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Impact of Climatic Variables on Major Field Crops in *Char* Areas of Mymensingh District

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Abstract
An agro-climatic study was conducted at different areas (Bhatiapara, Kashiar Char and Morichar Char) of Mymensingh district with 25 years of climatic data (i.e., temperature, humidity and rainfall) to observe the climatic variability and their impact on the productivity of three types of crops such as Boro, Jute and Wheat. Production of all the three crops were found as increasing. In Boro season, the production increased by 0.057 ton per hectare per year. Jute production increased by 0.029 ton per hectare and Wheat production increased by 0.067 ton per hectare in each year, respectively. Humidity has influence on seasonal Boro production whereas temperature and rainfall didn't influence the production. Temperature has influences on both Jute and Wheat production. From correlation analysis, it was revealed that average humidity has considerable influence on seasonal Boro production than all other crops. However, most of the time the production showed increasing trend with some exceptions. The study recommends that local adaptation practices should be scrutinized, the role of institutional support should be highlighted and national adaptation strategies and resilience should be strengthened.

Key words: Agriculture, Climate, Climatic variables, Productivity

Introduction

Bangladesh is identified as one of the most vulnerable countries to climate change. There are numerous projections about temperature and sea-level rises and their potential impacts. IPCC estimated that a 0.5 °C increase in mean temperature and a 10cm rise in sea level could lead to inundation of 15 percent (approximately 750 km^2) of the Sundarban forest, the largest mangrove ecosystem in Asia (Intergovernmental Panel on Climate Change-IPCC, 2001).The lofty Himalayas in the North and funnel shaped Bay of Bengal in the south have made Bangladesh a meeting place of the life giving monsoon rains and the catastrophic devastation of floods, cyclones, storm surges, droughts etc. (Paramanik, 1991). Agriculture, irrigated and rain fed, is inherently vulnerable to climatic hazards (Lenka, 1998). Bangladesh, situated in the monsoon region, is dependent for her economy on the activities of season. The summer season is the main rainy season in Bangladesh which accounts for about 72% of the annual rainfall during summer monsoon season (Ahasan *et al.,* 2008). Rainfall can vary considerably even within few distance and different variables over space and time which will have a big effect in determining the kind of crop to be grown, farming system to be adopted and the sequence of farm operations (Adejuwon, 2004). The solar radiation requirement of a rice crop differs from one growth stage to another. Shading during the reproductive and ripening phases caused significant reductions in yield (Islam and Morison, 1992). Increase in sunshine hour increases rice yield to some extent (Basak *et al.,* 2009). Relative humidity is also important which may affect grain formation, ripening and diseases

Sources of data

Daily data of different climatic elements such as maximum temperature (C), average humidity (%),

incidence in rice. High relative humidity favors crop growth through the vegetation stage (Amin *et al.,* 2004). DSSAT (Decision Support System for Agro-technology Transfer) model has predicted significant reduction in *Boro* rice yield due to climate change. Yield reductions of over 20% and 50% have been predicted for the years 2050 and 2070 respectively (Basak *et al.,* 2010). Karim *et al.* (1996) argued that a significant yield reduction may occur in rice (35%) due to changing climatic conditions in the future. Agriculture in Bangladesh is already under pressure, both from huge and increasing demands for food as well as from obstacles related to the degradation of agricultural land and water endowments (Ahmed *et al.* 2000).

Methodology

Location of the study area

Necessary data were obtained from the selected area in order to achieve the objectives set for the research. Some char areas such as Bhatiapara, Kashiar Char and Morichar Char of Mymensingh district have been considered as the study area.

Variables considered

Average seasonal maximum temperature (°C) data of respective crops were calculated instead of total temperature to analyze the impacts of temperature on crops. Total rainfall (mm) data of the season of respective crops were calculated to analyze the impact of rainfall on crops. Seasonal average humidity data was calculated and plotted to analyze the trend and it's correlation with annual yield (t/ha) of the selected areas of Mymensingh district (S.M.S.A. Tuhin *et. al.,* 2015).

