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Effect of temperature variation on *Aman* and *Boro* rice production of Barisal division in Bangladesh

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Abstract

A study was undertaken to study the impact of seasonal temperature variation on *Aman* and *Boro* rice production in Barisal division of Bangladesh. The study revealed that the relationship between changing patterns of seasonal mean temperature and yield of rice, which illustrates the average mean temperature for the correlation of time series data from 1958-2008. The regression model is used to analyze the different temperature trends, and to identify the possible factors and causes of these differences. The value of t-statistic for slope and p-value for different regression equations are estimated. Results show that the average maximum temperature is risk increasing for *Boro*, while it is risk decreasing for *Aman* for the period of 2006-2008. Besides, minimum temperature is risk increasing for *Boro* during 1994-2008 but it is risk decreasing for *Aman* except the year 1998. We observed that the summer temperature has been rising up during the period 1958-1974 and fallen down for 1992-2008. The average annual temperature changes from 0.5˚C to 1˚C over the period from 2005 to 2008 which impact on *Aman* and *Boro* rice yield. Therefore, the predictive approach provides an outline for future risk of the minimum temperature that has the impact on rice yield than maximum temperature, which can be used for rice production for its better management strategies.

Key words: Climate change, rice yield, regression model, temperature variation

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Introduction

Global warming has been a burning issue in recent times all over the world. Climate change is a major concern in Bangladesh. The variation of temperature that affects crop production over long periods and covers an extensive area of the country (Rivington et al. 2011). Bangladesh is traditionally classified into six seasons such as summer, rainy, autumn, late autumn, winter and spring. The seasons of Bangladesh regulate its economy, communication, trade and commerce, art and culture, and in fact, the entire lifestyle of the people. The effects of temperature have been increasing since 1958 and more quickly from 1974 over the country. The variation of temperature is characterized by local meteorological record data of the air temperature. January is the coldest month of average temperature of around 10°C and April is the warmest month of average temperature of around 30°C although the average temperature varies in different regions of the country.

The influence of higher air temperature and CO_2 on crop yield has been increased dramatically over the last 17 years period. Some researchers (Karim et al., 1996; Mahmood, 1998; Basak et al., 2010) used CERES-Rice model and the DASSAT model, to estimate the effects of climate variability in rice production of Bangladesh. Besides, the regression models areused over historical data to find a relationship between climate variables and crop yield (Isik et al. 2006). But they did not observe any changing pattern of seasonal temperature of different period of times in a region. Also time series data were analyzed in other articles, but they did not address the temperature variation on rice yield in Barisal. For example, Mote et al. (2018) observed that the effect of minimum temperature on rice yield was less as compared to maximum temperature in middle Gujrat. Sur et al. (2018) examined the time series data of Western Rajasthan and Gujarat region of India.

The monthly maximum temperature has increased 1.1˚C per 50 years at Dhaka division and monthly minimum temperature has decreased 0.2˚C per 50 years at Rajshahi division. It has clearly observed that the maximum temperature has been increased dramatically, but minimum temperature decreases slowly. The average temperature varies around 17˚C in the northwest and northeastern parts, and 20˚C to 21˚C in the coastal areas in January. And the average minimum temperature varies from 3˚C to 4˚C in January.

Recently, the solubility of oxygen in water decreases with higher temperature in irrigation and fisheries sectors reported by Asian Development Bank (ADB) (2004). In dry season, the water flow of the river is decreased. Temperature in winter season reduces the production of wheat and potatoes. Climate change impacts on irrigation requirements for all three cropping seasons: Rabi, Kharif-I, and Kharif-II. In winter season, Barisal has much less rainfall than summer season. Also this area has the average annual temperature around 25.9°C. Barisal was known as “Crop house of Bengal” for her tremendous rice producing region of the country. Total crop land of Barisal region is 16,88,779 ha where single cropped area is 20.02%, double cropped area is 43.99% and triple cropped area is 27.91%. Average agricultural land use intensity of Barisal region is 89%. Severely during *Boro* rice cultivation, some parts of Patuakhali, Pirojpur, Barguna and Bhola face cyclone and tidal surges is very common in this region.

