring growth rate of a variable, a simple linear trend model is usually employed which takes the following form (Gujrati, 2004)

$$y_t = \beta_0 + \beta_1 t + u_t$$

Here,
y_t = Climate variable which is regressed on time t
β_o = Constant
β_1 = Slope coefficient
t = Trend variable (time)
u_t = Error term

As well as for forecasting purpose, the above fitted trend equation is used and forecast accuracy was measured in terms of different criteria such as mean absolute deviation (MAD), mean absolute percent error (MAPE) and mean square deviation (MSD).

Third, a technique of analysis, linear regression, is used to observe the influence of climate variables on rice yield. The linear regression model has the following form:

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + e$$

Where,

$y = \hat{y} + e =$ Influence of climate variables on rice yield

$\beta_0 =$ Intercept

$x_1 =$ Average annual maximum temperature

$x_2 =$ Average annual minimum temperature

$x_3 =$ Average annual mean temperature

$X_4 =$ Average annual rainfall

e = Error term

The researchers have collected data from Weather Yard, BAU, Mymensingh to find out changing trend of major climate variables of the study area. Different issues of BBS were used to gather the data on rice yield. Using this approach and applying it to Mymensingh time series data for the 1975 to 2012, due to greater availability of data.

Results and Discussion

Various simple statistical methods were used to assess climate change and rice yield variability. Table 1 showed the commonly used climate variables (average annual maximum temperature, average annual minimum temperature, average annual mean temperature and average annual rainfall) and rice yield using simple statistical tools. These five variables were formulated from yearly data, Weather Yard, BAU, Mymensingh and eight annual issues of BBS. Three time periods were constructed to observe the variability over time.

Table 1. Climate and rice yield variability in Mymensingh over the 1975 to 2012

Variables	Statistical Tools	Year		
		1975-1987	**1988-2000**	**2001-2012**
Maximum temperature (^{0}C)	Mean	30.25	30.177	30.12
	Standard Deviation	0.365	0.407	0.412
	Coefficient of Variation	1.20%	1.35%	1.36%
	Range	29.78-31.15	29.54-30.81	29.52-30.8
Minimum temperature (^{0}C)	Mean	21.3	21.33	21.58
	Standard Deviation	0.347	0.646	0.3
	Coefficient of Variation	1.63%	3.03%	1.39%
	Range	20.57-21.91	19.63-22.07	20.8-21.88
Mean temperature (^{0}C)	Mean	25.22	25.24	25.47
	Standard Deviation	0.34	0.384	0.296
	Coefficient of Variation	1.35%	1.52%	1.16%
	Range	24.9-26.08	24.34-25.75	25.11-25.93
Annual Rainfall (mm)	Mean	255.97	237.439	214.23
	Standard Deviation	80.034	59.927	40.965
	Coefficient of Variation	31.27%	25.23%	19.12%
	Range	182.05-503.39	158.12-338.45	152.11-277.94
Rice Yield (kg ac^{-1})	Mean	1735.308	1992.25	2810.934
	Standard Deviation	133.425	202.75	78.844
	Coefficient of Variation	7.69%	10.17%%	2.80%
	Range	1500.04-1951.18	1527.81-2422.28	2710.54-2956.6

Source: Authors' own calculation based on data collection from four issues of Weather Yard, BAU & eight issues of BBS

First, the mean for average maximum temperature and average annual rainfall has decreased steadily over the three periods. While, mean of average minimum temperature, average mean temperature and rice yield has increased steadily over the three periods. Absolute variability, measured by standard deviation, also increased over the same period is higher but the relative variability, measured by CV, is higher for for average maximum temperature. Though CV and SD for average maximum temperature, average minimum temperature, average mean temperature, average annual rainfall and rice yield increased initially and then declined with frequent fluctuations indicating variability in climate and rice yield. All these provide evidence of changing climate and rice yield in Mymensingh district over the last 38 years.

