ORIGINAL ARTICLE

Effects of Climate Change on Rice Production at Khulna district, Bangladesh

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Received: 13 December 2018
Accepted: 30 June 2019
Published online: 30 December 2019

Abstract

In Bangladesh 164 million people depend on rice but due to climate change (CC) vulnerabilities the yield of rice is severely reducing. Therefore, this study aimed to explore the effects of CC on rice yield using recent trend analysis, Mann-Kendall (MK) trend test and correlation. For this study, the required climate and selected rice production data were collected from Bangladesh Meteorological Department (BMD) and Department of Agriculture Extension (DAE), Khulna. In time series statistics both parametric and nonparametric methods were applied to detect a monotonic trend of climatic variability and Aman rice production. Correlation between climatic variability and rice production was also investigated. The study exposed that the temperature and rainfall had an increasing trend and statistically significant whereas the relative humidity found decreasing. Overall, the bright Sunshine had positive trend but week. According to non-parametric trend test of climatic variability and Aman yield only minimum temperature showed a positive trend which found statistically significant. In contrast, Mann-Kendall trend test revealed that rainfall had positively significant while temperature had negative significant. The correlation revealed the Aman production is a strong response with minimum temperature whereas the Lona Coche showed a positive correlation with maximum temperature. The variation of Aman production exhibited a positive correlation with both Rainfall and humidity respectively and Lona Coche found a negative correlation. The sunshine had a week correlation against both yields. The findings suggest should give attention of temperature-tolerant rice varieties to mitigate possible adverse effects of CC.

Keywords: climate change, trend analysis, Mann-Kendall (MK) test, Rice Production, Bangladesh

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1. Introduction

The economy of Bangladesh is predominately by agricultural which accounts for about 35% of the gross domestic product (GDP) (Mistri et al. 2015). The country has achieved plenty of growth in rice production due to substantial cropping intensification, introduction of high yielding and saline tolerant rice varieties, expansion of irrigated areas and increased use of chemical fertilizers (Masud et al. 2014). Bangladesh is considered as the 4th largest rice producer in the world, and it comprises an area of about 11.10 million ha. for rice production (Hossain et al. 2008) whereas about 80% of the total cultivable land is being used for the production of rice (BBS 2002). This largest sector agriculture is already under stress due to huge demands for food, and from problems of agricultural land and water resources depletion (Mistri et al. 2015; Amin et al. 2015). However, recently Bangladesh is facing a serious challenge in rice production to feed the over population in the context of shrinking cultivable land and impact of CC. Ahmed and Alam (1999) reported that, Global warming induced changes in temperature and rainfall are becoming evident in global scale, as well as in our country. Hazards like floods, droughts, cyclones and others, which are aggravated by climate change and its variability being experienced more frequently in Bangladesh than ever before. Uncertainty of rainfall and uneven temporal and spatial distribution in one hand, creating flooding and of the other hand longer dry spells evoking droughty conditions (Lai, et. al. 1998; Masud et al. 2014).

Climatic factors such as temperature, rainfall, humidity and solar radiation are closely linked with agricultural production. Reduction in rice productivity has been predicted to be a major concern in years to come due to changing climatic conditions (Yuji et al. 2009). The effects of CC on rice yield are now emerging concern all over the world (Rimi et al. 2009). According to IPCC (2007), CC greatly influences the agricultural productivity especially crop yields vary considerably due to the higher and lower level temperature. Findings also reported that a little rainfall in early February help the cultivation of *Boro* to a significant extent while heavy local level rainfall may lead to severe floods in late August, which may reduce the significant suitable area for *Aman* cultivation. Rainfall is one of the important climatic factors for crop production (Karim et al. 1999). All crops have critical stages when it needs water for their growth and development. Moreover, excessive rainfall may cause flooding and water logging conditions that also lead to crop loss (WB 2000). If rainfall increases by 1mm it will decrease *Aman* rice production at their vegetative, reproductive and ripening stages (Amin et al. 2015). CC and its effect on rice production and about 74.31% of the principle crops *Aman* and 100% of *Boro* cropland has been damaged in the south-western part of Bangladesh due to flood remains for half of the year and the cropland is badly affected by salinity intrusion (Seal and Baten 2012). *Boro* rice is a potential source of production, which currently accounts for about 50% of total rice production in the country (BRRI 2006). CC in the south-west region of Bangladesh creates insecurities for food, water, human life, property, settlement, livelihood assets, livelihoods and others (MOEF 2009).

Recently, the studies of CC and its effects on rice production have gained attention. Rimi et al. (2009) conducted a study on Trend analysis of climate change and investigation on its probable impacts on rice production at Satkhira, Bangladesh. The findings of that study revealed that, the production of Aus rice summer crop decreased significantly with increasing maximum temperature, while the winter crop *Boro* production increased significantly with the increase of minimum temperature when the inter-annual amount of winter season rainfall fluctuation was little. Therefore, the production of *Boro* rice was insignificantly affected by these variables. In most cases, the study found that irrespective of crops and Global Climate Models (GCMs), climate change would have an adverse on rice yield. Another study conducted by Chowdhury and khan (2015) on the impact of climate change on rice yield in Bangladesh: a time series analysis. The results showed that, significant influence of climate variables on rice yield. The maximum temperature was statistically significant and negatively affects the production of rice and the minimum temperature had highly significant which was a positive impact on the yield of *Boro* rice only. The rainfall was found significant for all rice yields with positive effects on Aus and *Aman* and adverse effects on *Boro*. The humidity also has significant effect on the yield of all three rice.