The main objective of this study is to contribute the effects of temperature changes on the yield and variability for two main rice crops using panel data. The results provide further information about the possible yield losses which will occur with future changes of temperature. The effect of climate change (i.e. maximum temperature, minimum temperature) on rice production will vary among the climate zones.

Materials and Methods

The temperature datasets used in this work were taken from the Bangladesh Meteorological Department (BMD). The average daily maximum and minimum temperature data of the last fifty-one years (1958-2008) has been collected from different weather stations located all over the Bangladesh. Also rice production data are collected from the Statistial Office of Bangladesh Bureau of Statistics (BBS). In this study, we analyzed the temperature data in Barisal division of Bangladesh. The location of climatic regions of Bangladesh as shown in Figure 1. These weather stations are situated in the city center of the region.

There are many statistical methods for calculating trends such as parametric methods (regression and t-test) and non-parametric methods (Mann-Kendall test). This study we employed regression method and t-test (David et al. 1997; Thomas et al. 1993). The values of t-statistic are estimated for slope and p-value for different regression equations in Barisal division during six Bengali seasons in Bangladesh. First, a linear model was fitted to detect the temperature trend of a regression equation,

$$y = mt + c \qquad (1)$$

Where ‘m’ is the slope of the trend line, and ‘c’ is the intercept of trend line with y-axis.

The coefficient of determination (R^2) is a key output of a regression model which interpreted as the proportion of variance in the dependent variable that is predictable from the independent variable. The coefficient of determination (R^2) for a linear regression model with one independent variable is:

$$R^2 = 1 - \frac{SSE}{SST} \quad (2)$$

Where, SSE denote the sum of squared errors of our regression model and SST denote the sum of squared errors of our baseline model are:

$$SSE = \sum_{i=1}^{n}(y_i - \widehat{y_i})^2 \quad (3)$$

$$SST = \sum_{i=1}^{n}(y_i - \overline{y_i})^2 \quad (4)$$

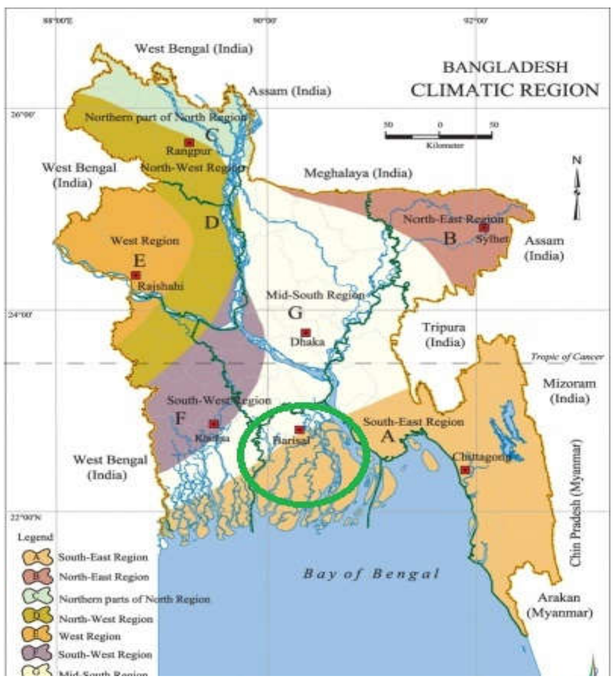

Figure 1. The location of climatic region of Bangladesh (banglapedia.org).

The long-term trend could be inferred from the slopes of these straight lines. Two tailed t-test was applied to test the statistical significance of the trends at 5% significance level. The test statistics t for testing the null hypothesis H_0: P=0.5 against the alternative hypothesis H_1: P≠0.5, is given by:

$$t = \frac{\bar{x} - \mu_0}{S/\sqrt{n}} \quad (5)$$

Where $\bar{x}$ = Sample mean, $\frac{S}{\sqrt{n}}$= Standard deviation, μ_0= Population mean.

