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Climatic Variability and Wet Season Rice (*Oryza sativa* L.) Production in North-West Bangladesh

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Abstract

Climate change is influencing rice (*Oryza sativa* L.) production in some agro-ecological regions of Bangladesh. The impact of seasonal climatic variability on rainfed lowland rice (transplanted aman or *T. Aman*) yield in north-west Bangladesh was analyzed based on historic weather data from 1971 to 2010. Wet season maximum and minimum temperatures were increasing by 0.0174 and 0.0083°C $year^{-1}$, respectively. Sunshine hours for the same period have decreased by 0.0259-0.027 hr $year^{-1}$. The representative concentration pathway (RCP) based projection showed increased maximum and minimum temperatures by 0.42-1.51 and 0.79-1.34°C, respectively in 2050. *T. Aman* rice yield could be reduced by 0.17-0.37 t ha^{-1} if temperature rises by 1°C. If sunshine hour decreases by 1 hr, yield reduction could be 0.20 t ha^{-1}. Combined effect of increased minimum temperature and decreased sunshine hours will govern *T. Aman* rice yield in future.

Keywords: *T. Aman* rice yield, climatic variability, MAKESENS model.

1. Introduction

Bangladesh has attained self-sufficiency in rice (*Oryza sativa* L.) production despite high population pressure on land and other natural resources. This has mostly happened because of replacement of local varieties by the modern high yielding ones. Most countries consider domestic food grain production as an important factor for food price stabilization and food security. However, the success of food self sufficiency has been challenged by the population growth rate and by climate change vulnerability in Bangladesh (MoEF, 2009).

The demand for cereal foods, especially for rice, is expected to rise by 1.5% per annum for the next few decades. More food has to be produced from less cropped land areas in future (Timsina *et al.*, 2016; BBS, 2016). Floods, cyclones, salinity and droughts are threatening food security of rural people. In coming years, these hazards are likely to aggravate (IPCC, 2013; Singh and Kalra, 2016). There are variable reports on rainfall amounts and its distribution (Rahman *et al.*, 1997), but increase in temperature is likely to be 0.5-1.1°C per century (Mondal and Wasimi, 2004). Besides, increasing trend of mean maximum and minimum temperatures in some seasons and decreasing trend in some others climatic parameters during 1961-1990 were also observed (Rahman and Alam, 2003).

Climate change potentially invites disastrous consequences on rice and thus food security in Bangladesh. Rice crop occupies almost 80% of the total cropped area and accounts for more than 90% of total grain production. So, it dictates the necessity of assessing the effects of climate change on rice production in Bangladesh to ensure food security and economic growth in future. However, empirical investigations of the influence of climate change on crop agriculture in this country are limited (Rashid and Islam, 2007).

North-west part of Bangladesh is act as a food granary. Impacts of climatic variability and extreme events can impair food security in that region. For example, rice production could be reduced by 10-25% due to increase in temperature (Peng *et al*., 2004). Maniruzzaman and Biswas (2014) also reported 35% reduction in wet season rice yield in Rajshahi region because of 1^{o}C rise in maximum temperature, although spatial distribution of trends is not available. Climatic variability and its extreme events are concerns, and there is a need to evaluate climatic variability through growth and yield of rice. We need to know the appropriate management options to face the challenges of climate change. The knowledge gained would be effectively useful in understanding the agri-response with the future climate change scenarios. Crop simulation tools are effective in this exercise, but the regression based approaches for understanding the dependence of growth and yield of crops with the historic weather data are also important. Regression models that use historical data on both climatic variables and yields are capable of providing accurate estimates of the changes in crop yield as a result of changes in climatic variables (Almaraz *et al.*, 2008). However, such climatic variability is not reported with respect to crop yield variations. In the present study, inter-seasonal climatic variability was characterized through yield of *T. Aman* rice in North-west region of Bangladesh.

2. Materials and Methods

2.1 Site description

The research was carried out at Bangladesh Rice Research Institute, Gazipur during 2015-16 . The north-west part of Bangladesh is situated at 23^{o}47′45″ N to 25^{o} 46′34″ N latitude and 88^{o}00′37″ E to 89^{o}49′11″ E longitude, and covers an area of about 23,295 km^{2}. It is composed of 4 districts those belong to Rajshahi region (Rajshahi, C. Nawabganj, Natore and Pabna), 4 districts under Rangpur region (Rangpur, Gaibandha, Kurigram and Lalmonirhat), 4 districts under Dinajpur region (Dinajpur, Nilphamari, Thakurgaon and Panchagarh) and 4 districts under Bogra region (Bogra, Joypurhat, Naogaon and Sirajganj). Total population of that area is 22.93 million of which more than 80% people live in rural areas those who mainly depend on agriculture. The density of population is about 860 people km^{-2}. The study area is relatively dry humid in which annual average rainfall is 1,400-1,900 mm. Almost 92.7% rainfall occurs during May to October. Inter-annual variability of non-monsoonal rainfall is more than 50% (Shahid, 2008). Temperature ranges from 25^{o}C to 40^{o}C in the hottest season and 8^{o}C to 25^{o}C in the coolest one. About 90% land area is used for wet season rice cultivation. High yielding *T. Aman* rice varieties are dominant and shares almost 95% of total cultivated crop in wet season (BBS, 2013), which is threatened frequently by drought (Shahid, 2008). In the last 40 years, the area suffered by 8 droughts of major magnitude. Farmers use supplemental irrigation water to avoid drought effect wherever possible.