Amin et al. (2015) reported that, the effects of all the climate variables have significant contributions to the production of major food crops. The maximum temperature significantly affects the yield of all food crops' except Aus rice whereas; minimum temperature insignificantly affects *Aman* rice. Similarly, rainfall significantly benefits cropping area of Aus rice, but significantly affects both yield and cropping area of *Aman* rice. Usually, humidity was found positively correlated with the yield of Aus and *Aman* rice but, negatively influenced the cropping area of Aus rice besides. Sunshine also has significant influence on *Boro* rice yield (Zhang et al. 2014; Ferdous and Baten 2011; Mirza 2002). There are number of studies, climate change and its impact on rice production but a few have intensively examined the relationship between CC and crop production (Ferdous and Baten 2011; Amin et al. 2015). So, it is necessary to assess the potential impacts CC and rice production between high yield variety and local variety for an understanding of the national impacts of recent climate trend on principal food grain would help to anticipate impacts of future CC on the food security of the country.

In Bangladesh, the principal crop-growing period is divided into two main seasons, Rabi and Kharif. The Rabi season starts to form the month of November and ends on April during this time the rainfall availability is very little whereas the Kharif season starts from May and ends in October when the moisture supply from rainfall is enough to support rain-fed or unirrigated crops (Chowdhury and khan 2015). According to SRDI 2000, the defining study area consists of one Agroecological Zone (AEZ) of Bangladesh namely; Ganges Tidal Floodplain (AEZ-8); the extent of the entire AEZ is 17,066 sq.km. Acid sulphate soil occupies a significant part of the area, where it is extremely acidic during the dry season. Most of the top soils are acidic and sub soils are neutral to mildly alkaline (Rimi et al. 2009). Therefore, the main objective of this study was to explore the effects of CC on rice (two specific varieties) production by statistical analysis of recent trend, Mann-Kendall (MK) test and correlation.

2. Methodology

Study area

This study was conducted at the Koyra upazila under Khulna District of Bangladesh. The occupying area is 1775.41 sq km, located in between 22°12′ and 22°31′ north latitudes and in between 89°15′ and 89°26′ east longitudes. It is bounded by Paikgacha upazila on the north, the Bay of Bengal and Sundarban on the south, Dacope upazila on the east, Assasuni and Shyamnagar upazila on the west. The main water bodies Main rivers: Dharla, Pasur, Arpngachia, Taldhup, Malancha, Kobadak, ball; Koyra canal is notable (Masud et al. 2014; Banglapedia 2014). As the study area is located near the world largest mangrove forests named Sundarbans (UNESCO, world heritage site). The highest temperature observes in April and May while lowest in December and January. The region has high relative humidity (80-90%) with mean annual rainfall ranges from about 1900mm to 2500mm. June, July and August are the wettest months while December, January and February the driest (Hossain et al. 2016).

Data acquisition and interpretation

The required rice production and climate data, specifically of Khulna were gathered from authentic organizations. The climatic data (maximum and minimum temperature, relative humidity, total rainfall and bright sunshine) was assembled from Bangladesh Meteorological Department (BMD 2013). The district level rice production data on selected variety (*Aman-Upshi* and *Lona Coche*-local variety) were collected from the Department of Agricultural Extension (DAE) Khulna for the period of

1994 to 2010. The rice yield data was not recoded previous years of 1994. The independent variables of this study were maximum temperature, minimum temperature, rainfall, relative humidity and the sunshine. The computation of climatic variability and yield production was done with the help of XLStat software for non-parametric analysis.

Data analyses

In the present study, the linear and monotonic trend was investigated mostly annual, seasonal and monthly time series data with short term and long-term pattern of climatic variability and yield in the study area. The parametric method is used so that sum of squared error becomes the least. In trend analysis, it is most widely accepted techniques and is most robust in case of normally distributed data. Where the distribution of the variable is not Gaussian the non-parametric technique be more appropriate in the analysis of trend. Both parametric and non-parametric techniques were used to investigate the trend in different climatic variable and yield in order to their relative strength and weakness. In parametric and non-parametric trend test were applied by employing t-test and Mann-Kendall (MK) test and Sen' Slop estimation.

Trend Analysis and examined effects on Rice Production

In order to know the variability of each climatic parameter and rice yield during the period of 1980-2010, the analysis work is done recent trend to identify the variation of each climatic parameters. The data were analyzed in year basis to explore the recent variation. To find out a variation of annual rice production against the various climate variables a possible correlation has done.

3. Results and discussion

The trend of maximum and minimum temperature

The trend of annual average maximum temperature is increasing in the study area over the period of (1980-2010), which is a positive trend and statistically significant. Figure 1 reveals that the annual average maximum temperature is rising and the rate of the trend is 0.023°C/yr. Figure 2 shows that the annual average minimum temperature is slightly increasing trend and the rate of the trend is 0.079°C/yr, which is regular and medium positive trend.

The trend of annual total monsoon rainfall

The analysis depicts that, the trend of annual total monsoon rainfall distribution through the period of 1980-2010 in the study area is rising but weak positive Figure 3. However, the pattern of rainfall distribution is irregular and not significant statistically. The trend is rising and the rate is 0.787 mm/yr. Therefore, the trend of monsoon rainfall pattern over the period has been altered.

The trend of relative humidity and bright sunshine

Figure 4, exhibits that the trend of annual average relative humidity is also decreasing which is a negative and irregular trend. Therefore, the trend is downing at 0.020%/yr. on the other hand, the trend analysis of annual average bright sunshine over the period 1980-2010 could reveal that, it had slight increasing which is positive but medium trend Figure 5.