The magnitude of this long term change can also be calculated from this model. The analysis can be divided into three steps such as 1958-1974, 1975-1991 and 1992-2008, respectively to estimate the temperature trends in the growing seasons. The relationship between the seasonal temperature variation and yield are always linear since it has limited effects over these factors.

Results and Discussion

The average temperature of three different periods during six Bengali seasons in Barisal division was presented in Figure 2. The descriptive statistic for temperature variation and yield in different periods of time shows in Table 1. We observe the exact trends in climatic variables (i.e., maximum temperature, minimum temperature) by estimating a linear trend model with time (t) as an explanatory factor over the whole period.

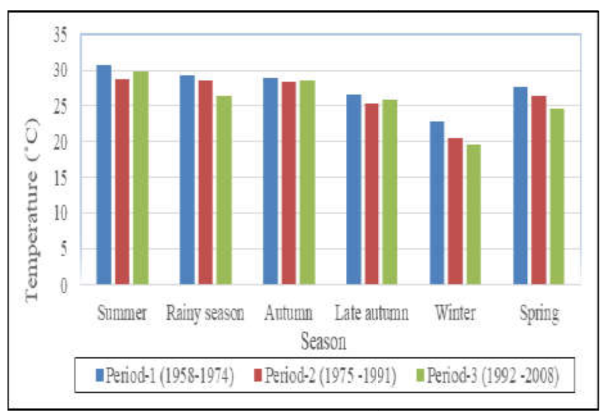

Figure 2. The average temperature of three periods during six Bengali seasons.

The value of t-statistic for slope and p-value for different regression equations is represented in Table 2 during six seasons. The average maximum temperature positively influences at autumn, summer and rainy season in the period 1975-1991 and negatively affected at the late autumn season of all the periods. Besides, the average minimum temperature negatively influence at winter season in period 1991-2008.

Table 1. Descriptive statistics for average temperature variation and yield in different periods.

Variables	Period-1 (1958-1974)			Period-2 (1975-1991)			Period-3 (1992-2008)		
	Mean	**Std. Dev.**	**Variance**	**Mean**	**Std. Dev.**	**Variance**	**Mean**	**Std. Dev.**	**Variance**
aMaxTemp	28.50	0.62	0.30	29.61	0.73	0.45	30.50	0.84	0.66
aMinTemp	18.22	0.84	0.46	19.45	0.56	0.58	22.52	0.75	0.35
Yield-*Aman*	0.72	0.66	0.42	0.85	0.56	0.12	1.75	0.96	0.55
Yield-*Boro*	0.81	0.72	0.45	1.45	0.55	0.08	2.04	1.12	0.45

Note: aMinTemp means average minimum temperature (^{0}C), aMaxTemp means average maximum temperature (^{0}C), **Source:** Authors own estimation based on BMD and BBS.

Table 2. Result of t-statistic for slope and p-value for different regression equations.