These aspects of variability become clear where these observations are plotted against time. Fig. 1 to Fig. 4 were constructed by using the mean of the respective climate variables. From Fig. 1 the variability in maximum temperature over the period 1975-2012 can be found visually. It also showed, next five years forecasting value for

mean maximum temperature. Mean maximum temperature, on average, appeared to be decrease over the period. However, overall trend is decreasing.

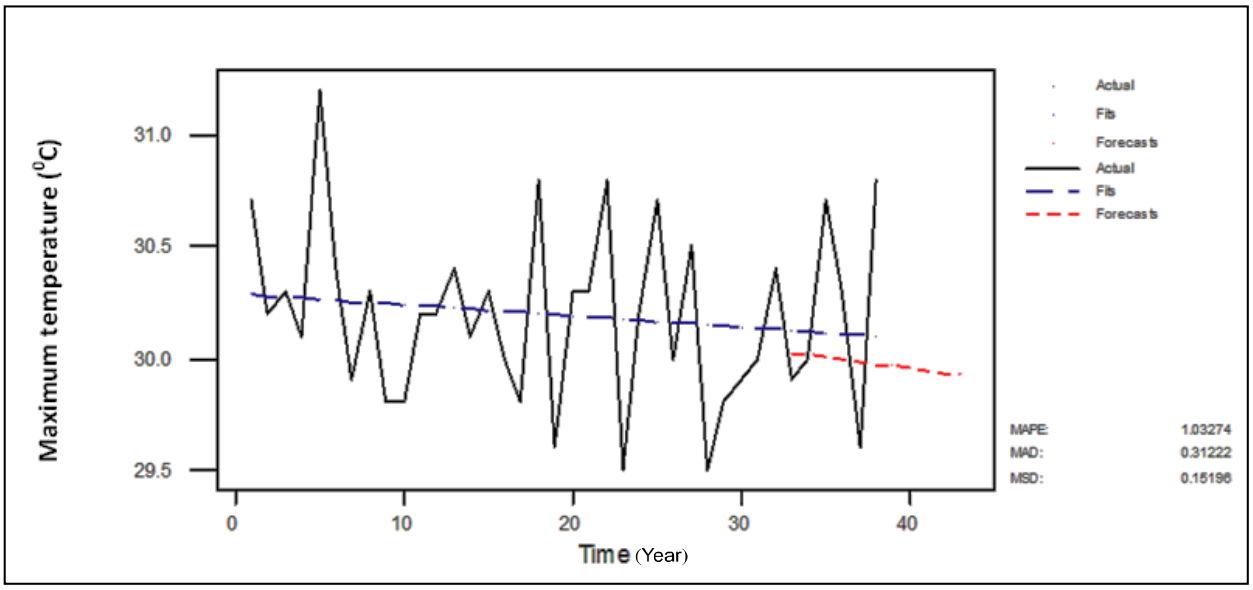

Fig. 1. Actual, fitted and forecast plot for average maximum temperature (^{0}C)

Fig. 2 indicated variability in mean minimum temperature for the period 1975 to 2012 with an extended five year forecasted values. It was found that the average annual minimum temperature increased from 1975-1992. But from 1993-1996 it was in decreasing trend. However from the succeeding year it was again increasing. Nevertheless, the overall trend was increasing. The information showed in Fig. 3 indicated that variability in average mean temperature for the period 1975 to 2012 with an extended five year forecasted values. It indicated that the average annual mean temperature has increased over the period. However, the overall trend was increasing in nature.