The Non-parametric trend test of climatic variability and *Aman* yield revealed that, all parameters were no significant except minimum temperature (Tab. 1). According to the Q value the significance level of minimum temperature at 0.056 which is a positive and statistically significant trend.

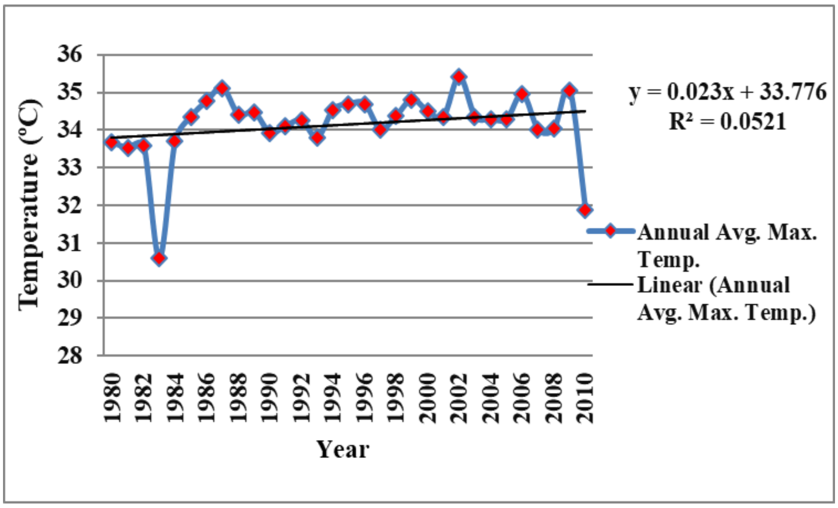

Fig. 1. Trend of annual average maximum temperature.

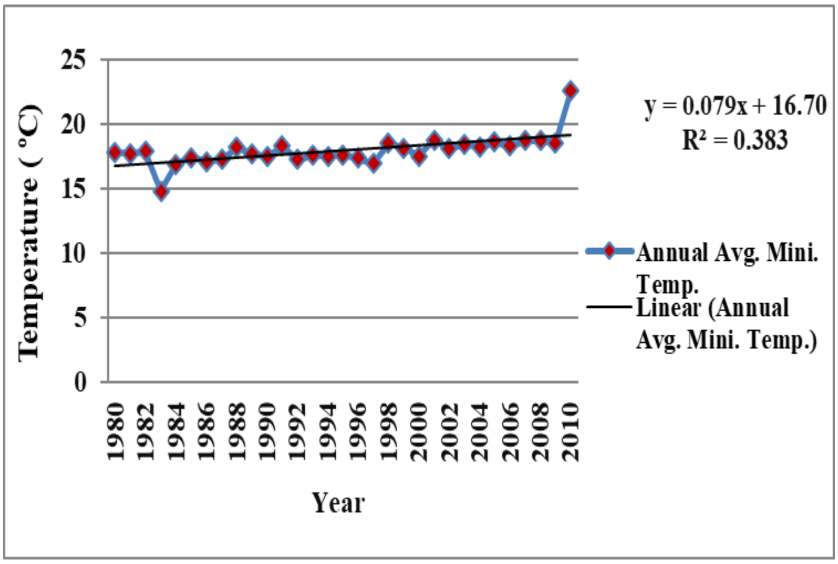

Fig. 2. Trend of annual average minimum temperature.

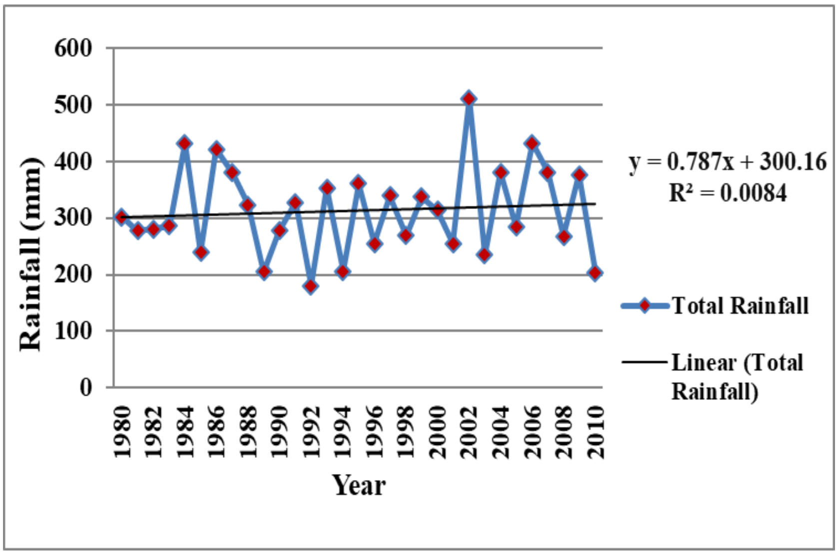

Fig. 3. Trend of annual total monsoon rainfall.