Parameter	Season	Period	Regression equation	T-statistic	P value	Sig. (%)
Daily average temperature	Summer	(1958-1974)	$y = -0.11\ t + 30.26$	-2.828	0.010	$(-)*$
		(1975-1991)	$y = 0.03\ t + 28.26$	2.304	0.035	$(+)*$
		(1992-2008)	$y = 0.02\ t + 28.68$	1.299	0.212	$(+)*$
	Rainy season	(1958-1974)	$y = -0.05\ t + 28.66$	0.937	0.362	$(+)*$
		(1975-1991)	$y = 0.04\ t + 27.74$	-2.034	0.059	$(-)*$
		(1992-2008)	$y = 0.01\ t + 28.19$	-0.662	0.517	$(-)*$
	Autumn	(1958-1974)	$y = -0.04\ t + 28.51$	0.585	0.567	$(+)*$
		(1975-1991)	$y = 0.01\ t + 27.93$	-1.243	0.232	$(-)*$
		(1992-2008)	$y = 0.004t + 27.91$	0.580	0.570	$(+)*$
	Late autumn	(1958-1974)	$y = -0.06\ t + 24.45$	1.203	0.247	$(+)*$
		(1975-1991)	$y = -0.03\ t + 23.82$	-0.745	0.467	$(-)*$
		(1992-2008)	$y = -0.01\ t + 23.73$	0.974	0.344	$(+)*$
	Winter	(1958-1974)	$y = -0.08\ t + 20.18$	2.039	0.058	$(+)*$
		(1975-1991)	$y = 0.03\ t + 18.35$	0.904	0.380	$(+)*$
		(1992-2008)	$y = 0.03\ t + 18.36$	2.483	0.024	$(+)*$
	Spring	(1958-1974)	$y = -0.09\ t + 26.47$	0.814	0.428	$(+)*$
		(1975-1991)	$y = 0.02\ t + 25.19$	-0.186	0.855	$(-)*$
		(1992-2008)	$y = 0.01\ t + 25.33$	0.562	0.582	$(+)*$

Note: (+) indicates increasing trend; * indicate significance level 5%.

Graphs are provided those demonstrate the variations of temperature with comparisons of different time periods (Figure 3-8). The growing season of *Aman* rice is July-December (rainy season, autumn, late autumn) and *Boro* rice is January-June (winter, spring, summer) (BBS, 2017). This method is for the assesses the impact of temperature variation on seasonal *Aman* and *Boro* rice model. In Figure 9 represent the **e**ffect of annual mean temperature on rice yield of the growing season in Barisal. To describe the effect of temperature on *Aman* and *Boro* rice yield is statistically significant at the 5% level. Besides, the seasonal average minimum temperature has a positive impact that reduces the yield of *Aman* rice.

The seasonal average maximum temperature has a positive impact that could not influence the yield of *Aman* rice since the coefficient of aMaxTemp is statistically insignificant. Further, the yield of *Aman* rice is 0.72 ton/ha, 0.85 ton/ha, and 1.75 tons/ha in period-1, period-2, and period-3, respectively are increasing dramatically. Otherwise, the seasonal average minimum temperature has negative impact that reduces the yield of *Boro* rice. Also the seasonal average maximum temperature has a positive impact that could not influence the yield of *Boro* rice since the coefficient of aMaxTemp is statistically insignificant. Further, the yield of *Boro* rice is 0.81 ton/ha, 1.45 ton/ha, and 2.04 ton/ha in period-1, period-2, and period-3, respectively are increasing dramatically. The temperature variation (i.e., cold trend of the dry season and hot trend in the rainy season) may be due to the decrease and increase of latent heat flux for summer and winter seasons, respectively. The average temperature of Bangladesh ranges from 17°C to 20.6°C during winter and 26.9°C to 31.1°C during summer (Shahid 2008). Also the average annual temperature increase by 1.4 ± 0.6°C by 2050 (Ramamasy et al. 2007) and the average monthly temperature might continue to rise invariably every month. We observed that the linear trend in the average temperature increasing 0.5°C in January whereas it can be 0.4°C in July.

Summer season occurs from mid-April to mid-June, when the days are hot and dry. But from mid-March, the effect of this season is generally feels. This time some natural disaster occurs such as *kalbaishaki* strom. The average minimum temperature ranged from 25.5˚C to 27.5˚C and the average maximum temperature ranged from 29.5˚C to 30.9˚C at summer season in Barisal division are shown in Figure 3. Also the values of the coefficient of determination, R-square (R^2) shows that the variation of rice yield with climate factors (temperature) are 0.44, 0.11, and 0.06, respectively in different period of time. Monthly minimum, maximum, and mean temperature has shown a positive increase with a rate of 3.98˚C, 4.59˚C, and 3.46˚C, respectively.