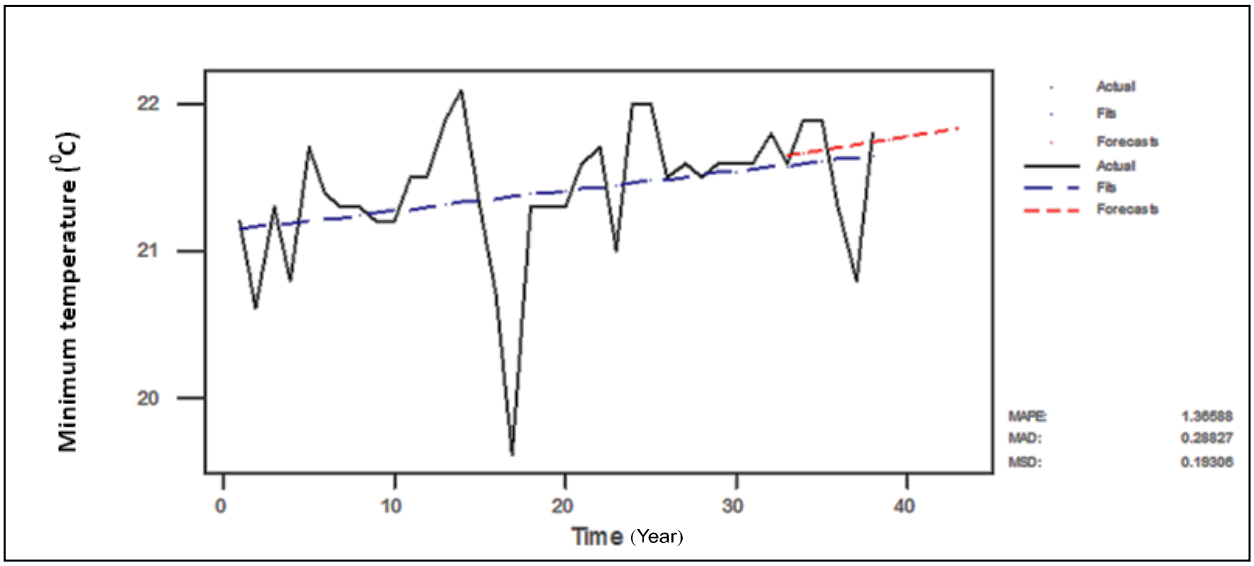

Fig. 2. Actual, fitted and forecast plot for average minimum temperature (^{0}C)

The result obtained from plotting data showed that the variability in average annual rainfall for the period 1975 to 2012 with an extended five year forecasted values (Fig. 4). It has found that the average annual rainfall had decreased over the period. However the overall trend was decreasing in nature.

Table 2 showed the forecasting values for climatic variables for succeeding five years. For average annual maximum temperature as forecasted that it would be decreased from 2013 to 2017. The rate of decreasing is -.053%. On the other hand, average minimum temperature for the next five years in Mymensingh district will be being increasing trend and rate of increasing would be 0.258%. Data presented in Table 2 also indicated the forecasting values for average mean temperature and average annual rainfall. The average mean temperature was increasing and the rate was 0.172%. Average annual rainfall is decreasing and rate of decreasing is -3.093%.

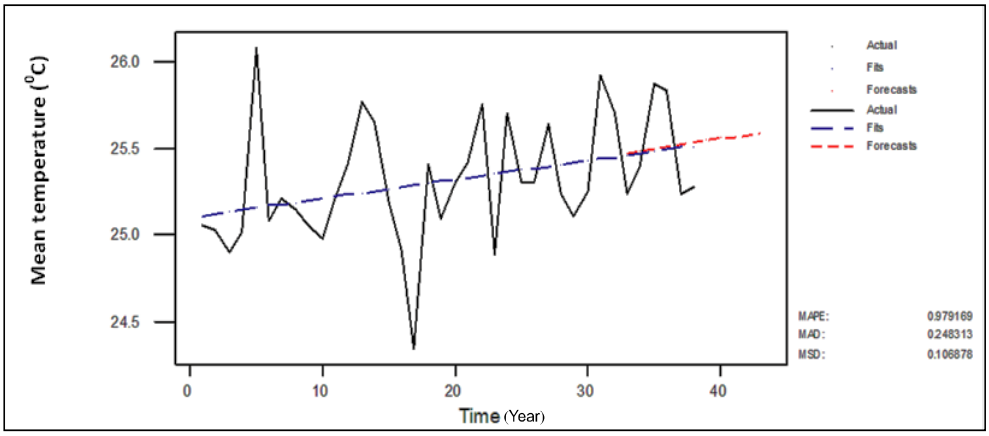

Fig. 3. Actual, fitted and forecast plot for average mean temperature (^{0}C)