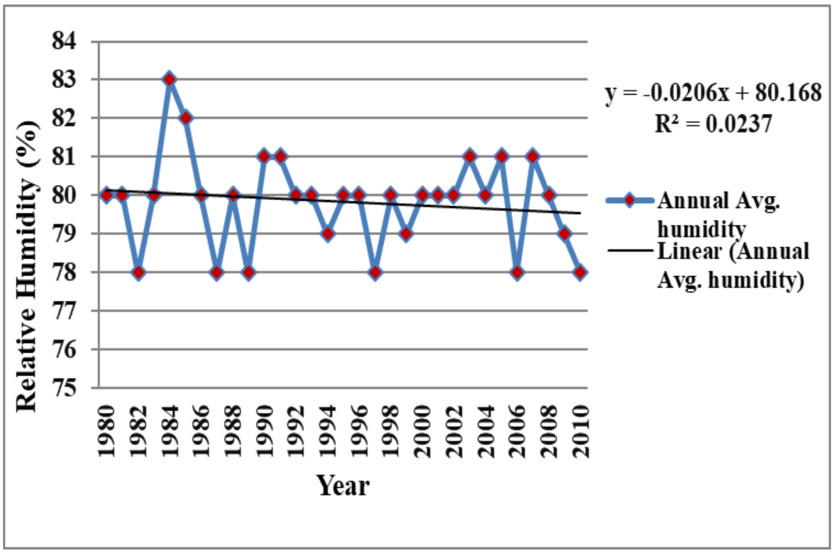

Fig. 4. The trend of annual average humidity.

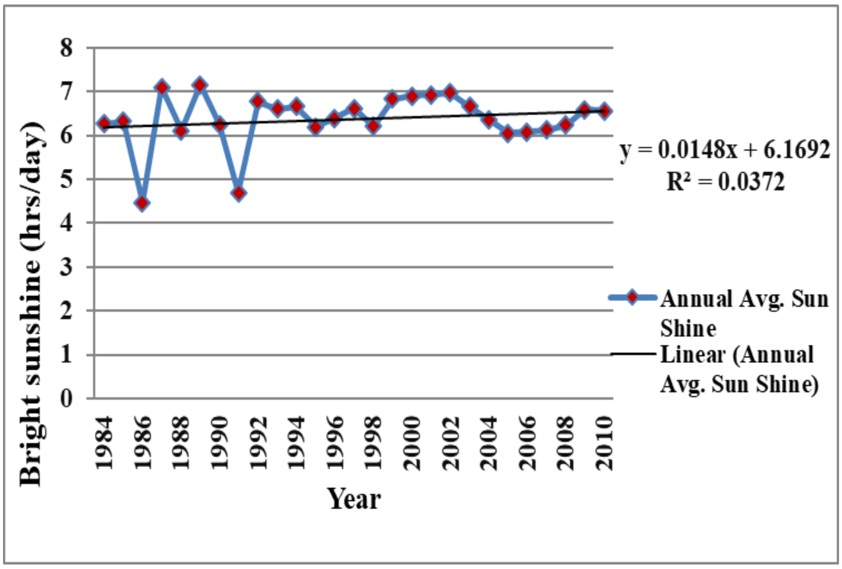

Fig. 5. Trend of annual bright sunshine.

Tab. 1. Non-parametric trend test of climatic variability and Aman yield.

Number of observation	Parameter	Mann-Kandall (MK) test (Z)	Significant level	Sens' Slop estimation (Q)	Year of observation	variables
30 yrs.	Max Temperature	1.58	NS	0.024	1980-2010	Climate Variability
30 yrs.	Min Temperature	3.94	***	0.056		
30 yrs.	Rainfall	-0.20	NS	-1.385		
30 yrs.	Relative Humidity	-0.57	NS	0.000		
26 yrs.	Sunshine	0.08	NS	0.002	1984-2010	
10 yrs.	Aman	-0.31	NS	-0.010	2000-2010	Yield
10 yrs.	Lona Coche	-0.39	NS	-0.013	2000-2010	

*α=0.001 level of significance, **α=0.01 level of significance, ***α=0.05 level of significance, NS=No significant

Correlation between yield and climatic variability

The correlation between *Aman* production and minimum temperature in the study area over the period of (1994-2010) shows that, the trend is strongly positive which statistically highly significant Fig. 6 (a). But for the *Lona Coche* production the trend has found negative Fig. 6(b). The Fig. 7 (a) exhibits, that the variation of *Aman* production with annual maximum temperature is also showing negative trend while of *Lona Coche* production has found increasing trend which is statistically positive Fig. 7 (b). Therefore, the high yield variety *Aman* can grow within lower and medium higher-level temperature whereas; the local variety *Lona Coche* might not tolerate the lower and higher-level temperature.

It is revealed from Fig. (8a) that, the variation of *Aman* production with annual monsoon rainfall in the study area over the period of (1994-2010) had an increasing trend which is statistically positive correlation. While the *Lona Coche* production trend was found decreasing with annual monsoon rainfall which is statistically strongly negative, Fig. 8 (b). Although, *Aman* is rain-fed crop, the abundant production of *Aman* depends on the regular monsoon rainfall but the negative trend of rainfall may adversely affect the production of *Lona Coche* yield (Fig. 8 b).

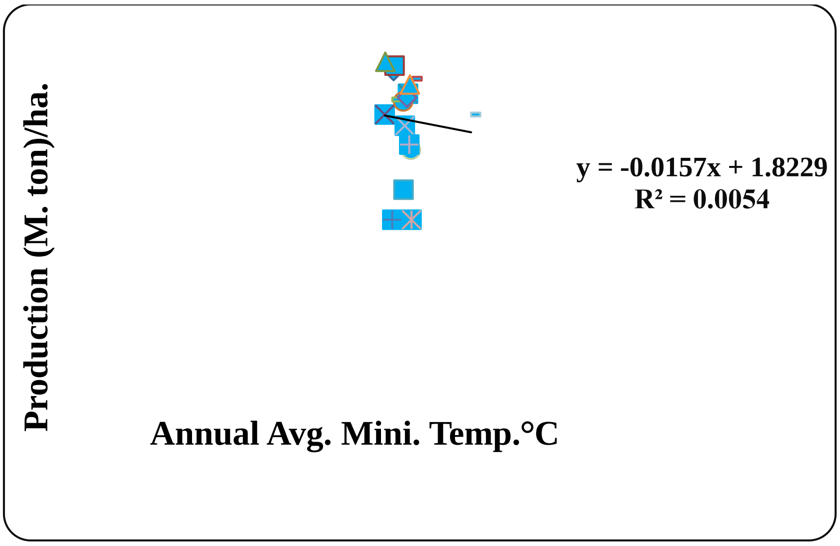

Fig. 6a. Correlation between *Aman* production and minimum temperature period (1994-2010).