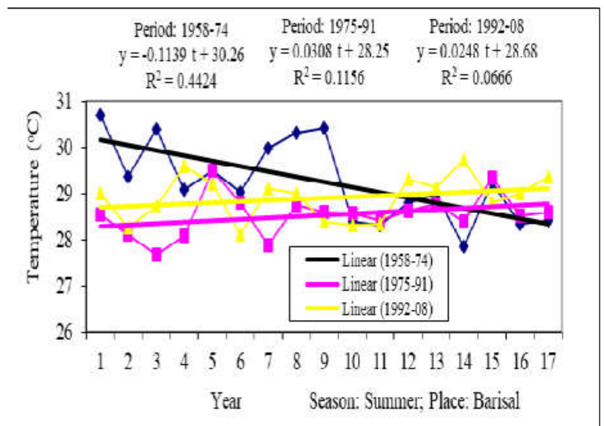

Figure 3. Seasonal yearly temperature during the summer in Barisal.

Rainy season starts from mid-June and ends mid-August. The average total rainfall during the rainy season from 70 to 80 percent of the total annual rainfall and most of the places remain inundated during this period. The average minimum temperature ranged from 25.5˚C to 27.5˚C and the average maximum temperature ranged from 28.5˚C to 29.5˚C at rainy season in Barisal division are shown in Figure 4. Also the values of the coefficient of determination, R-square (R^2) shows that the variation of rice yield with climate factors (temperature) are 0.343, 0.342, and 0.072, respectively in different period of time. Monthly minimum, maximum, and mean temperature has shown a positive increase with a rate of 1.87˚C, 3.54˚C, and 1.14˚C, respectively during the period of last 17 years.

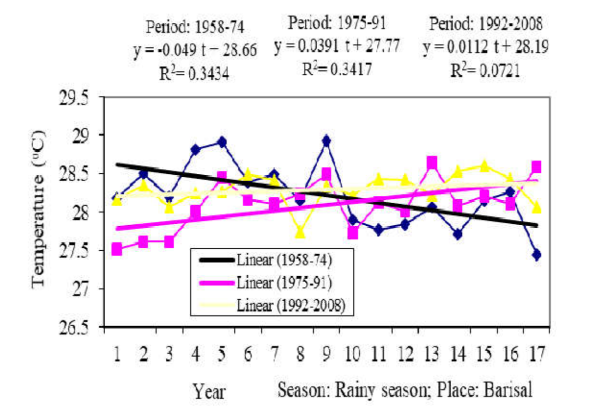

Figure 4. Seasonal yearly temperature during the rainy season in Barisal.

Autumn season consists of the month mid-August to mid-October. The average minimum temperature ranged from 25.6˚C to 27.3˚C and the average maximum temperature ranged from 27.14˚C to 28.95˚C at an autumn season in Barisal division are shown in Figure 5.

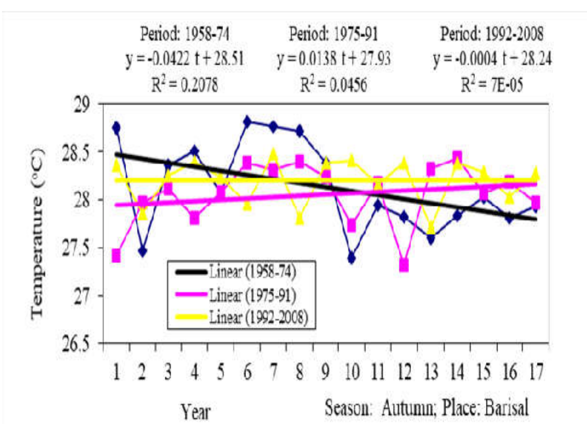

Figure 5. Seasonal yearly temperature during the autumn in Barisal.