Total sunshine (hours) and seasonal total rainfall (mm) at Mymensingh station for the period of January 1994 to December 2018 (i.e. 25 years) were used in this study. Data were collected from Bangladesh

Meteorological Department (BMD), Bangladesh Agricultural University (BAU) station, Khamar Bari, Mymensingh and Bangladesh Bureau of Statistics (BBS).

Analytical techniques

Correlation, regression, trend analysis and data visualization between production data and climatic variables was carried using MATLAB. First tabulated data of yearly production and climatic variables were arranged according to corresponding year. These dataset was imported into MATLAB software as individual column vector. Then the data set is processed, the climatic variables according to crop season were separated and using proper scripts data was analyzed. For correlation coefficient, ´Pearson Correlation Coefficient` (according to row and pairwise) was used. The linear equation (Y = BX+C) was used to analyze climatic data.

Where,

Y	=	Dependent variable such as production;
X	=	Independent variable such as climatic variables (Temperature, Humidity and Rainfall);
B	=	Coefficient; and
C	=	Constant.

Anticipated impacts of climatic variables

In order to identify the anticipated impact of climatic variables influencing average crop production, the following multivariate regression with marginal effect analysis was used (Gujarati, 2003):

$$K_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + E_i$$

Where,

K_i	=	Average crop production (ton/ha).
X_1	=	Temperature (°C);
X_2	=	Rainfall (mm);
X_3	=	Humidity (%);
β_0	=	Intercept;
β_1 to β_3	=	Regression coefficients of the independent variables; and
E_i	=	Error term.

The marginal probabilities of the anticipated impact of climatic variables influencing average crop production were estimated based on expressions derived from the marginal effect of the regression model was as follows:

$$dK/dX = \beta i \ \{P_i (1 - P_i)\}$$

Where,

β_i = Estimated regression coefficient with respect to the ith factor; and

P_i = Estimated probability of average crop production.

Results and Discussion

Production trends of Boro rice, Jute and Wheat

Production of all the three crops (Boro rice, Jute and Wheat) were found increasing without following any trend statistically rather the productions were fluctuated. The production of Boro rice was highest in year 2007 of about 4.216 ton per hectare whereas highest production jute was recorded in 1999 and 2002 about 8.8 ton per hectare. In case of Wheat it was 3.2 ton per hectare in 2015, 2016 and 2018 among 25 years from 1994 to 2018.

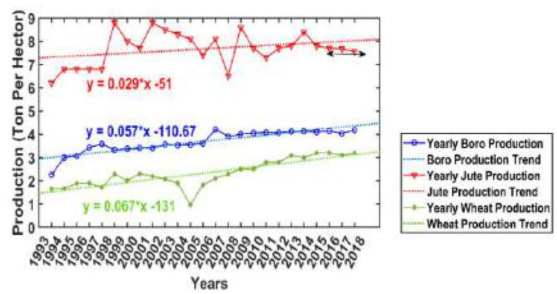

Fig. 1. Trend analysis of production of three crops

Sasonal productivity of Boro Rice and climatic variables

Rainfall not only fluctuates over the years but also fluctuate over the months with less degree of predictability. However, it is in increasing trend for summer season, but in decreasing trend for winter.

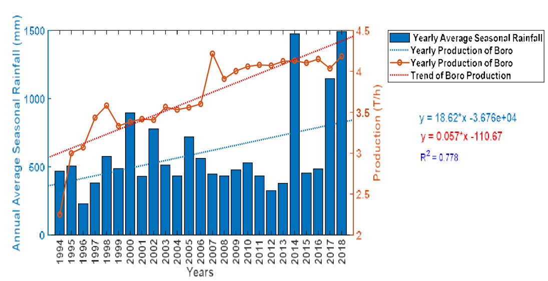

Fig. 2. Boro rice production with rainfall

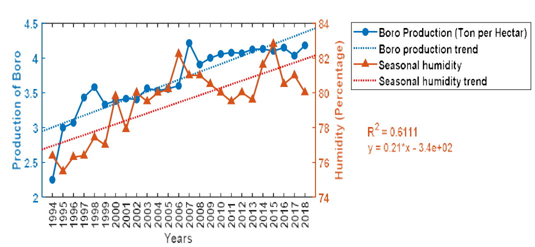

Fig. 3. Boro rice production with humidity

Fig. 2 showed the seasonal rainfall followed a positive trend in last 25 years. The coefficient of determination of the yearly seasonal average rainfall was 0.778. Year 2014 and 2018 has a sudden higher amount of rainfall than all the other years. According to Fig. 3 trend analysis showed that the average humidity was increasing 21% per year. Amin *et al.* (2004) Relative humidity may affect grain formation after milk stage, ripening and diseases in rice. High relative humidity favors crop growth through the vegetation stage.