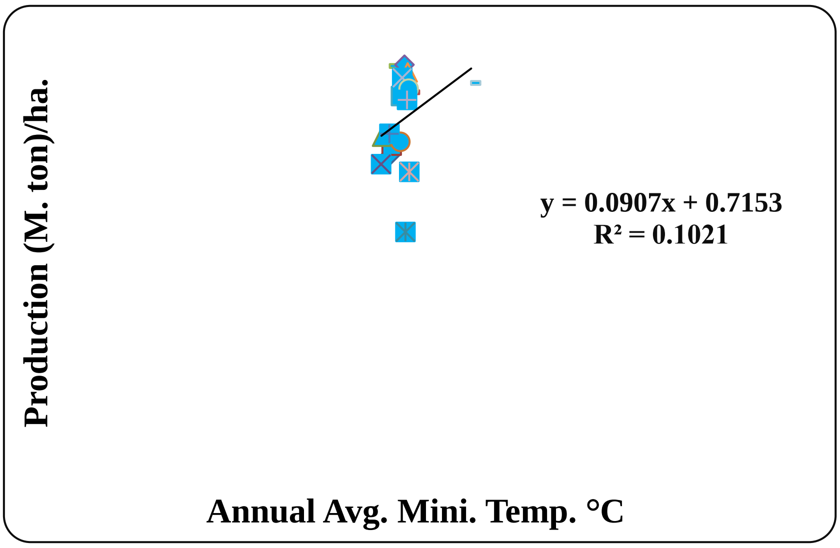

Fig. 6b. Correlation between *Lona Coche* production and minimum temperature period (1994-2010).

The variation of *Aman* production with annual relative humidity had a positive trend but week correlation Fig. 9 (a, b). On the other hand, the yield of *Lona Coche* has found decreasing trend against relative humidity which is statistically negative Fig. 9 (b). The higher relative humidity is always favorable for the higher production of crops as its influence the plant development and photosynthesis of the leaves (Masud-Al *et al.* 2014). Therefore, the relative humidity has an observable effect on Local variety production.

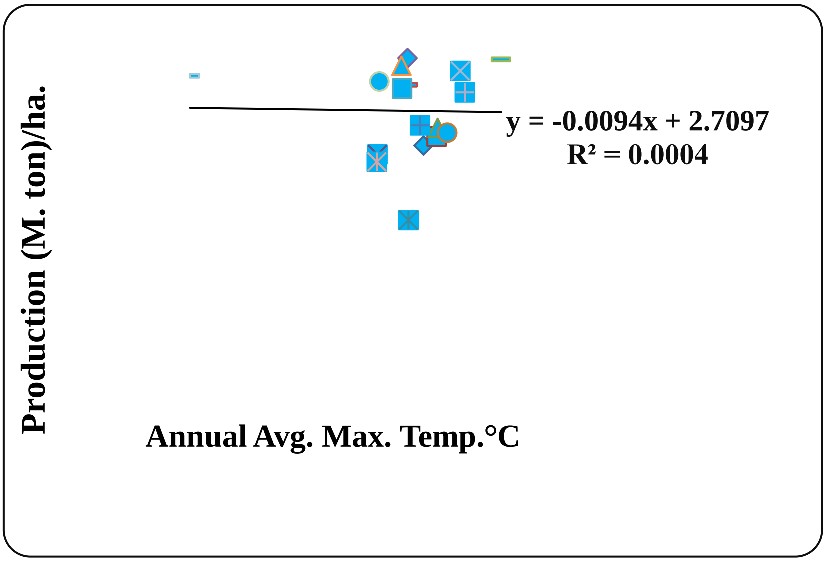

Fig. 7a. Correlation between *Aman* production and maximum temperature period (1994-2010).

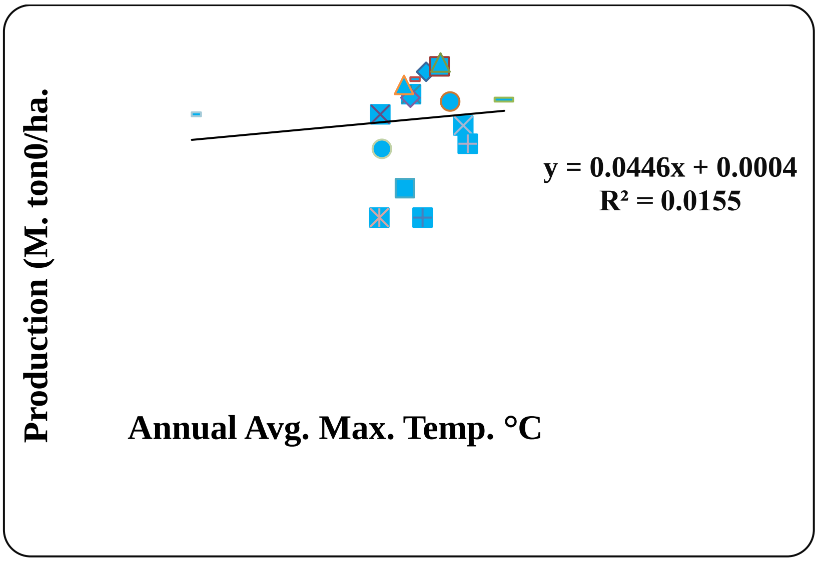

Fig. 7b. Correlation between *Lona Coche* production and maximum temperature period (1994-2010).