2.2 Data source and temporal trend analysis

Temperature, rainfall and sunshine duration data from 1971-2010 were obtained from four stations of Bangladesh Meteorological Department (BMD) and rice grain yield data were collected from Bangladesh Bureau of Agricultural Statistics for the whole north-west districts. The Mann–Kendall trend test (Mann, 1945) was used to detect trends in time series data and the test statistic distribution was explained by Kendall (1975) for testing non-linear trends and turning points. The test assumes a monotonic trend and thus rejects the presence of any seasonal or other cycles in the data. The Mann-Kendall test is preferred when various stations are tested in a single study (Hirsch *et al.*, 1991). Sen's slope estimator was used to determine the magnitude of change in the climatic parameter. The present study computed the confidence interval at $p = 0.01$ and $p = 0.05$. Representative Concentration Pathway (RCP) based projected data on temperature and rainfalls were used as average of Geophysical Fluid Dynamics Laboratory's Earth System Model (GFDL-ESM2M), Hadley Centre Global Environment Model version 2 Earth System Model (HadGEM2-ES), Institute Pierre Simon Laplace Low Resolution Climate System Model Version SA (IPSL-CMSA-LR), Model for Interdisciplinary Research on Climate version 5 (MIROC5) and Meteorological Research Institute Coupled Global Climate Model version 3 (MRI-CGCM3). The projected data of 2050 and 2100 were compared with average of 2001-2010 data, to judge the future projection with the present time normal trend. Four pathways: RCP8.5 (>8.5 W m^{-2} by 2100), RCP6 (6 W m^{-2} after 2100), RCP4.5 (4.5 W m^{-2} after 2100) and RCP2.6 (3 W m^{-2} before 2100 and then declines) - the last is also referred to as RCP3-PD was considered in the present investigation.

Trend analyses for inter-annual and inter-seasonal, maximum, minimum and mean temperatures, rainfall and sunshine duration were carried out for those four locations. The descriptive statistics for yield of *T. Aman* rice and seasonal climatic elements were prepared. Growth rates of area and productivity of *T. Aman* rice were worked out as decadal basis by using the following formula:

Growth rate = (X2 – X1)/ No. of years ------- (1)
Where,
X2 = calculated decadal year, area or yield
X1 = previous decadal year, area or yield

Annual and seasonal deviations of temperature, rainfall and sunshine hours and yield from the trend line were computed as follows (Maniruzzaman *et al*., 2017):

Percent deviation (%) = $\{(Yi - \bar{Y})/\bar{Y}\}*100$ --- (2)
where,
Yi = mean values of each climatic parameter or yield
i = number of years i.e. 1, 2, 3, ------------------ n
$\bar{Y}$ = normalized (or trend) value of each climatic parameters or yield

The combined effect of maximum and minimum temperatures, rainfall and sunshine hours on *T. Aman* rice yield was computed through multiple regression analyses. Several *T. Aman* varieties are grown in the test regions, but for the convenience of the climate change impact study average grain yield of all *T. Aman* varieties (as reported in BBS records) cultivated in the tested locations was considered as ideotypic response of variety. The predicted yield of *T. Aman* rice based on climatic parameters was computed as:

$Y_{T.\ Aman} = \alpha_1 T_{max} + \alpha_2 T_{min} + \alpha_3 RF + \alpha_4 SSH + C$ ---- (3)
where,
$Y_{T.\ Aman}$ = Yield of *T. Aman* rice in t ha^{-1}
T_{max} = Average maximum temperature (^oC) from June to November
T_{min} = Average minimum temperature (^oC) from June to November
RF = Total rainfall (mm) from June to November
SSH = Average sunshine hours (hrs) from June to November
C = Error term
t = Time (i.e. year)
$\alpha_1, \alpha_2, \alpha_3$ and α_4 = Regression coefficients

3. Results and Discussion

Table 1 shows descriptive statistics of *T. Aman* rice yield and seasonal climatic elements aggregated over the years from 1971 to 2010. The average rice yield in wet season varied from 2.39 to 2.64 t ha^{-1} (having range of 1.35-3.78 t ha^{-1}), which exposed to average maximum and minimum temperatures of 31.17-31.99°C and 23.67-24.21°C, respectively. These temperature ranges were favorable for good *T. Aman* harvest. Though average rainfall (1243-1813 mm) was adequate for *T. Aman* rice, minimum (637 mm) and maximum (3033 mm) rainfall years were very much unfavorable for rice culture. This means *T. Aman* crop suffered from droughts in some years and floods in the other years resulting in yield losses. Sunshine hours varied consistently over the study areas with a range of 4.00 to 9.30 hrs per day.