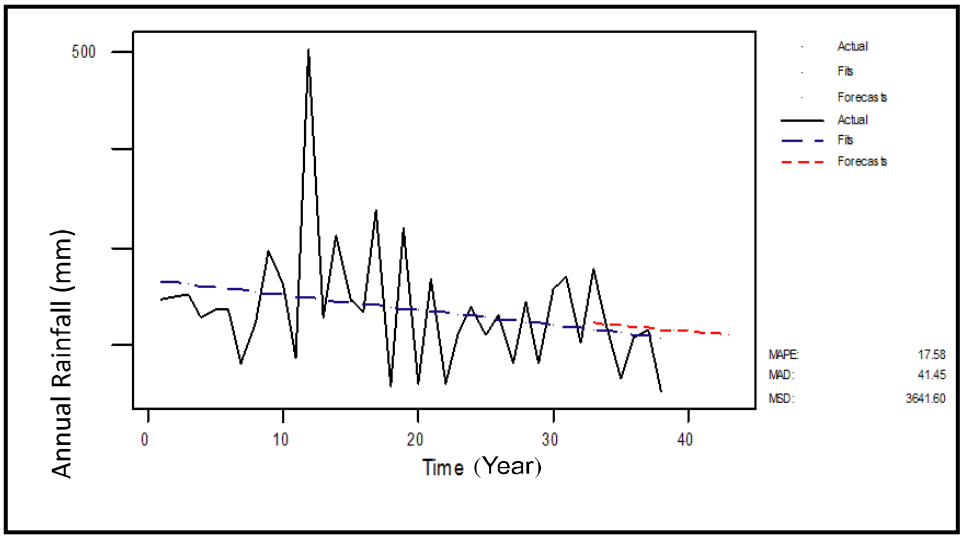

Fig. 4. Actual, fitted and forecast plot for average annual rainfall (mm)

Table 2. Forecasted Value of climate variables

Year	Maximum Temperature y_{max} = 30.26−.0041	Minimum Temperature y_{min} = 21.14+.0141	Mean Temperature y_{mean} = 25.10+.011t	Annual Rainfall y_{rain} = 266.61−1.551
2013	30.108	21.684	25.529	206.283
2014	30.104	21.698	25.540	204.736
2015	30.100	21.712	25.551	203.189
2016	30.096	21.726	25.562	201.642
2017	30.092	21.740	25.573	200.095
% change	-0.053	0.258	0.172	-3.093
Accuracy Measures	MAPE: 1.033 MAD: 0.312 MSD: 0.152	MAPE: 1.366 MAD: 0.289 MSD: 0.193	MAPE: 0.979 MAD: 0.248 MSD:0.107	MAPE: 17.577 MAD: 41.450 MSD: 3641.60

Source: Authors' own calculation based on data collection from four issues of Weather Yard, BAU & eight issues of BBS

From the information of Table 3 it has found that the model has an F-value of 4.309 with a p value of 0.006. This implies that the overall model is statistically significant at the 1% level. The R^2 value means that 34.3% of the variation in rice yield was explained by the climate variables. Moreover, the Durbin-Watson statistic reveals that the model does not suffer from the problem of serial correlation. The values of VIF imply that there was no multi-collinearity among the independent variables while the P-value of the Breusch-Pagan chi-square ensures that the model was not suffering from the problem of heteroscedasticity. The p-value of average maximum temperature was 0.004, for minimum temperatures was 0.832, for average mean temperature was 0.043 and for average annual rainfall was 0.023 which indicate all the variables except minimum temperature were statistically significant. However, the relationship between yield and maximum temperature was significantly negative. The mean temperature had a significant positive effect on yield while annual average rainfall has also negative effect on rice yield. The result suggested that both climate variables affect rice yield considerably.