The correlation between crop production and bright sunshine also revealed a positive response but weak Fig. 10 (a, b). However, the solar radiation affects many physiological processes of the plant, particularly photosynthesis. The light requirement varies with plant species (Ali 2010). There are critical stages of plant growth when solar radiation is especially important. For the same amount of daily solar radiation, the photosynthesis rate increase with day length (Marshall and Haferkamp 1988).

The Mann-Kendall test revealed that, the trend of monsoon rainfall had medium significance (**α=0.01, z= 2.67) for the month of September while the trend of temperature had week significance. The rice production had found week significant both for the monsoon rainfall and temperature.

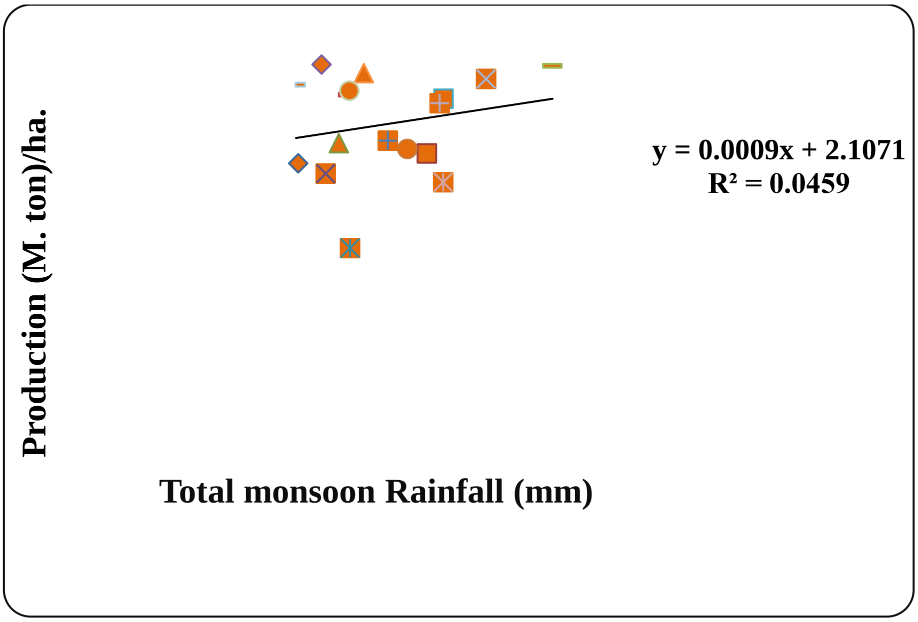

Fig. 8a. Correlation between *Aman* production and total monsoon rainfall period (1994-2010).

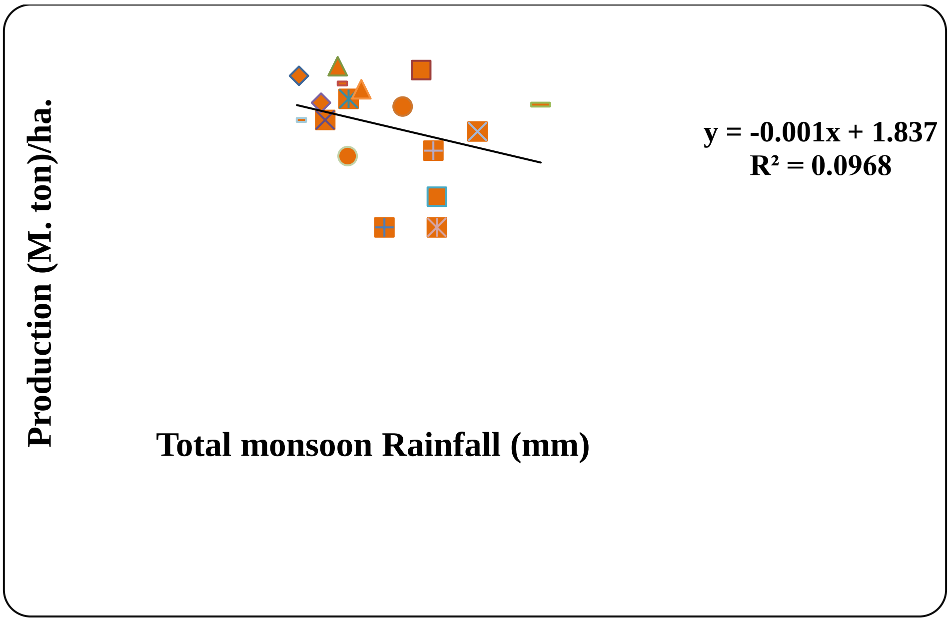

Fig. 8b. Correlation between *Lona Coche* production and total monsoon rainfall period (1994-2010).