3.1 T. Aman rice area and yield trends

In general, *T. Aman* rice area showed mixed trend of increase or decrease, except for Rajshahi where continuous decreasing trend was observed but grain yield increased from 1981 to 2010 (Table 2) because of adoption of modern high yielding varieties, improved fertilizer and cultural managements and use of supplemental irrigation water. The share of *T. Aman* rice to total rice production is 38% in Bangladesh (BBS, 2013) and its contribution will be changed if temperature, rainfall and sunshine duration changes in future (IPCC, 2013).

3.2 Annual and seasonal temperature patterns

The Mann-Kendall trend test showed a significant increase in maximum and mean temperatures. Sen's slope showed increase in average annual maximum, minimum and mean temperatures by 0.001°C $year^{-1}$, 0.016°C $year^{-1}$ ($Z = 3.20$, $p<0.001$) and 0.009°C $year^{-1}$ ($Z = 2.52$, $p<0.05$), respectively from 1971 to 2010 (Figure 1). However, wet seasonal maximum, minimum and mean temperatures increased by 0.0174°C $year^{-1}$ ($Z = 3.85$, $p<0.001$), 0.0083°C $year^{-1}$ and 0.0129°C $year^{-1}$ ($Z = 3.53$, $p<0.001$), respectively. Increasing trend of maximum temperature in wet season might be responsible for higher evapo-transpiration rate along with exposure of drought in study locations. Shahid (2010) also reported increased annual mean and minimum temperatures by 0.005°C $year^{-1}$ and 0.013°C $year^{-1}$, respectively during 1958-2007. Hasan and Rahman (2013) showed that maximum temperature was increasing by 0.005°C $year^{-1}$, with maximum increase in November (0.02°C $year^{-1}$). Minimum temperature was also increasing by 0.014°C $year^{-1}$, but the highest increase (0.027°C $year^{-1}$) was observed in February. The analysis was done on yearly basis, whereas for making simple presentation we have presented the decadal trend in Table 2.

In 2050 wet season, maximum temperature in the study region is likely to increase by 0.42 to 1.51°C compared to 2001-2010 depending on RCPs but it would be 0.79 to 1.57°C for minimum temperature and 0.61 to 1.21°C for mean temperature (Table 3). At the end of this century, maximum temperature is likely to increase by 0.25 to 3.58°C and minimum by 0.41 to 3.75°C with an average of 0.36 to 3.66°C depending on RCPs (Table 3). In both the projected years, increase in minimum temperature is rapid compared to maximum temperature. Increase in minimum temperature is more alarming for crop production due to increased respiratory loss and greater water demand. Agarwala *et al.* (2003) reported that annual temperature will be increasing by 1.0°C, 1.4°C and 2.4°C, respectively during 2030, 2050 and 2100 in Bangladesh; whereas wet season temperature will be increasing by 0.8°C, 1.1°C and 1.9°C, respectively for the same years. Our findings are almost similar to Agarwala *et al.* (2003). Based on data from 1961 to 1990, Karmakar and Shrestha (2000) reported that the projected annual maximum temperature in Bangladesh will increase by 0.4 and 0.73°C in 2050 and 2100, respectively, which is also similar but lower to our findings.

Table 1. Descriptive statistics of historic *T. Aman* rice yield and some weather variables (1971-2010) in north-west region of Bangladesh