Seasonal productivity of Jute and climatic variables

The average maximum temperature in jute season has a positive trend with very low value of correlation coefficient and co efficient of determination which means the changes of the maximum average temperature couldn't be predicted. The production of jute has a slightly higher slope than average maximum temperature.

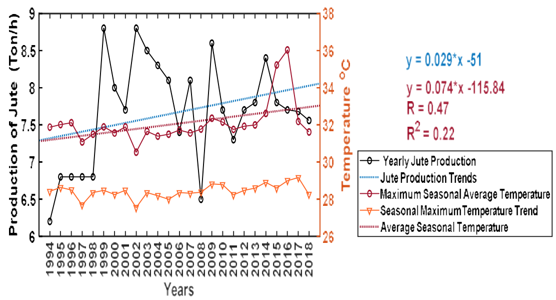

Fig. 4. Jute production with temperature

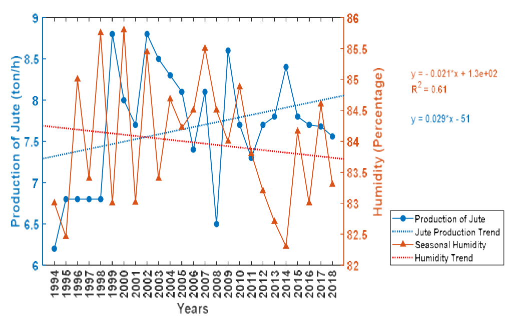

Fig. 5. Jute production with humidity

Islam *et al.* (1999) found that 1°C increase in maximum temperature at vegetative, reproductive and ripening stages there was a decrease in Aman rice production by 2.94, 53.06 and 17.28 tons, respectively. In fig. 5, Humidity has significant effect on some crops and an important determinant of crop productivity. Average humidity in the jute production season followed a moderate decreasing pattern whereas the production of jute had an increasing pattern of change. The seasonal average humidity was decreasing at a rate of 0.021% per year in jute production season. During grain formation, low humidity may cause grain to shrink, but high humidity favors disease, particularly in rainfed rice (Amin *et al.* 2004).

Relationship of production of crops with climatic variables

There was no relationship between average humidity and seasonal production of jute. Fig. 6 showed the value of R^2 was nearly zero that implies production can't be predicted by average humidity or there's no influence of average humidity in jute production.

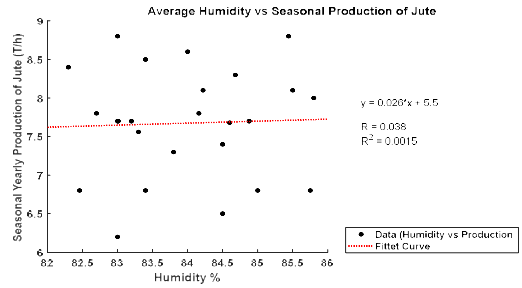

Fig. 6. Humidity and production of jute

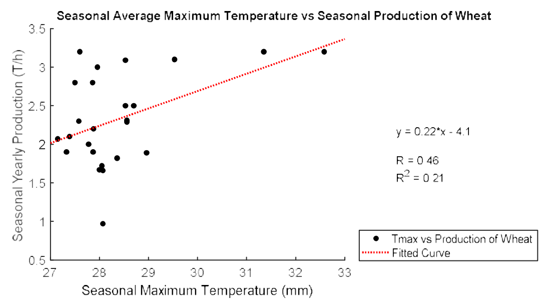

Fig. 7. Temperature and wheat production

Ferdous (2011) Relative humidity may affect grain formation after milk stage, ripening and diseases incidence in rice. High relative humidity favors crop growth through the vegetation stage. During grain formation, low humidity may cause grain to shrink, but high humidity favors disease, particularly in rainfed rice (Amin *et al*. 2004). In fig. 7, the very low value of coefficient of determination implies that there was not influence of maximum temperature on wheat production. Rosenzweig and Hillel (1995) reported that high temperature is a constraint to yield production and cause a significant yield reduction over Bangladesh. When temperatures exceed the optimal for biological processes, crops often respond negatively with a steep decline in net growth and yield.