1. Conclusion

The study attempted to examine the effects of climate change on specific rice variety between high yield variety *Aman (Upshi)* and *Lona Coche* (local variety). The effects of climate change on rice yield depend on actual patterns of climatic factors also differences of local growing seasons, crop management. Both higher level and lower level of temperature may decrease rice yield due to spikelet sterility and higher respiration losses. The time series analysis exhibited that, the trend of temperature and total rainfall had an increasing which was statistically positive whereas the relative humidity had found decreasing. Overall, the bright sunshine had positive trend but week. In addition, the non-parametric trend test of climatic variability and *Aman* yield only minimum temperature showed a positive trend which statistically significance. In contrast, Mann-Kendall trend test found, rainfall had positively significant while temperature had negatively significant. The findings indicated that the climatic variables have substantial effects on the both production of *Aman* and *Lona Coche*. According to correlation, the *Aman* production had a strong response with minimum temperature whereas the *Lona Coche* showed a positive correlation with maximum temperature. The variation of *Aman* production exhibited a positive correlation with both Rainfall and humidity respectively and *Lona Coche* found a negative correlation. The sunshine had a week correlation against both yields. Due to climate change effect, the production of *Lona Coche* has been affected; it means that the variety cannot tolerate the lower temperature, excessive rainfall and high relative humidity. The future challenge would focus on salt and temperature-tolerant high yield rice varieties to mitigate possible adverse effects of CC to ensure sustainable agriculture.

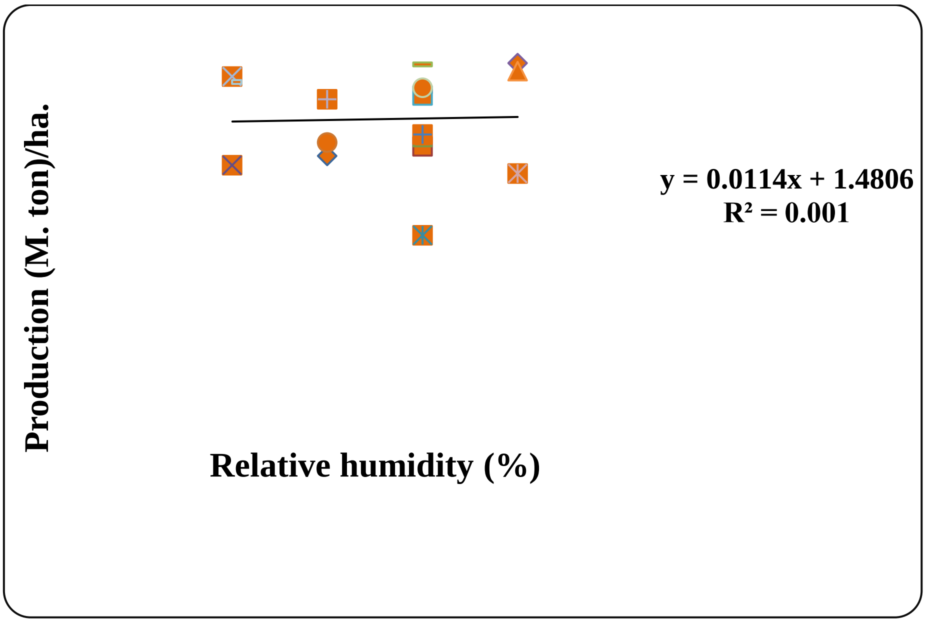

Fig. 9a. Correlation between *Aman* production and relative humidity period (1994-2010).

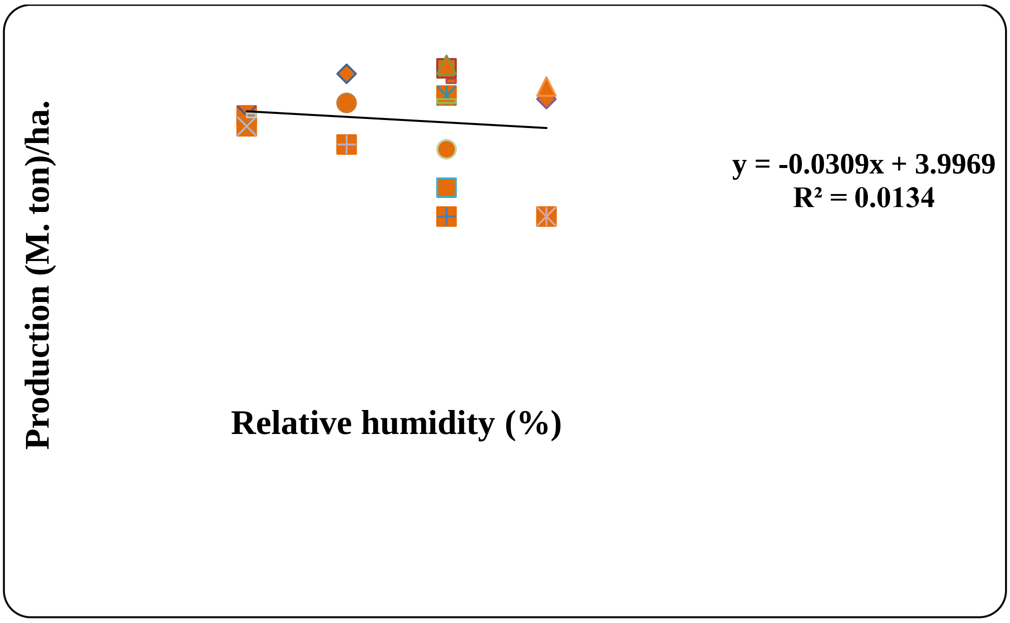

Fig. 9b. Correlation between *Lona Coche* production and relative humidity period (1994-2010).