Also the values of the coefficient of determination, R-square (R^2) shows that the variation of rice yield with climate factors (temperature) are 0.208, 0.046, and 0.000007, respectively in different period of time. The monthly average minimum temperature, maximum temperature, and mean temperature show the positive trend over Bangladesh. The maximum temperature are increased in September at 2.05˚C, minimum temperature are increased in October at 2.73˚C, and mean temperature are increased at 0.79˚C. Monthly minimum, maximum, and mean temperature has shown positive increase with a rate of 2.98˚C, 4.49˚C, and 2.06˚C, respectively during the period of last 17 years (1991-2008).

Late autumn season consists of the month mid-October to mid-December. The average minimum temperature ranged from 20.1˚C to 21.8˚C and the average maximum temperature ranged from 24.14˚C to 27.25˚C in late autumn season in Barisal division are shown in Figure 6. Also the values of the coefficient of determination, R-square (R^2) shows that the variation of rice yield with climate factors (temperature) are 0.07, 0.06, and 0.007, respectively in different period of time.

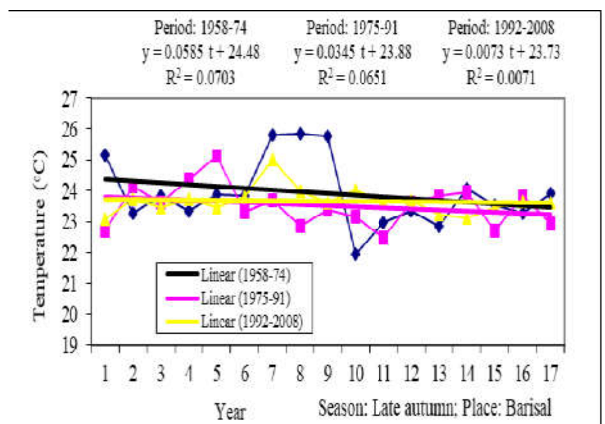

Figure 6. Seasonal yearly temperature during the late autumn in Barisal.

The maximum temperature are increased in November at 1.95˚C, minimum temperature are increased in December at 1.93˚C, and mean temperature was increases at 0.85˚C. Monthly minimum, maximum, and mean temperature has shown a positive increase with a rate of 1.87˚C, 3.92˚C, and 1.01˚C, respectively.

Winter season is the coldest part of the year, in contrasts to all other seasons. These seasons occur from mid-December to mid-February. The average temperature varies from 20˚C to 21˚C in the coastal area. The winter season is very dry, which less than 4 percent of the total annual rainfall of these causes the temperature is less down. The values of the coefficient of determination, R-square (R^2) shows that the variation of rice yield with climate factors (temperature) are 0.07, 0.07, and 0.12, respectively in different period of time. The maximum temperature are increased in December at 1.1˚C, minimum temperature are increased in February at 1.43˚C, and mean temperature was increases at 0.55˚C are represented in Figure 7. Monthly minimum, maximum, and mean temperature has shown a positive increase with a rate of 1.49˚C, 3.99˚C, and 2.1˚C, respectively during the period of last 17 years (1975-1991).

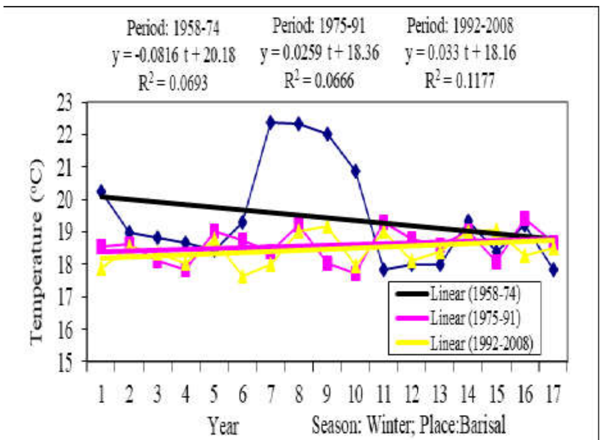

Figure 7. Seasonal yearly temperature during the winter in Barisal.