All of three crops had increasing production trend from 1994 to 2018 in Mymensingh district. Seasonal productivity of Boro showed an increasing trend in Mymensingh district. Temperature, humidity and rainfall showed an increasing trend in this season. Seasonal productivity of Jute also showed an increasing trend. Rainfall and temperature for this season followed increasing trend. Only seasonal humidity showed a decreasing trend in this season. In season of wheat production, all the climatic variables along with the wheat production itself showed increasing pattern.

Table 1. Correlation statistics between crop productions and climatic variables

Crop Name	Data compared	Correlation co efficient	Significance
Boro	P_{Boro}vs T_{max}	0.1054	Not significant
	P_{Boro}vs H_{avg}	0.7292	0.01
	P_{Boro}vs R_{mm}	0.2607	Not significant
Jute	P_{Jute}vs T_{max}	0.0032	0.01
	P_{Jute}vs H_{avg}	0.0382	Not significant
	P_{Jute}vs R_{mm}	-0.0332	Not significant
Wheat	P_{Wheat}vs T_{max}	0.4591	0.05
	P_{Wheat}vs H_{avg}	0.2264	Not significant
	P_{Wheat}vs R_{mm}	0.2967	Not significant

Table1 shows correlation statistics between crop productions and climatic variables. Weak positive correlation was observed between crop production and climatic variables with a statistical non-significance in most cases.

Table 2. Estimates of coefficients and marginal effects

Variables	Coefficient (β)	Standard Error	T	P>|t|	95% confidence interval		dK/dX
Constant	-6.614	4.232	0.61	0.551	-0.164	0.300	-
Temperature (X_1)	0.067	0.111	0.57	0.576	-0.000	0.000	0.067
Rainfall (X_2)	0.000**	0.000	2.22	0.037	0.006	0.197	0.000
Humidity (X_3)	0.102	0.045	-1.56	0.133	-15.417	2.187	0.102

Note: ** indicates significant at 5% probability level.

From the above table,
if temperature is increased by 1°C, the probability of increasing crop production will be increased by 0.067 times. Hatfield and Prueger (2015) underline that a rise of 1°C to 4°C above the optimal temperature of certain plants has the potential to decrease the productivity between 2.5% and 10%.If rainfall is increased by 1 mm, the probability of increasing crop production will be increased by 0.000 times (significant at 5% probability level).Rainfall regime is the most important climatic factor influencing crop cultivation activities particularly in tropical regions of Nigeria (Ayanlade *et al.* 2010). If humidity is increased by 1%, the probability of increasing crop production will be increased by 0.102 times. Amin *et al.* (2004) Relative humidity may affect grain formation after milk stage, ripening and diseases in rice.

Conclusion

The study concludes that climatic information should be used for all aspects of crop production. The change of climatic variables could affect the productivity of crop. The productivity of crop increased in most of the areas but seasonal variability of climatic parameters could vary by the types of crops. Diversifying and generating off-farm employment opportunities in rural Bangladesh may also be crucial measures for the sustenance of rural masses. The present study was mainly focused on climatic variables impacts on seasonal productivity. Future studies may consider analyzing the climatic variables on other agricultural sectors, e.g. fisheries and livestock to assess the economic benefits or losses. We also suggest more research efforts in future for in-depth analyses of the economic impacts of climate change on farm income at the rural household level using a more holistic approach. The study encountered a number of limitations that could be taken into account in any relevant future investigation. In order to reach a final conclusion on the effects of climatic variable on field crops, more investigation over a longer study period at different locations across Bangladesh should be undertaken.

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