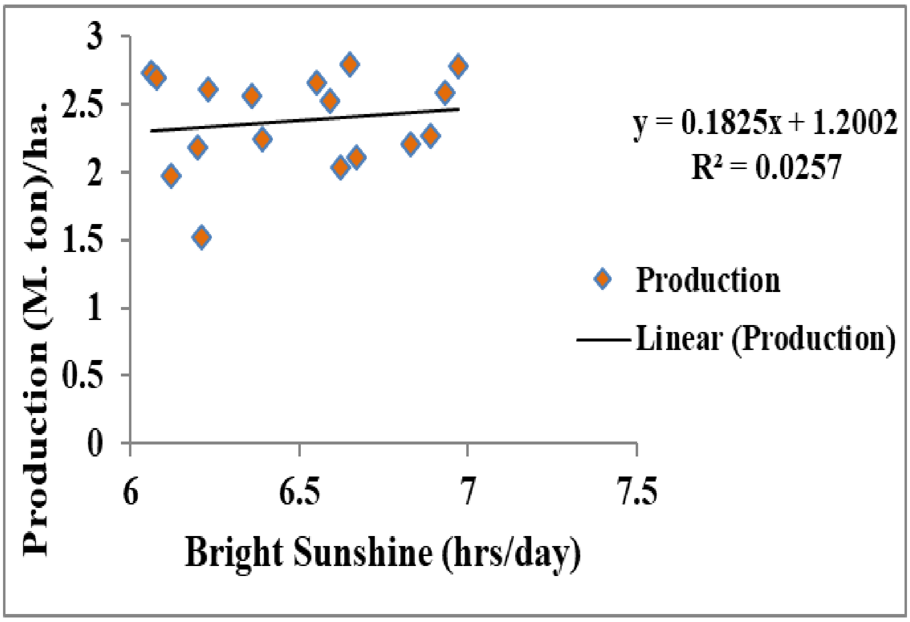

Fig. 10a. Correlation between *Aman* production and bright sun shine period (1994-2010).

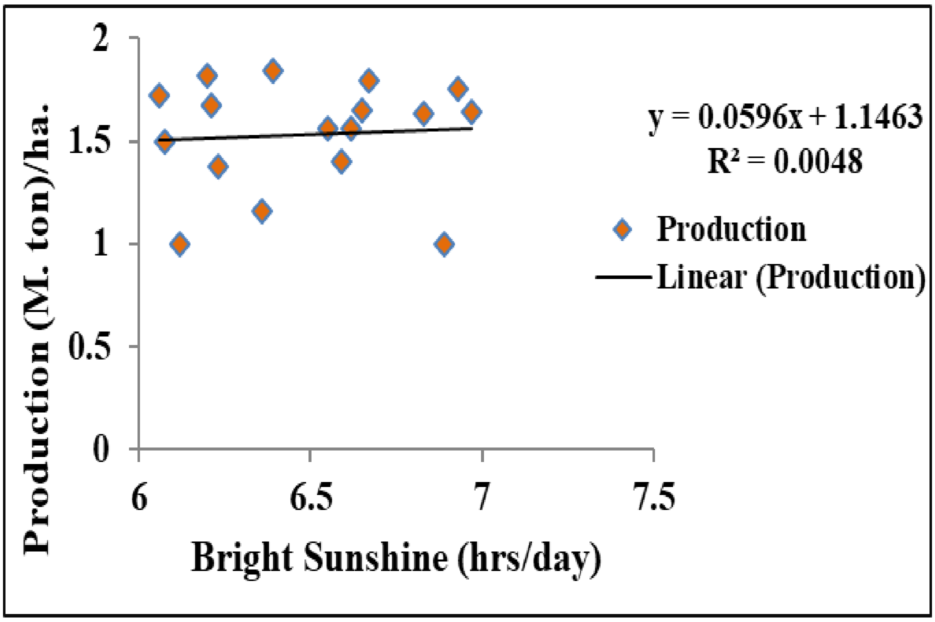

Fig. 10b. Correlation between *Lona Coche* production and bright sun shine period (1994-2010).

1. Acknowledgements

The authors acknowledged the contribution of the Bangladesh Meteorological Department (BMD) for making climatologic data available to us. Thanks, are also due to the department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Department of Agricultural Extension (DAE), Khulna and Soil Resource Development Institute (SRDI), Khulna for their supports and help carrying out the study. They also thank the anonymous reviewers who provided valuable comments on the paper.

Tab. 2. Mann-Kendall trend test of Temperature and Rainfall of study area.

Year	A number of yrs.	month	Mann-Kendall trend (Z)	Sen's slope estimate (Q)	Parameter of test	Year of observation
1980-2010	30	June	-1.26 ^{NS}	-3.167	Rainfall in mm	1080-2010
	30	July	1.38 ^{NS}	3.880		
	30	August	-1.63 ^{NS}	-3.923		
	30	Sept.	2.67**	7.074		
	30	Oct.	0.22 ^{NS}	0.500		
	30	Monsoon Average Rainfall	0.78 ^{NS}	3.604		
		June	-0.39 ^{NS}	-0.050	Temperature (^{0}C)	
		July	-1.34 ^{NS}	-0.200		
		August	-1.34 ^{NS}	-0.150		
		Sept.	-2.19*	-0.133		
		Oct.	-2.73**	-0.200		
1994-2010	16	Lona Coche	-2.27*	-0.024	Yields	1980-2010
	16	Aman	2.02*	0.039		

*α=0.001 level of significance, **α=0.01 level of significance, ***α=0.05 level of significance, NS=Non-significant.

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