Statistics	Yield ($t\ ha^{-1}$)				Maximum temperature (^oC)				Minimum temperature (^oC)				Rainfall (mm)				Sunshine hours			
	Raj	Din	Rang	Bog.	Raj.	Din.	Rang.	Bog.	Raj.	Din.	Rang.	Bog.	Raj.	Din.	Rang.	Bog.	Raj.	Din.	Rang.	Bog.
Mean	2.41	2.39	2.57	2.64	31.99	31.35	31.17	31.76	24.08	23.67	23.68	24.21	1243	1646	1813	1458	6.03	6.93	5.86	5.87
Std. dev.(±)	0.74	0.50	0.43	0.53	0.45	0.55	0.55	0.54	0.45	0.39	0.50	0.39	289	458	447	358	0.46	1.10	0.56	0.60
Maximum	3.78	3.73	3.37	3.76	33.5	33.42	33.48	32.78	25.38	24.78	24.62	25.25	1869	2847	3033	2325	7.13	9.30	7.35	7.28
Minimum	1.35	1.63	1.80	1.59	30.87	30.43	30.40	30.45	23.22	22.70	21.85	23.27	637	901	967	758	4.88	4.00	5.02	4.87
Skewness	0.34	0.88	0.17	0.01	-0.15	1.32	2.01	-0.25	0.23	0.16	-1.26	0.30	-0.10	0.76	0.57	0.45	0.18	-0.30	0.81	0.49
Kurtosis	-1.17	0.49	-1.04	-1.06	1.32	4.05	7.14	-0.01	0.50	1.27	3.44	0.31	-0.35	0.50	0.88	-0.44	0.98	1.25	0.70	-0.44

Raj. = Rajshahi, C. Nawabganj, Natore and Pabna, Din. = Dinajpur, Nilphamari, Thakurgaon and Panchagarh, Rang. = Rangpur, Gaibandha, Kurigram and Lalmonirhat, Bog. = Bogra, Joypurhat, Naogaon and Sirajganj

Table 2. Decadal changes in cultivated area of *T. Aman* rice and yield in north-west region of Bangladesh

Year	Rajshahi region				Dinajpur region				Rangpur region				Bogra region			
	Area (ha)	GR yr^{-1}	Yield ($t\ ha^{-1}$)*	GR yr^{-1}	Area (ha)	GR yr^{-1}	Yield ($t\ ha^{-1}$)	GR yr^{-1}	Area (ha)	GR yr^{-1}	Yield ($t\ ha^{-1}$)	GR yr^{-1}	Area (ha)	GR yr^{-1}	Yield ($t\ ha^{-1}$)	GR yr^{-1}
1970-71	462591	-	1.896	-	361660	-	1.889	-	520972	-	2.107	-	266478	-	1.973	-
1979-80	423324	-4363	1.672	-0.025	344387	-1919	1.887	0.000	543154	2465	2.203	0.011	256158	-1147	2.044	0.008
1989-90	408269	-1506	2.482	0.081	438425	9404	2.611	0.072	590684	4753	2.719	0.052	235243	-2092	2.925	0.088
1999-00	392980	-1529	3.055	0.057	418976	-1945	2.256	-0.036	580972	-971	3.050	0.033	234777	-47	2.819	-0.011
2009-10	388760	-422	3.783	0.073	443973	2500	3.735	0.148	546369	-3460	3.295	0.025	246513	1147	3.199	0.038

* Paddy (Adopted from BBS, 1973, 1982, 1991, 2001 and 2011), GR= Growth rate

Table 3. Projections for changes in *T. Aman* seasonal temperature and rainfall in north-west region of Bangladesh based on 2001-2010

Year	RCPs	Temperature change (°C)			Average rainfall change (%)
		Tmax	Tmin	Tmean	
2050	RCP2.6	0.62 (1.6)	0.79 (1.8)	0.72 (1.7)	30.03 (8.9)
	RCP4.5	1.51 (1.4)	1.34 (2.3)	1.20 (1.8)	28.28 (12.5)
	RCP6.0	0.42 (1.8)	0.81 (1.7)	0.61 (1.7)	22.63 (7.8)
	RCP8.5	0.98 (2.1)	1.57 (2.3)	1.21 (2.2)	17.82 (10.2)
2100	RCP2.6	0.25 (1.8)	0.41 (2.6)	0.36 (2.3)	44.78 (8.8)
	RCP4.5	1.33 (2.2)	1.75 (1.9)	1.56 (2.0)	49.71 (9.7)
	RCP6.0	2.03 (2.3)	2.12 (2.5)	2.02 (2.4)	10.10 (6.8)
	RCP8.5	3.58 (2.6)	3.75 (2.8)	3.66 (2.7)	35.58 (10.5)

Figures in the parentheses indicate standard deviation (±).

Shahid (2011) projected that mean temperature is likely to increase by 0.8°C in 2025, 1.4°C in 2050, 1.9°C in 2075 and 2.4°C in 2100. In 2100, the minimum increase in mean temperature would be about 1.4°C in July that is closer to our findings. Our investigation reveals that increase in temperature in north-west region of Bangladesh would be lower than projected by others (Karmakar and Shrestha, 2000; Agarwala *et al.*, 2003; Shahid, 2011; IPCC, 2013). Most of these reports are based on global climate models (General Circulation Models) outputs, which usually require accurate regional calibration and vary depending on models. Historically, mean annual temperature was at around 25.17°C and average minimum and maximum temperatures were 19.98°C and 30.36°C, respectively. Similarly, mean annual, minimum and maximum temperatures during wet season were 27.74°C, 23.91°C and 31.57°C, respectively. Mean annual temperature in Rajshahi region was about 25.75°C and mean minimum and maximum temperatures were 20.83°C and 30.87°C, respectively. High temperature (as high as 45.1°C) is generally observed in April and May and the lowest (3.4°C) in January.