Spring season occurs between summer and winter, spreads over from mid-February to mid-April. These seasons is a very short time period in Bangladesh and practically prevails during the March month only. The average temperature in March varies from 24˚C to 27˚C all over the country, and the relative humidity from 50 to 70 percent. The climate is very pleasant and inspires people so-called the king of seasons. The temperature variation of spring season in Barisal division is shown in Figure 8. Also the values of the coefficient of determination, R-square (R^2) shows that the variation of rice yield with climate factors (temperature) are 0.27, 0.01, and 0.002, respectively in different period of time. Monthly minimum, maximum, and mean temperature has shown a positive increase with a rate of 2.88˚C, 3.22˚C, and 2.12˚C, respectively during the period of last 17 years (1975-1991).

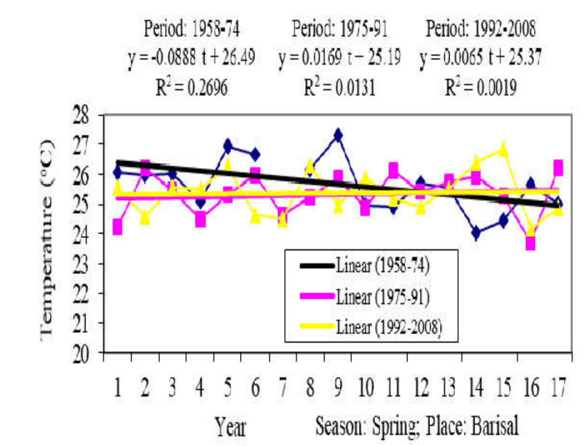

Figure 8. Seasonal yearly temperature during the spring in Barisal.

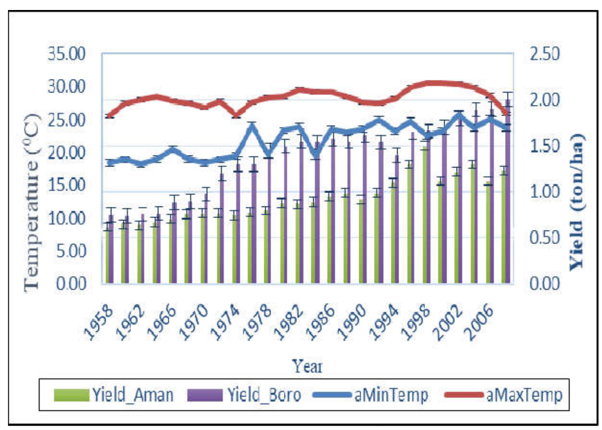

Figure 9. Effect of annual mean temperature on rice yield of the growing season in Barisal.

Results from this paper provide a clear description of temperature change in the different seasons, which can be generalized to a broader area. Knowledge of the key factors that may affect climate change on different levels provides insights that allow the concentration of efforts in areas most likely to be effective to improve the local climate.

Conclusions

In this paper, we have estimated the effects of seasonal temperature variation on rice production based on panel data in Barisal division of Bangladesh. In our estimates, the monthly mean temperature shows a positive trend with respect to time over Barisal division in all the seasons. The average maximum temperature is risk increasing for Boro, while it is risk decreasing for Aman in the period 2006-2008. Besides, minimum temperature is risk increasing for Boro in the period 1994-2008 but it is risk decreasing for Aman except the year 1998. In period 1975-1991, minimum temperature has the positive impact on the winter season but all other seasons have negative impact. Also maximum temperature has the positive impact of all six seasons. The dry season months like December or January might have a greater amount of temperature change around 0.5°C to 0.8°C in 1975-2008. It is evident that the dry winter months in these regions will show relatively more warming in the future. The results suggest that the region wise adaptation policy should be implemented to develop local adaptation policy for reducing yield variability, and ensuring food safety. In the future, district wise effects of climate parameter (i.e. temperature) can be studied instead of the division of the country.

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