Table 3. Summary of linear regression associated with influence of climate variables on rice yield

Variables	Coefficient	t- statistic value	p-value	Collinearity Statistics VIF
Constant	4971.802	.803	.428	
Maximum temperature	-641.045	-3.125	.004**	1.453
Minimum temperature	45.516	.214	.832	2.176
Mean temperature	640.516	2.102	.043*	2.506
Rainfall	-2.715	-2.390	.023*	1.129

***=significant at 1% level of probability*
**=significant at 5% level of probability*
R^2=0.343
Adjusted R^2=0.263
F-statistic=4.309
Significant F- statistic =.006
Breusch-Pagan chi-square=1.665, p value= 0.797
Durbin-Watson=1.95
VIF=variance inflation factor
Source: Authors' own calculation based on data collection from four issues of Weather Yard, BAU & eight issues of BBS

The information of Tables 1, 2 and 3 as well as figures indicated that the changing trends of climatic variables were highly fluctuating and not favorable for better crop production. The temperature was rising, while rainfall was decreasing indicated that the desertification of the study area was an ultimate fate.

Climatic variables and rice yield of Mymensingh district are unstable and changing significantly. The trend of maximum air temperature and average annual rainfall were decreasing whereas, trend of minimum annual temperature and mean annual temperature were increasing. The calculated rate of change of the forecasted values supported the results. The influence of major climatic variables like annual maximum temperature, annual mean temperature and annual rainfall influences on the rice yield had a significant effect. From the above results it was found that average annual maximum temperature and average annual rainfall negatively influenced rice yield significantly whereas average mean temperature positively influences rice yield. So, these climatic variables significantly affected rice yield and yield might be reduced due to extreme fluctuations of climate variables in coming future. So, necessary measures should be formulated to mitigate this phenomenon and adapt new strategies to minimize the adverse impact of climate change on rice yield.

References

Amin M G M, Ali M H and Islam A K M R. 2004. Agro-climatic analysis for crop planning in Bangladesh. Bangladesh J. Agril. Engineer. 15:1-40.

BBS (Bangladesh Bureau of Statistics). 1975. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 1980. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 1986. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 1992. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 1996. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 2001. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 2009. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 2012. Statistical Pocket Yearbook of Bangladesh. Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

BRRI (Bangladesh Rice Research Institute). 2002. Annual Internal Rev. for July 2001- June 2003. Plant Physiology Division, BRRI, Gazipur, Bangladesh.

Basak J K, Ali M A, Islam M N and Alain M J B. 2009. Assessment of the effect of climate change on boro rice production in Bangladesh using CERFS-Rice model, Proceedings of the International conference on Climate Change Effect and Adaptation Strategies for Bangladesh, 18-20 February 2009. pp.103-113.

Islam M T, Khan L R and Moniruzzaman M. 2002. Relationship of rainfall and drought in rainfed rice cultivation in Barind area. Bangladesh J. Agril. Engineer. 13:43-53.

Gujrati D N. 2004. Basic Econometrics. 4th edition, Mcraw-Hill, New York, USA.

Khan M A I. 2008. Climate change and its effect on rice productivity in coastal area of Bangladesh. MS Thesis. Dept. Environ. Sci. BAU, Mymensingh, Bangladesh.

Kuri S K. 2013. Smallholder Farmers' Awareness Regarding Adverse Effect of Climate Change on Farm Ecosystem. MS Thesis. Dept. Agricul. Ext. Edu. BAU, Mymensingh, Bangladesh.

Weather Record. 1988. Weather Yard, Dept. Irrig. Water Manag. BAU, Mymensingh, Bangladesh. XIV. pp.33-39.

Weather Record. 1999. Weather Yard, Dept. Irrig. Water Manag. BAU, Mymensingh, Bangladesh. XXV. pp.32-39.

Weather Record. 2009. Weather Yard, Dept. Irrig. Water Manag. BAU, Mymensingh, Bangladesh. XXXV. pp.32-39.

Weather Record. 2012. Weather Yard, Dept. Irrig. Water Manag. BAU, Mymensingh, Bangladesh. XXXVIII. pp.33-39.

Blank