Decrease in rice yield due to higher temperature is mainly associated with reduced growth duration of a crop (Shahid, 2011). The other reasons could be greater respiration loss and increased evaporative demand.

3.3 Annual and seasonal rainfall patterns

Average annual rainfall of the study region increased by 1.38 mm year^{-1} and wet season rainfall increased by about 0.7266 mm year^{-1} (Figure 2). The average wet season rainfall in north-western region of Bangladesh varied from 1243 to 1813 mm (Table 1), which is sufficient if it is uniformly distributed in wet season. But, in some years it is as low as 637 mm and distribution is not also uniform. Long-term (1971-2010) rainfall data revealed that both annual and wet seasonal rainfall was slightly increasing in trend (Figure 2). Supplemental irrigation was essential in those low rainfall years for successful *T. Aman* rice production.

Hussain (2011) reported increased rainfall during March through November in both 2050 and 2070 A.D. Shah *et al.* (2013) reported changing precipitation patterns. Our findings also revealed very much fluctuating rainfall patterns. Rainfall in wet season is likely to be increased and thus might create flooding situation in wet season, which may influence in *T. Aman* rice production (Table 3).

3.4 Annual and season-wise sunshine hour

Annual average sunshine hours in study locations were decreasing ($Z = -6.05$, $p<0.001$). Sen's slope estimator showed annual sunshine hour decrease of 0.027 hrs year^{-1} from 1971 to 2010; but wet season sunshine hours decreased by 0.0259 hrs year^{-1} ($Z = -4.82$, $p<0.001$) for the same period (Figure 3). Sunshine hour is decreasing at a continuous rate per year, which is primarily because of increased suspended particulate matter (SPM) and aerosols concentration in the atmosphere. Our findings are in agreement with the works in South Asian Region under Atmospheric Brown Cloud Project of UNEP (Kalra *et al.*, 2006).. Shah *et al.* (2013) also reported decreased annual sunshine hours by about 5.3% per decade. These indicate that there would be reduction in *T. Aman* rice yield because of reduced sunshine hours. In general, sufficient and quality sunlight is needed for increased production of tillers and panicles (Shi *et al.*, 2002). So, radiation-use efficient varieties are to be developed for the farmers in future.

3.5 Inter-seasonal climatic variability effects on T. Aman rice yield

Average maximum temperature of study regions varied from 31.17 to 31.99^{o}C and average rice yield varied from 2.39 to 2.64 t ha^{-1} (Table 1). If maximum temperature increases by 1^{o}C, *T. Aman* rice yield is likely to decrease by 10.94% i.e. about 0.27 t ha^{-1} (Figure 4a). Since north-western part of the country is relatively hotter during wet season, even relatively lower increase in maximum temperature would cause noticeable yield reduction because of increased evapo-transpiration, increased respiratory activities and thus reduced net assimilates available for growth and reduced growth duration of *T. Aman* rice. On the contrary, average minimum temperature in the study regions varied from 23.673 to 24.21^{o}C (Table 1). Wet season minimum temperature was in increasing trend (Figure 1). If minimum temperature increases by about 1^{o}C, *T. Aman* rice yield would be reduced by 6.72%, i.e. about 0.17 t ha^{-1} (Figure 4b).

Mean temperature during wet season was increasing in trend (Figure 1). If mean temperature increases by about 1^{o}C, *T. Aman* rice yield reduction would be 14.83% i.e. about 0.37 t ha^{-1} (Figure 4c), which is very much similar to the findings of Mabe *et al.*, 2014. Under elevated temperature of 2^{o}C and 4^{o}C, the grain yield was 13.3 and 23 percent less than ambient temperature (Rani and Maragatham, 2013). The country is predicted to experience an increase in average temperature of 1.4^{o}C by 2050 and consequently, the rice production is likely to decline by 8-17% (IPCC, 2007). According to IPCC estimates, increasing temperature and changing rainfall pattern along with flooding, drought and salinity, Bangladesh might face a decline in crop production by 2050. Against 1990 base year, the predicted declines were 8% in rice and 32% in wheat (MoEF, 2009).

Seasonal rainfall was slightly increasing in north-western part of Bangladesh (Figure 2). Effect of seasonal total rainfall on *T. Aman* rice yield was insignificant (Figure 4d). Water demand was fulfilled through supplemental irrigation in most cases. So, decrease in rainfall has not yet been created any yield loss in north-west region of the country.

Seasonal sunshine hours were in decreasing trend (Figure 3). If sunshine hour decreases by 1 hour, *T. Aman* rice yield is likely to decrease by 8.17% i.e. about 0.20 t ha^{-1} (Figure 4e). Shah *et al.* (2013) reported 3.4% reduced wet season sunshine hour per decade indicating its negative effect on rice yield. They also reported reduced grain yield and yield components with the reduction of solar radiation. Combined effect of average maximum and minimum temperatures and sunshine hours on rice yield was computed through multiple regression analyses. Predicted rice yield was in close agreement with the observed yield (Figure 5). Our analyses indicate that increase in temperature and reduction in sunshine hours would play an important role for reduction of *T. Aman* rice yield in future. The model has an F-value of 12.65 with a p-value of 0.000 indicating that overall model result was statistically significant at 1% level of probability. About 25% of the variations in *T. Aman* rice yields are explained by climatic variables. The t-value of average maximum temperature was 4.27 and for average sunshine hours was -4.88, which were statistically significant at 1% level of probability.

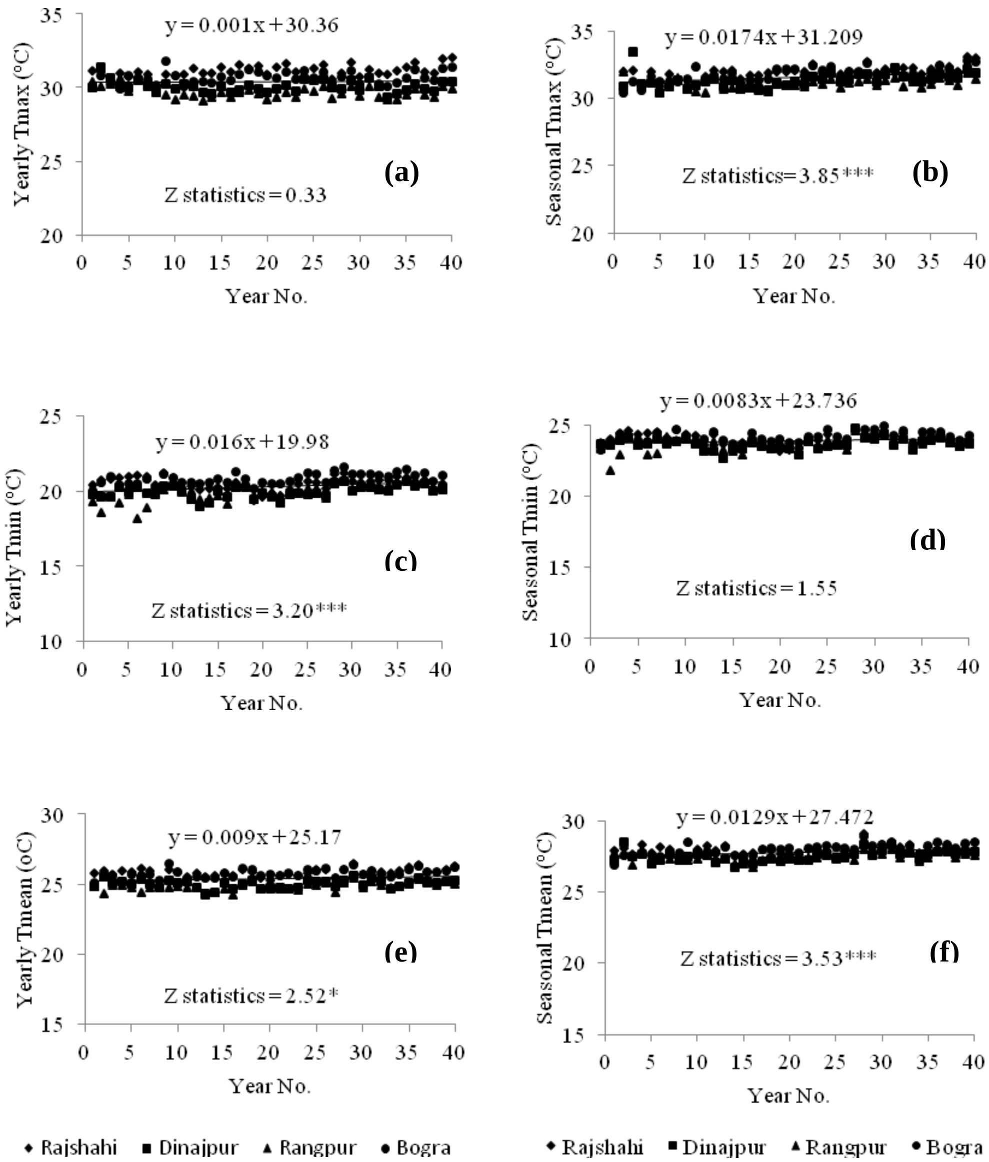

Figure. 1. Observed trends in average yearly and *T. Aman* seasonal temperature: (a & b)-maximum, (c & d)- minimum and (e & f)- mean in north-west region of Bangladesh. Year no. starts from 1971 (* $p < 0.05$; ** $p<0.01$; *** $p<0.001$)

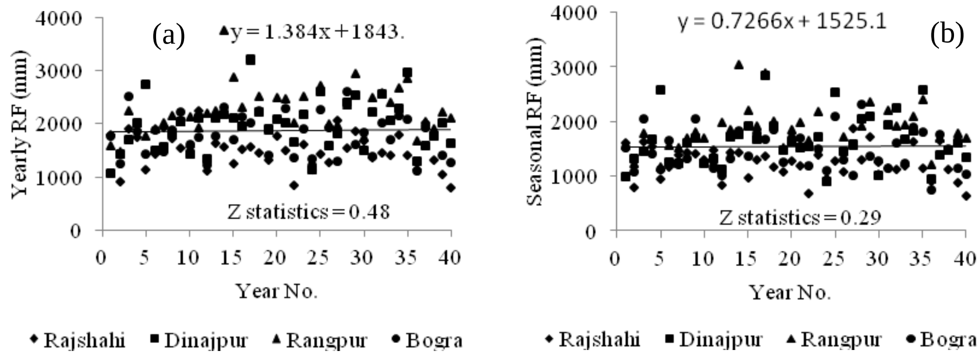

Figure 2. Observed trends in rainfall: (a)- yearly and (b)- *T. Aman* season in north-west region of Bangladesh. Year no. starts from 1971

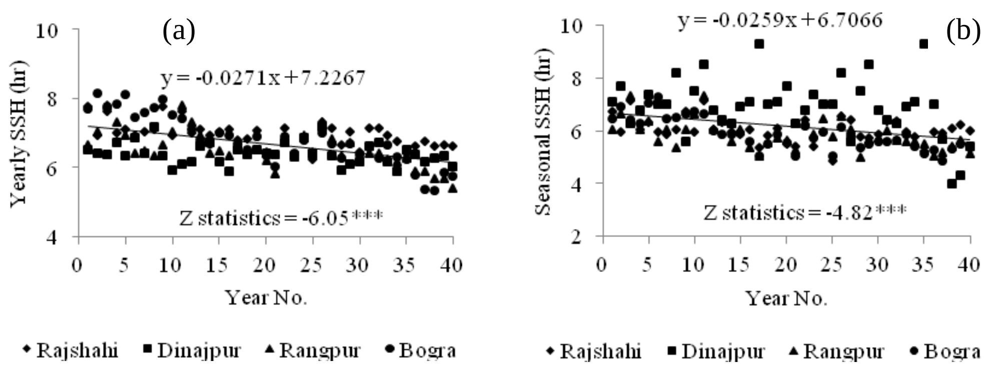

Figure 3. Observed trends in average sunshine hours: (a)- yearly and (b)- *T. Aman* season in north-west region of Bangladesh. Year no. starts from 1971 (* $p < 0.05$; ** $p<0.01$; *** $p<0.001$)

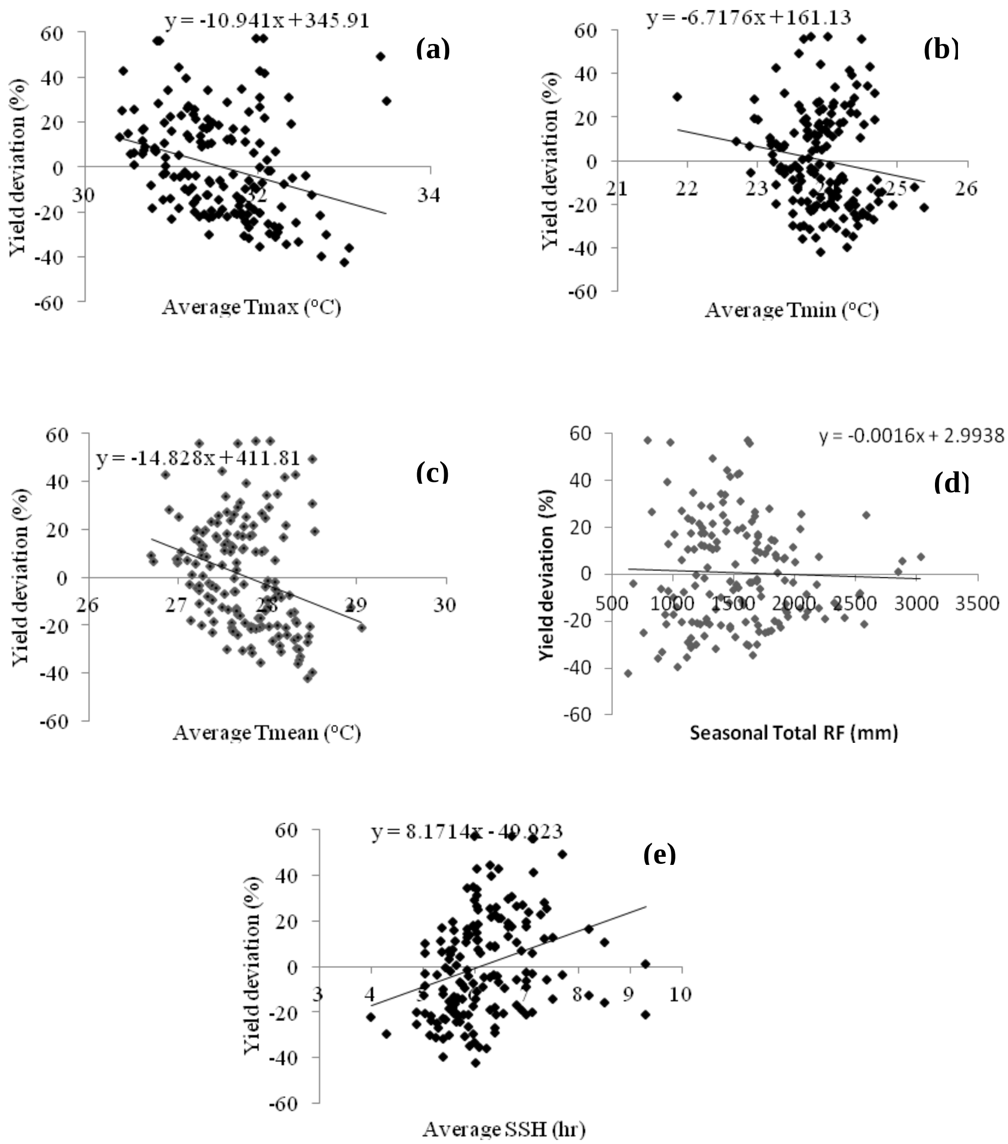

Figure 4. Relationship of percent deviation in *T. Aman* rice yield with seasonal (a) maximum, (b) minimum and (c) mean temperatures, (d) total rainfall and (e) avrerage sunshine hours in north-west region of Bangladesh

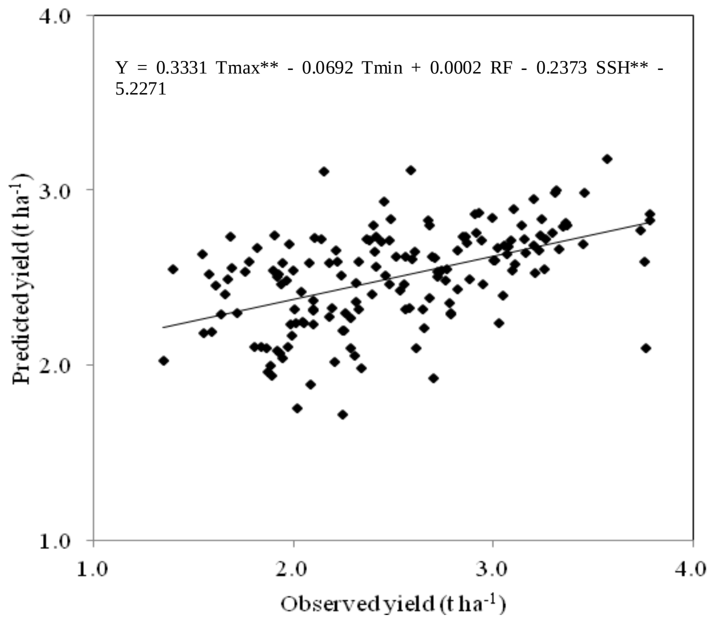

Figure 5. Multiple regression of maximum (Tmax) and minimum (Tmin) temperatures, total rainfall (RF) and sunshine hours (SSH) on *T. Aman* rice yield in north-west region of Bangladesh

4. Conclusions

The trend line analyses were done based on annual and seasonal climatic variables following MAKESENS model. Historical weather data of north-west parts of Bangladesh showed inter-annual and inter-seasonal variabilities. This indicates that climate change occurred in terms of increased temperatures, rainfall and reduction in sunshine hours. Increase in minimum temperature and decrease in sunshine hours are likely to reduce *T. Aman* rice yields in north-west part of Bangladesh. The study clearly indicates the usefulness of the regression based approach for evaluating the impact of climatic variability through yield of *T. Aman* rice. However, to make the characterization more realistic, there is a need to include other unaddressed biotic and abiotic factors in future, where simulation models could play an important role.

5. Acknowledgement

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